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K^{40} U^{238} Th^{232}

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THE RADIATION FIELD IN AIR DUE TO DISTRIBUTED GAMMA-RAY SOURCES IN THE GROUND

By
H. Beck
G. de Planque

May 1968

Health and Safety Laboratory
U. S. Atomic Energy Commission
New York, New York

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HEALTH AND SAFETY (TID-4500)

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ABSTRACT

A much more complete and detailed picture of the external environmental γ-ray radiation field has been obtained through γ-ray transport calculations of exposure rates, differential energy spectra, integral exposure rate spectra, and angular exposure rate distributions due to sources distributed on or in the soil half space.

The radiation field is examined not only for the natural emitters ^{40}K, ^{238}U, and ^{232}Th but also for γ-rays whose energies are typical of weapons test fallout. The energy spectra and exposure rate angular distributions are shown to vary with detector height and source distribution with resulting important implications in regard to detector calibration and prediction of ground level exposure rates from aerial survey data.

Exposure rate results as a function of detector height in air above the soil air interface are tabulated for various source energies and source distributions. Although the calculated results are for specific soil and air densities, soil moisture and composition, the data can easily be adapted to other soil and air conditions.

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I. INTRODUCTION

A knowledge of the radiation field in air due to γ-ray emitters distributed in the soil is important for estimating exposure rates from a given source concentration, evaluating hazards to the population, and properly interpreting and relating radiation measurements made at ground level and at airplane altitudes. The sources of this radiation are the naturally occurring radioisotopes, fallout from nuclear weapons tests, or unanticipated releases into the environment from a nuclear reactor installation.

The calculation of the exposure rate in air due to these sources in the soil has usually been based on infinite medium buildup factors. The exposure rate from a distributed source in the soil was usually calculated by assuming a single medium composition, either all air if the sources were distributed close to the interface or all soil (aluminum was usually substituted for soil) if the sources were distributed throughout the soil half space. The easily computed direct beam exposure rate for each point source element in the chosen medium was multiplied by the appropriate buildup factor and an integration performed numerically (or analytically by substituting a functional fit to the buildup factor data) to obtain the total exposure rate(1). This rough solution was necessary because of the lack of analytical transport methods for solving the one-dimensional two-media γ-ray transport problem. The infinite medium buildup factor approach, besides failing to account for the differences in the transport properties of soil and air at low energies, provided no information on the energy and angle distribution of the γ-rays entering the detector; information important for interpreting field measurements.

In this report, we present accurate calculations of γ-ray exposure rates in air (better than ±5% S.D.) for source distributions characteristic of natural and fallout γ-ray emitters in the soil as well as differential energy spectra, integral exposure rate spectra, and exposure rate angular distributions heretofore not available. In addition, we discuss sensitivity of the data to source energy, source depth distribution in the soil, and detector height above the interface. The calculations were carried out using a combination of the P-3 and DP-1 polynomial expansion matrix equation method for solving the two media transport problem[2]. Comparison of these results with those obtained using the infinite medium moments method based on buildup factors indicated that the latter method was probably fairly accurate (±10%) for detector positions close to the interface but may have been significantly in error far from the interface, especially for low energy sources distributed in the soil[2].

In addition to the specific calculations of the differential energy spectra, integral exposure rate spectra, and exposure rate angular distributions, the effects of varying the soil composition, moisture content, and density are considered together with an evaluation of the calculational accuracy.

II. ADAPTATION OF THE POLYNOMIAL EXPANSION MATRIX EQUATION METHOD TO THE AIR-SOIL INTERFACE PROBLEM

Calculational details for solving the two media transport problem by the P-3 and DP-1 polynomial expansion matrix equation method appear in a previous report(2). In general, the method consists of separating the spatial and angular dependencies of the angular flux in a truncated series of orthogonal polynomials and making use of the orthogonality properties to reduce the Boltzmann equation to a set of coupled integro-differential equations for each spatial component of the flux. These equations are solved by dividing the energy range into a number of groups and replacing the integration over energy by a summation over these groups. The integro-differential equations are rewritten as a set of differential matrix equations(3). These equations have relatively simple exponential solutions. The solution for a given energy group constitutes the source term for the next lower group. Thus, starting at the source energy, the differential energy and angle spectrum can be constructed stepwise down to any desired energy. Total exposure rates and angular exposure rates are obtained by weighting the differential spectra by the appropriate energy absorption coefficient and integrating over the energy and angular intervals of interest. All cross section data used for these calculations were taken from Hubbell(4).

The calculations discussed in this report are for a given set of soil and air densities, soil moisture content, and soil composition. However, as this section points out, our data can be applied to other soil and air conditions.

A. Exposure Rate Dependence on Soil Density

The calculated exposure rates are for a soil _in situ_ density of 1.6 gm/cm^3. Actual _in situ_ densities of soils can range from less than 1.0 gm/cm^3 to over 2.0 gm/cm^3, although a typical range(5) would be 1.1 to 1.8 gm/cm^3.

Since in our calculations we are dealing with a one-dimensional medium in the sense that only the direction perpendicular to the soil-air interface enters into the γ-ray transport equation and then only in terms of the γ-ray mean free path (mfp), the effect of changing the soil density is equivalent to a changing scale factor in this direction. This is because the γ-ray mean free path is equal to the inverse of the total attenuation coefficient, a quantity directly proportional to the density of the medium. Therefore, the soil density can affect calculations with certain source distributions.

For a source distributed exponentially with depth ($S = S_0 e^{-\alpha z}$, where S is the activity at depth z, S_0 is the surface activity, and α is the reciprocal of the relaxation length), changing the density, ρ, is equivalent to changing the effective source distribution such that $\alpha' = 1.6\ \alpha/\rho$. (In each case the total source activity in a 1 cm^2 column = 1 γ/sec). Thus, increasing the soil density effectively buries the source more deeply, decreasing the flux and exposure rate at the detector in the air half space. Therefore, in order to use the data given at certain relaxation lengths in this report for a density other than 1.6 gm/cm^3, one would have to apply the above transform, $\alpha' = 1.6\ \alpha/\rho'$, to determine which relaxation length to use. Since $\alpha \rightarrow \infty$ corresponds to an infinite plane source it follows that the soil density has no effect for this case.

When our calculations are for a uniformly distributed source of one γ-ray emitted per cm^3 at 1.6 gm/cm^3, the calculated exposures and fluxes are valid for a uniformly distributed source of intensity $1.6/\rho$ gammas emitted/cm^3-sec where ρ is the actual <u>in situ</u> soil density. This is so because changing the density by some factor is equivalent to changing the source intensity in the mean free path interval (dt, which is t mfp from the interface) by this same factor.

B. Exposure Rate Dependence on Air Density

The air density used in our calculations was 1.204 mg/cm^3 corresponding to a temperature of 20°C. Since γ-ray distances must be measured in mean free paths, the fluxes and exposures for other air densities can be obtained through adjustments to our data as in the case of differing soil densities. Thus, our data at h meters represents the flux or exposure rate at a distance $(1.204 \times 10^{-3}/\rho')h$ where ρ' is the new air density.

C. Exposure Rate Dependence on Soil Composition and Moisture Content

In our calculations, the assumed soil constituent concentrations given in percentage of total weight were SiO_2 - 67.5%, Al_2O_3 - 13.5%, Fe_2O_3 - 4.5%, CO_2 - 4.5%, and H_2O - 10.0%.

Changing the composition of the soil medium affects the fluxes and exposures more fundamentally than changes in density since Compton scattering, which is the dominant process at the higher energies, is proportional to the average Z/A of the soil while photoelectric absorption, which dominates at low energies, depends on the atomic number Z. Thus, a soil with more water in it would have an increased Z/A due to the lesser number of electrons per hydrogen atom as compared to most of the other soil constituents and, therefore, relatively more Compton scattering.

High Z materials in the soil such as iron could also affect the exposure rates and spectra. We investigated this possible dependence on soil composition by comparing calculations for our standard mock soil which has an average (Z/A) of .503 with similar calculations for pure aluminum having a (Z/A) of .482, a range of (Z/A) typical of most soils. Relatively minor differences were found in the exposure rates calculated for these two materials indicating that the radiation field is not extremely sensitive to the exact composition of the soil. For a .662 MeV plane source distributed on the interface, the differences for both the unscattered and total exposure rates at h = 1 meter were less than 1%, while at h = 100 meters, the differences were less than 0.5%. The differences were slightly larger when the source was distributed in the soil. For a uniformly distributed 1.0 MeV source, the unscattered aluminum exposure rate was found to be about 4% greater than the corresponding soil value at h = 1 meter and about 3.5% greater at h = 100 meters. The total exposure rates were 3.4% greater for aluminum than for soil at both heights.

A further comparison was made by calculating the exposure rates for soils whose ratios of constituents other than water were the same as our mock soil, but whose moisture contents were 0% and 25% as compared to the 10% of our standard soil. In all cases the density was kept constant at 1.6 gm/cm^3 and the source was 1.0 MeV, uniformly distributed, since the aluminum calculations indicated the greatest differences occur for a distributed source. The 0% and 10% moisture soils gave almost identical results while the 25% moisture soil gave exposure rates only 1.7% lower than the 10% moisture soil at both 1 meter and 100 meters. This small difference is in the direction expected since the increased moisture content would cause slightly more Compton scattering relative to photoelectric absorption. The (Z/A) for the 0% moisture content soil was .497, while the (Z/A) for the 25% case was .512.

Thus, the calculations are relatively insensitive to minor differences in soil composition and moisture content and should be valid for a wide range of soils. Corrections would, of course, have to be made when the density changes due to rainfall. These corrections are discussed under Section II, A.

D. <u>Error Estimates</u>

Exposure rates, in this report, are given in units of MeV/gm-sec and represent the energy absorbed in a gram of air, per unit time, i.e. the flux weighted by the photon energy and mass energy transport coefficient for air. The flux was calculated down to a low energy cutoff of $\tau_0 + 13.2 \left(\tau_0 = \frac{.511}{E}\right)$. This low energy cutoff has been found to include over 99% of the energy except for the highest energies and for very large interface to detector distances. For these latter cases a correction was made by interpolating the differential energy spectrum down to lower energies. For all calculations, annihilation radiation, bremsstrahlung, and coherent scattering were neglected.

The polynomial expansion method can be expected to provide exposure rate estimates for scattered γ-rays of accuracy better than 5%[2]. In many cases the scattered component is smaller than the unscattered component. The latter was calculated exactly and any error in it is due only to errors in the cross section data. Thus, the error in the total exposure rate is smaller than the error in the scattered component. To improve the calculational procedure, the values of the differential scattered flux and the exposure rate at the source energy were calculated directly using an exact expression. Inasmuch as the γ-ray cross section data are felt to be quite accurate (better than 2%) for the source energies and media used in our calculations, we conclude that the error in exposure rate values as well as in the differential energy spectra and the integral exposure rate spectra is always less than ±5%. The angular distributions are not as accurate and the error here may be as much as ±10% or more for the scattered component when the detector is near the interface[2].

III. RADIATION IN AIR DUE TO THE UNIFORMLY DISTRIBUTED NATURALLY OCCURRING SOURCES IN THE SOIL

Gamma radiation in air due to naturally occurring isotopes in the soil is usually calculated by assuming uniform distribution in the soil. The only natural emitters of consequence are ^{40}K, ^{238}U, and ^{232}Th. The latter two isotopes decay by means of a long chain process and ^{40}K decays to ^{40}A with the emission of a single 1.46 MeV γ-ray. For the ^{238}U series, most of the γ-rays are emitted by RaC (^{214}Bi) and RaB(^{214}Pb) which are daughters of ^{222}Rn, a gaseous daughter of ^{226}Ra. Because it is a gas, ^{222}Rn can emanate from soil particles, diffuse through the soil air to the surface and escape into the atmosphere. This effect tends to reduce the γ-ray emission in the soil due to ^{238}U by as much as 50%, thus lessening the importance of the ^{238}U series relative to the other two emitters(1). The ^{232}Th series contributes a large number of γ-rays of varying energies from several different daughter isotopes. Although one of these emitters is a gas, thoron (^{220}Rn), the short half life of this isotope (54.5 sec) prevents any significant escape and subsequent loss of soil gamma activity.

Since the decay schemes of ^{226}Ra and ^{232}Th (particularly the relative intensities of the various decay levels) are still somewhat uncertain, we give in Table 1 the source spectra and intensities used for the calculations in this report. These energies and intensities are our estimates based on the best available data. Some of the weaker energy lines have been grouped together or included with stronger lines in order to keep the total number of source energies manageable.

Table 2 gives the exposure rates for monoenergetic sources ranging from 0.25 to 2.75 MeV vs. detector height so that if necessary the reader can recalculate ^{238}U and ^{232}Th exposure rates for other source spectra. The ^{238}U

and ^{232}Th exposure rates were obtained by interpolating from the data in Table 2 for the source energies in Table 1, multiplying by the number of γ-rays emitted per ^{238}U and ^{232}Th disintegration and summing.

Calculations of the exposure rates for uniformly distributed sources in the soil are discussed and evaluated together with the differential energy spectra, integral exposure rate spectra, and angular exposure rates.

A. Exposure Rates

The total exposure rates as well as the direct beam or unscattered component are given in Table 2 as functions of source energy for various detector heights. Figure 1 illustrates the variation of exposure rates with height for three different source energies. Note that the total exposure rate changes very little in the first 10 meters above the interface but then begins to drop off fairly rapidly with height with the lower energy sources falling more rapidly than the higher energy sources due in large part to the more rapid decrease of the unscattered component for low source energies. The scattered components fall off less rapidly than the total exposure rate. Since the calculated exposure rates for ^{40}K, ^{238}U series, and the ^{232}Th series all showed almost exactly the same variation with height even though their source spectra varied considerably (Table 3), a single curve is given in Figure 1 for the variation with height of the natural gamma emitters.

The variation with height of the natural emitter exposure rate, given in Figure 1, was crudely verified by us at a single location by making ionization chamber measurements at h = 1 meter and h = 7 meters above a predominantly (95%) natural γ-radiation field. The measured variation in exposure rate with height of 14% compares reasonably well with the 11% reduction predicted by Figure 1, and is within the experimental error.

Our previous calculations of ^{238}U, ^{232}Th and ^{40}K exposure rates based on the infinite medium buildup factors are also given in Table 3. These calculations for an infinite medium assumed that the energy absorbed at the earth-air interface per gram of air would be ½ the energy emitted per gram of soil(1). Since for low energies the absorption in soil is greater than in air this tended to overestimate the exposure rate. By comparing the ^{40}K results (Table 3), we see that this overestimate was only about 4% for 1.46 MeV. It would have been greater for a lower energy source. The much larger differences in the old and new calculated ^{238}U exposure rates, however, are due not as much to the more accurate method (which accounts for only about 5-8% of the difference) as to the different source relative intensities used in the present work. In any case, the small changes in the values of ^{238}U, ^{232}Th and ^{40}K exposure rates per unit concentration of these elements do not significantly alter any of the results given in any of our previous reports on environmental radiation(1,6).

The present report, of course, is much more detailed than our previous work, since it provides data on energy and angle distributions and detector height dependence rather than just exposure rates at one meter above the interface.

B. Differential Energy Spectra

The relative contributions of various energy photons to the total scattered energy spectrum is determined by examining the differential energy spectra. The differential energy spectra of the scattered energy flux (flux x energy) for three source energies, .364 MeV, 1.0 MeV, and 2.5 MeV are shown in Figure 2 for h = 1.0 meter and h = 100 meters. The effect of the increased scattering in air relative to soil at the lower energies is illustrated in the figure by the shift to lower energy and buildup of the Compton peak at around 50-100 keV as the detector height is increased. The relatively high photoelectric cross section in soil compared to air causes it to act as a sink for low energy γ-rays, an effect which is enhanced the lower the source energy. To further illustrate the magnitude of this effect, we have also shown in Figure 2 the spectrum for a 1 MeV source at 1 meter in an infinite air medium instead of a soil-air medium. For this source energy the difference in the total exposure rate is only about 5% in all since about 50% of the exposure rate is due to unscattered γ-rays. At lower source energies, where the scattered γ-rays contribute a larger portion of the total exposure rate, the effect on the total exposure rate of using infinite air calculations would be more significant.

C. Integral Exposure Rate Spectra

Another way to examine the effect of different regions of the energy spectrum on the total exposure rate is to examine the integral exposure rate spectrum, i.e. the fraction of the total exposure rate due to γ-rays of energy less than E. This approach can be extended easily to the analysis of the composite ^{238}U and ^{232}Th spectra. Figure 3 illustrates that as the detector height increases the fraction of the total exposure rate due to low energy photons increases. The effect is more pronounced the lower the initial source energy since the percentage of unscattered γ-rays is lower and the fractional change in energy due to a collision is smaller. For the 2.5 MeV source only 2% of the exposure rate is from γ-rays of less than 100 keV at h = 1 meter and only 5% at h = 100 meters, while for a .364 MeV source, the corresponding values are 13% and 30%. The values at the source energy in Figure 3 indicate the fraction of the exposure rate due to scattered γ-rays. This fraction, of course, decreases with increasing energy.

Figure 4 shows the integral spectra for ^{40}K, ^{238}U series and ^{232}Th series. The U and Th spectra are quite similar.

The curves which represent the results at 100 meters illustrate the softening of the spectral composition of the radiation with height. The ^{40}K spectrum at 1 meter is quite a bit harder than the ^{238}U and ^{232}Th spectra but as the detector height is increased this difference becomes smaller since the higher energy sources in the ^{238}U and ^{232}Th series dominate resulting in a lesser overall rate of softening as compared to that for the single 1.46 MeV ^{40}K source. Figure 4 indicates, however, that the fraction of the exposure rate due to photons of less than 200 keV can become quite significant as the detector height is increased, depending on the source. Since many detectors used in the field have an energy dependence different from that of air at low energies, it may be inappropriate to use the same calibration factors for these instruments at different heights above the interface. This would be especially true for an instrument calibrated in terms of photon number per unit time such as a scintillation counter since a large increase in the exposure rate due to low energy photons would result in an even larger increase in the actual number of photons at that height. (This can be seen by dividing the points in Figure 2 by energy to obtain the differential number flux curves).

The softening of the natural emitter γ-ray energy spectrum with detector height has been experimentally verified qualitatively in the field both by Gustafson et al[7] and by ourselves in similar field experiments carried out in 1965 using NaI(Tl) detectors.

D. Differential Angular Exposure Rates

The differential angular exposure rates at the detector for three different source energies at h = 1 meter, 100 meters, and 300 meters are shown in Figure 5. These curves are given in terms of exposure rate per radian due to photons traveling in the direction θ, normalized to a total exposure rate of 1.0, where θ is the angle relative to the perpendicular, i.e. 0° is on the perpendicular to the interface heading away from the soil half space. We see from the figure that these distributions peak at around 70° - 80° for h = 1 meter, 40° - 60° for h = 100 meters, and 30° - 40° for h = 300 meters. The height of the peak decreases as the source energy decreases while the "skyshine" (photons traveling toward the ground) increases (see Table 4). As the detector height increases, the "skyshine" for a given source energy also increases. The flattening out of the angular distribution as the source energy decreases becomes more pronounced as the detector height is increased. The angular distributions of the scattered and unscattered γ-rays are quite comparable (see Figure 6) to the total exposure angular distributions although the unscattered distributions are slightly more peaked.

The angular exposure rate distributions for ^{40}K, ^{238}U, and ^{232}Th (Figure 7) are similar to those for :364, 1.0, and 2.5 MeV sources shown in Figure 5. There is little difference in the three distributions for h = 1 meter and only slightly more for h = 100 meters. Skyshine contributes 11% of the ^{40}K exposure rate, 13% of the ^{238}U exposure rate, and 12% of the ^{232}Th exposure rate at h = 1 meter and 12%, 15%, and 13% of the exposure rate at 1 = 100 meters.

The natural exposure rate angular distribution, therefore, is fairly insensitive to the relative amounts of ^{40}K, ^{238}U, and ^{232}Th in the soil although it does vary with detector height. Thus, a detector with an angular response must be calibrated properly with elevation in order to interpret readings of natural gamma exposure rates made at various heights above the interface.

IV. RADIATION IN AIR DUE TO EXPONENTIALLY DISTRIBUTED (FALLOUT) SOURCES IN THE SOIL

Radioisotopes in the soil as a result of fallout from weapons tests (or accidental escape from reactors) usually remain on or just below the surface of the ground. For very short times after deposition, the sources can even be assumed to be distributed as an infinitesimally thin plane source directly on the interface. For longer lived fallout which has been in the biosphere for some time, we have found that a reasonable approximation is to assume the sources to be distributed exponentially with depth in the soil according to the relation $S = S_0\ e^{-\alpha z}$ where S is the activity at depth z, S_0 is the surface activity, and α is the reciprocal of the relaxation length ($\alpha \rightarrow \infty$ is equivalent to a plane source on the interface). For fallout deposited in the U. S. during 1962 - 1965 an assumed relaxation length of 3 cm gave a reasonable fit to actual depth distribution measurements[8].

Many investigators calculate the exposure rate from fallout isotopes as if the source were a plane source buried at some depth z beneath the surface in order to account for the effect of ground "roughness". For a widely distributed source, for detector heights at least a meter above the interface and for a moderately flat surface, the assumption of an average exponential depth distribution should be more realistic and should also account for ground roughness since an exponential source is equivalent to burying plane sources successively deeper in the ground with decreasing intensities. The choice of the best relaxation length to use for a given source depends on such factors as the type of surface, the source energy, the time since deposition, and the type of soil.

Variations in the source energy, relaxation length, and detector height affect the exposure rate, energy spectra, and angular distributions in air. It is important to understand the significance of these variations to properly interpret as well as predict the results of fallout measurements made either at ground level or from an airplane or helicopter. Thus, the results of our computations of radiation due to exponentially distributed sources are discussed in this light.

A. Exposure Rates

Total exposure rates for exponentially distributed sources of source strength one gamma emitted per cm^2 of interface surface are listed in Table 5, A. Unscattered exposure rates are tabulated separately in Table 5, B. The data in Table 5 should be sufficient to allow the reader to construct exposure rate vs. height curves for any source energy and relaxation length. The dependence of the exposure rate on detector height is shown in Figures 8, 9, and 10 for several source energies and depth distributions. ($\alpha \rightarrow \infty$ corresponds to a plane source. All our calculations of the scattered component for a plane source were arrived at using α = 10,000. The unscattered component was calculated exactly.)

From Figures 8 and 9 we see that the variation with detector height is relatively insensitive to source energy, especially below h = 100 meters. Figure 10 illustrates the effect of the depth distribution on the exposure rate at various detector heights. The scattered component falls off very slowly with height all the way up to about h = 30 meters, but as the depth distribution approaches a plane source the unscattered component causes the total exposure rate to begin to drop off more quickly with height. The exposure rates for various depth distributions all tend to converge at higher altitudes, i.e. the effect of the source depth distribution is reduced. This is qualitatively what we would expect when using an exponential source distribution model to represent ground roughness, since ground roughness effects decrease as the detector height is increased.

From Figure 11 we see that the ratio of the exposure rates at h = 1 meter even for two sources quite far apart in energy does not depend on the depth distribution. This is important since often one can make the assumption that two isotopes are distributed similarly with depth. If one then has an experimental measure of the ratio of their activities at any depth one can, using the results of this report, estimate the ratios of their exposure rates. If an independent measure of the total exposure rate can then be made, a fairly complete picture of the radiation field can be deduced.

A more detailed examination of the variation in exposure rate with detector height is shown in Figure 12 where the ratios of the exposure rates at 10, 100, and 300 meters to that at 1 meter are plotted for different source distributions. Here we see that the 10 meter/1 meter and 100 meter/1 meter ratios do not vary too rapidly with source energy. Since over a wide range of depth distributions this ratio changes by only a factor of about 2, one can make reasonable estimates of the exposure rate at ground level using measurements made from an airplane or helicopter even if the exact source spectrum of the radiation is unknown. This fact could be of importance for some types of emergency radiological surveying procedures.

Figure 13 indicates the ratio of the exposure rate due to scattered γ-rays relative to the total exposure. The shape of the curves for h = 1 meter and h = 100 meters is fairly similar, reflecting corresponding dependence on source energy. The percentage of the scattered component to the total, as determined from Figure 10, however, is much more dependent on the source depth distribution at h = 1 meter than it is at h = 100 meters. This again indicates the increased effect of the extra soil cover on exposure rates at lower detector heights relative to higher altitudes.

The fractions of the total exposure rate due to "skyshine" are given in Table 6. The "skyshine" is quite sensitive to both source energy and detector height and becomes a very significant portion of the total exposure rate at low source energies and higher detector positions.

B. Differential Energy Spectra

The effect of the source depth distribution on the differential energy spectra of the scattered energy flux is shown in Figure 14 for a .662 MeV (^{137}Cs) source. At h = 1 meter the spectrum for the distributed source (α = .33) is softer than that for the plane source while at h = 100 meters there is little difference in the shapes of the two spectra. Thus, it would not be possible to make inferences about the depth distribution or the exact exposure rate at ground level by using an altitude measurement of the energy spectra.

C. Integral Exposure Spectra

The softening of the scattered energy flux spectra at h = 1 meter results in a corresponding softening in the integral exposure rate spectra (Figures 15, 16, 17) especially for h = 1 meter. All three figures show the same general features. The diminished influence of the source depth distribution at h = 100 meters is evident. The fraction of the exposure rate due to γ-rays below a given energy, E, increases and the total scattered component increases as the source energy decreases, comparable to the result we obtained for the uniformly distributed sources. Again, we must emphasize the need to properly interpret energy dependent dosimeter readings, since at h = 100 meters over 20% of the exposure rate from an ^{131}I source (.364 MeV) is due to γ-rays of energy less than 100 keV as opposed to a corresponding 6% for 1.25 MeV (^{60}Co) γ-rays.

D. Angular Distributions

For a plane source or even a source distributed slightly with depth, at detector heights close to the interface the largest portion of the exposure rate is due to unscattered γ-rays (Figure 13). The direct beam or unscattered γ-ray angular distributions at such source depths rise to a very sharp peak in the angular region $\theta = 89^\circ - 90^\circ$, and this peak dominates the scattered component and results in a very skewed total exposure rate angular distribution (Figure 18a). The shape of this distribution is slightly dependent on source energy becoming less peaked as the source energy decreases. The sharpness of the peak is only slightly diminished as the source becomes more deeply distributed in the ground and is still very acute even for $\alpha = .33$. The angular distributions flatten out considerably as the detector height is increased but even at h = 100 meters (Figures 18a and 18b) these are still more peaked than the corresponding distributions for uniformly distributed sources (Figures 5 and 6). The peaks of the curves for $\alpha = .33$ (Figure 18b) are slightly reduced and shifted toward the vertical ($\theta = 0^\circ$) compared to the corresponding curves for the plane source. This fact might be useful in estimating the depth distribution of a given isotope from an angular distribution measurement taken in an airplane or helicopter.

Since the response of almost all instruments has some angular dependence, our observations are significant for interpreting field measurements. It is clear from the data presented here that careful instrument calibrations are essential in order to properly interpret measurements made at different detector heights.

V. CONCLUSIONS

The energy spectra and angular exposure rate distributions for fallout sources differ considerably from those for the natural emitters because of the different source depth distributions. The magnitude of this difference depends on the exact depth distribution of the fallout emitters. The computations in this report indicate that both distributions also vary with detector height, emphasizing the necessity of carefully calibrating detectors used for measuring gamma radiation in the field.

The calculated exposure rates, differential energy spectra, and angular exposure rates can be used for interpreting and analyzing the results of land and aerial surveys over extensively contaminated areas as well as for predicting the results of such surveys for a known level of contamination. In certain instances experimental data taken at high altitudes can be used to infer information about the radiation field near the interface. This can be done by utilizing the curves given in this report, taking into account the source spectrum and depth distribution of the isotopes contributing to the field.

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TABLE 1

SOURCE SPECTRA USED FOR ^{238}U and ^{232}Th EXPOSURE RATE CALCULATIONS

^{238}U Series		^{232}Th Series	
Source Energy (MeV)	Photons per Disintegration	Source Energy (MeV)	Photons per Disintegration
.24	.11	.16	.12
.29	.24	.24	.80
.35	.38	.33	.19
.49	.08	.44	.05
.61	.42	.51	.09
.77	.11	.58	.30
.94	.04	.73	.10
1.12	.19	.92	.56
1.24	.08	1.60	.28
1.39	.09	1.80	.01
1.58	.06	2.62	.35
1.76	.21		
2.20	.08		
2.44	.02		

TABLE 2

EXPOSURE RATES - UNIFORMLY DISTRIBUTED SOURCE*

A. Total Exposure Rate†

E (MeV) \ h (m)	0	.1	.5	1	3	5	10	30	100	300
.25	6.24(-2)	6.23(-2)	6.16(-2)	5.99(-2)	5.88(-2)	5.71(-2)	5.33(-2)	4.24(-2)	2.04(-2)	2.42(-3)
.364	9.92(-2)	9.89(-2)	9.79(-2)	9.68(-2)	9.34(-2)	9.06(-2)	8.48(-2)	6.74(-2)	3.38(-2)	4.75(-3)
.50	1.40(-1)	1.40(-1)	1.38(-1)	1.37(-1)	1.32(-1)	1.28(-1)	1.20(-1)	9.62(-2)	4.95(-2)	8.06(-3)
.662	1.91(-1)	1.90(-1)	1.88(-1)	1.86(-1)	1.80(-1)	1.75(-1)	1.64(-1)	1.32(-1)	7.02(-2)	1.32(-2)
.75	2.19(-1)	2.19(-1)	2.17(-1)	2.14(-1)	2.07(-1)	2.01(-1)	1.89(-1)	1.53(-1)	8.26(-2)	1.63(-2)
1.0	2.95(-1)	2.94(-1)	2.91(-1)	2.88(-1)	2.79(-1)	2.71(-1)	2.55(-1)	2.07(-1)	1.16(-1)	2.62(-2)
1.25	3.72(-1)	3.71(-1)	3.68(-1)	3.64(-1)	3.53(-1)	3.43(-1)	3.25(-1)	2.66(-1)	1.53(-1)	3.86(-2)
1.46	4.36(-1)	4.35(-1)	4.32(-1)	4.28(-1)	4.15(-1)	4.04(-1)	3.83(-1)	3.16(-1)	1.85(-1)	4.99(-2)
1.76	5.26(-1)	5.25(-1)	5.21(-1)	5.18(-1)	5.02(-1)	4.89(-1)	4.64(-1)	3.86(-1)	2.34(-1)	6.83(-2)
2.00	6.01(-1)	6.00(-1)	5.95(-1)	5.90(-1)	5.73(-1)	5.60(-1)	5.31(-1)	4.45(-1)	2.75(-1)	8.38(-2)
2.25	6.70(-1)	6.69(-1)	6.64(-1)	6.59(-1)	6.40(-1)	6.26(-1)	5.95(-1)	5.01(-1)	3.14(-1)	1.01(-1)
2.50	7.44(-1)	7.43(-1)	7.37(-1)	7.32(-1)	7.12(-1)	6.96(-1)	6.62(-1)	5.61(-1)	3.55(-1)	1.20(-1)
2.62	7.83(-1)	7.81(-1)	7.75(-1)	7.69(-1)	7.49(-1)	7.32(-1)	6.97(-1)	5.93(-1)	3.79(-1)	1.30(-1)
2.75	8.19(-1)	8.18(-1)	8.12(-1)	8.06(-1)	7.85(-1)	7.67(-1)	7.32(-1)	6.22(-1)	4.01(-1)	1.40(-1)

*Source Strength = 1 γ per cm^3-sec.

†MeV/gm-sec = 65.9 μr/hr; 1 μr/hr = 7.65 mrad/yr.

TABLE 2 (Cont'd)

B. Unscattered γ-Rays†

E (MeV) \ h (m)	0	.1	.5	1	3	5	10	30	100	300
.25	1.89(-2)	1.87(-2)	1.82(-2)	1.77(-2)	1.60(-2)	1.48(-2)	1.25(-2)	7.21(-3)	1.65(-3)	5.31(-5)
.364	3.33(-2)	3.31(-2)	3.22(-2)	3.14(-2)	2.88(-2)	2.68(-2)	2.29(-2)	1.40(-2)	3.70(-3)	1.72(-4)
.50	5.32(-2)	5.28(-2)	5.16(-2)	5.04(-2)	4.66(-2)	4.37(-2)	3.79(-2)	2.42(-2)	7.34(-3)	4.71(-4)
.662	7.87(-2)	7.83(-2)	7.67(-2)	7.50(-2)	6.99(-2)	6.59(-2)	5.80(-2)	3.85(-2)	1.30(-2)	1.09(-3)
.75	9.36(-2)	9.31(-2)	9.13(-2)	8.94(-2)	8.35(-2)	7.90(-2)	6.98(-2)	4.72(-2)	1.67(-2)	1.58(-3)
1.0	1.37(-1)	1.36(-1)	1.34(-1)	1.31(-1)	1.24(-1)	1.17(-1)	1.05(-1)	7.38(-2)	2.90(-2)	3.51(-3)
1.25	1.82(-1)	1.81(-1)	1.79(-1)	1.76(-1)	1.66(-1)	1.58(-1)	1.43(-1)	1.04(-1)	4.41(-2)	6.46(-3)
1.46	2.22(-1)	2.21(-1)	2.18(-1)	2.15(-1)	2.03(-1)	1.95(-1)	1.77(-1)	1.31(-1)	5.84(-2)	9.63(-3)
1.76	2.80(-1)	2.79(-1)	2.75(-1)	2.71(-1)	2.58(-1)	2.48(-1)	2.27(-1)	1.71(-1)	8.10(-2)	1.53(-2)
2.00	3.27(-1)	3.26(-1)	3.22(-1)	3.17(-1)	3.02(-1)	2.91(-1)	2.68(-1)	2.04(-1)	1.01(-1)	2.07(-2)
2.25	3.73(-1)	3.72(-1)	3.67(-1)	3.62(-1)	3.47(-1)	3.34(-1)	3.09(-1)	2.39(-1)	1.21(-1)	2.70(-2)
2.50	4.23(-1)	4.22(-1)	4.17(-1)	4.12(-1)	3.95(-1)	3.81(-1)	3.53(-1)	2.75(-1)	1.44(-1)	3.39(-2)
2.62	4.50(-1)	4.49(-1)	4.44(-1)	4.39(-1)	4.21(-1)	4.06(-1)	3.77(-1)	2.97(-1)	1.58(-1)	3.91(-2)
2.75	4.74(-1)	4.73(-1)	4.68(-1)	4.62(-1)	4.44(-1)	4.29(-1)	3.98(-1)	3.14(-1)	1.68(-1)	4.21(-2)

†MeV/gm-sec = 65.9 μr/hr; 1 μr/hr = 7.65 mrad/yr.

TABLE 3

EXPOSURE RATES IN AIR DUE TO ^{40}K, ^{238}U, and ^{232}Th IN THE SOIL (μr/hr)

Detector Height (meters)	Exposure Rate* per 1% ^{40}K	% Decrease from 0 Meter Value	Exposure Rate* per 1 ppm ^{238}U‡	% Decrease from 0 Meter Value	Exposure Rate* per 1 ppm ^{232}Th	% Decrease from 0 Meter Value
0	1.68	0	.667	0	.314	0
1	1.65 (1.71†)	2	.654 (.76†)	2	.307 (.36†)	2
3	1.60	5	.635	5	.298	5
5	1.56	7	.618	7	.290	8
10	1.47	13	.583	13	.274	13
30	1.22	27	.476	29	.226	28
100	0.72	57	.274	59	.133	58
300	0.19	89	.068	90	.036	89

*1% ^{40}K = .0586 dis/cm^3, 1 ppm ^{238} = .0198 dis/cm^3, 1 ppm ^{232}Th = 6.57 x 10^{-3} dis/cm^3, soil density, ρ = 1.6 gm/cm^3.

†Previously reported values[1].

‡Exposure rate due to radon daughters in the atmosphere has been neglected but should not amount to more than a few percent of the total exposure rate even close to the interface[1,6].

TABLE 4

PERCENTAGE OF TOTAL EXPOSURE RATE DUE TO SKYSHINE FOR UNIFORMLY DISTRIBUTED SOURCES

Source	h = 1 meter	h = 100 meters
.364 MeV	21%	24%
1.0 MeV	13%	16%
2.5 MeV	8.6%	9.5%
^{238}U series	13%	15%
^{40}K	11%	12%
^{232}Th series	12%	13%

TABLE 5

EXPOSURE RATES - EXPONENTIALLY DISTRIBUTED SOURCE*

A. Total Exposure Rate†

$\alpha^{‡} = .1$

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	4.06(-3)	3.91(-3)	3.91(-3)	3.68(-3)	3.53(-3)	3.32(-3)	2.23(-3)	8.63(-4)	1.20(-4)
.364	6.34(-3)	6.31(-3)	6.13(-3)	5.86(-3)	5.65(-3)	5.20(-3)	3.99(-3)	1.89(-3)	2.84(-4)
.50	8.73(-3)	8.70(-3)	8.47(-3)	8.07(-3)	7.78(-3)	7.18(-3)	6.33(-3)	2.70(-3)	4.52(-4)
.662	1.16(-2)	1.15(-2)	1.12(-2)	1.07(-2)	1.03(-2)	9.50(-3)	7.38(-3)	3.72(-3)	7.04(-4)
.75	1.31(-2)	1.31(-2)	1.27(-2)	1.21(-2)	1.17(-2)	1.08(-2)	8.37(-3)	4.25(-3)	8.53(-4)
1.0	1.72(-2)	1.71(-2)	1.67(-2)	1.59(-2)	1.54(-2)	1.42(-2)	1.11(-2)	5.87(-3)	1.33(-3)
1.25	2.11(-2)	2.09(-2)	2.02(-2)	1.96(-2)	1.89(-2)	1.76(-2)	1.39(-2)	7.43(-3)	1.86(-3)

*Source strength = 1 γ per cm^2-sec.

†MeV/gm-sec = 65.9 μr/hr; 1 μr/hr = 7.65 mrad/yr.

‡α is the reciprocal of the relaxation length which defines the depth distribution (see page 14).

TABLE 5 (Cont'd)

α = .33

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	7.82(-3)	7.55(-3)	7.45(-3)	6.93(-3)	6.55(-3)	6.03(-3)	3.90(-3)	1.44(-3)	1.98(-4)
.364	1.24(-2)	1.22(-2)	1.17(-2)	1.11(-2)	1.09(-2)	9.47(-3)	7.10(-3)	3.18(-3)	4.80(-4)
.50	1.67(-2)	1.66(-2)	1.56(-2)	1.50(-2)	1.42(-2)	1.29(-2)	9.64(-3)	4.48(-3)	7.43(-4)
.662	2.172(-2)	2.16(-2)	2.08(-2)	1.95(-2)	1.864(-2)	1.69(-2)	1.257(-2)	6.02(-3)	1.12(-3)
.75	2.455(-2)	2.435(-2)	2.34(-2)	2.20(-2)	2.10(-2)	1.90(-2)	1.412(-2)	6.82(-3)	1.34(-3)
1.0	3.17(-2)	3.15(-2)	3.03(-2)	2.85(-2)	2.72(-2)	2.46(-2)	1.85(-2)	9.19(-3)	2.03(-3)
1.25	3.87(-2)	3.81(-2)	3.66(-2)	3.46(-2)	3.29(-2)	3.00(-2)	2.27(-2)	1.15(-2)	2.86(-3)
2.25	6.11(-2)	6.08(-2)	6.06(-2)	5.52(-2)	5.27(-2)	4.83(-2)	3.75(-2)	2.01(-2)	5.77(-3)

α = .5

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	9.34(-3)	9.02(-3)	8.84(-3)	8.16(-3)	7.69(-3)	7.03(-3)	4.48(-3)	1.61(-3)	2.23(-4)
.364	1.44(-2)	1.43(-2)	1.36(-2)	1.27(-2)	1.21(-2)	1.09(-2)	7.91(-3)	3.52(-3)	5.30(-4)
.50	1.96(-2)	1.94(-2)	1.86(-2)	1.73(-2)	1.64(-2)	1.47(-2)	1.08(-2)	4.95(-3)	8.20(-4)
.662	2.55(-2)	2.54(-2)	2.42(-2)	2.26(-2)	2.15(-2)	1.92(-2)	1.41(-2)	6.60(-3)	1.24(-3)
.75	2.87(-2)	2.85(-2)	2.73(-2)	2.54(-2)	2.41(-2)	2.16(-2)	1.58(-2)	7.47(-3)	1.46(-3)
1.0	3.72(-2)	3.68(-2)	3.52(-2)	3.28(-2)	3.12(-2)	2.80(-2)	2.06(-2)	1.01(-2)	2.19(-3)
1.25	4.48(-2)	4.45(-2)	4.23(-2)	3.96(-2)	3.76(-2)	3.40(-2)	2.52(-2)	1.25(-2)	3.02(-3)

TABLE 5 (Cont'd)

α = 1.0

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	1.188(-2)	1.178(-2)	1.11(-2)	1.005(-2)	9.37(-3)	8.43(-3)	5.21(-3)	1.81(-3)	2.52(-4)
.364	1.81(-2)	1.80(-2)	1.68(-2)	1.553(-2)	1.459(-2)	1.29(-2)	9.11(-3)	3.95(-3)	5.95(-4)
.50	2.47(-2)	2.44(-2)	2.30(-2)	2.11(-2)	1.98(-2)	1.75(-2)	1.25(-2)	5.53(-3)	9.10(-4)
.662	3.21(-2)	3.18(-2)	2.99(-2)	2.74(-2)	2.57(-2)	2.27(-2)	1.615(-2)	7.36(-3)	1.36(-3)
.75	3.61(-2)	3.58(-2)	3.36(-2)	3.08(-2)	2.89(-2)	2.46(-2)	1.806(-2)	8.29(-3)	1.61(-3)
1.0	4.64(-2)	4.59(-2)	4.32(-2)	3.88(-2)	3.72(-2)	3.28(-2)	2.35(-2)	1.09(-2)	2.38(-3)
1.25	5.76(-2)	5.75(-2)	5.19(-2)	4.94(-2)	4.61(-2)	3.97(-2)	3.87(-2)	1.38(-2)	3.21(-3)

α = 10.0

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	1.99(-2)	1.91(-2)	1.64(-2)	1.39(-2)	1.26(-2)	1.07(-2)	6.27(-3)	2.07(-3)	2.83(-4)
.364	3.04(-2)	2.86(-2)	2.47(-2)	2.12(-2)	1.93(-2)	1.62(-2)	1.08(-2)	4.44(-3)	6.70(-4)
.50	4.16(-2)	4.04(-2)	3.44(-2)	2.89(-2)	2.62(-2)	2.20(-2)	1.47(-2)	6.23(-3)	1.01(-3)
.662	5.39(-2)	5.27(-2)	4.48(-2)	3.75(-2)	3.39(-2)	2.86(-2)	1.89(-2)	8.27(-3)	1.49(-3)
.75	6.06(-2)	5.92(-2)	5.04(-2)	4.19(-2)	3.80(-2)	3.20(-2)	2.12(-2)	9.23(-3)	1.76(-3)
1.0	7.33(-2)	7.15(-2)	6.49(-2)	4.97(-2)	4.44(-2)	4.10(-2)	2.34(-2)	1.23(-2)	2.58(-3)
1.25	9.25(-2)	9.07(-2)	7.80(-2)	6.47(-2)	5.84(-2)	4.93(-2)	3.32(-2)	1.53(-2)	3.47(-3)

TABLE 5 (Cont'd)

Plane Source

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25		2.67(-2)	1.89(-2)	1.500(-2)	1.33(-2)	1.12(-2)	6.42(-3)	2.09(-3)	2.87(-4)
.364		4.11(-2)	2.89(-2)	2.31(-2)	2.05(-2)	1.68(-2)	1.02(-2)	4.50(-3)	6.79(-4)
.50		5.65(-2)	3.95(-2)	3.12(-2)	2.77(-2)	2.28(-2)	1.50(-2)	6.31(-3)	1.02(-3)
.662		6.36(-2)	5.14(-2)	4.05(-2)	3.59(-2)	2.96(-2)	1.934(-2)	8.37(-3)	1.51(-3)
.75		7.19(-2)	5.77(-2)	4.55(-2)	4.03(-2)	3.32(-2)	2.16(-2)	9.37(-3)	1.79(-3)
1.0		1.057(-1)	7.38(-2)	5.94(-2)	5.14(-2)	4.26(-2)	2.79(-2)	1.24(-2)	2.61(-3)
1.17		1.19(-1)	8.37(-2)	6.64(-2)	5.82(-2)	4.83(-2)	3.18(-2)	1.44(-2)	3.17(-3)
1.25		1.27(-1)	8.89(-2)	7.06(-2)	6.18(-2)	5.13(-2)	3.39(-2)	1.55(-2)	3.50(-3)
1.33		1.33(-1)	9.34(-2)	7.43(-2)	6.50(-2)	5.40(-2)	3.57(-2)	1.66(-2)	3.92(-3)
1.76		1.65(-1)	1.18(-1)	9.33(-2)	8.13(-2)	6.76(-2)	4.52(-2)	2.08(-2)	5.48(-3)
2.25		1.97(-1)	1.38(-1)	1.12(-1)	9.65(-2)	7.96(-2)	5.22(-2)	2.58(-2)	6.95(-3)
2.75		2.29(-1)	1.59(-1)	1.33(-1)	1.15(-1)	9.61(-2)	6.52(-2)	3.09(-2)	9.69(-3)

TABLE 5 (Cont'd)

B. Unscattered γ-Rays†

α = .1

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	1.51(-3)	1.49(-3)	1.39(-3)	1.25(-3)	1.15(-3)	9.54(-4)	5.34(-4)	1.17(-4)	3.61(-6)
.364	2.59(-3)	2.57(-3)	2.41(-3)	2.19(-3)	2.02(-3)	1.70(-3)	1.00(-3)	2.53(-4)	1.12(-5)
.50	4.02(-3)	3.99(-3)	3.77(-3)	3.44(-3)	3.20(-3)	2.74(-3)	1.69(-3)	4.84(-4)	2.95(-5)
.662	5.77(-3)	5.73(-3)	5.44(-3)	5.01(-3)	4.68(-3)	4.05(-3)	2.59(-3)	8.26(-4)	6.57(-5)
.75	6.76(-3)	6.72(-3)	6.39(-3)	5.89(-3)	5.53(-3)	4.81(-3)	3.13(-3)	1.04(-3)	9.23(-5)
1.0	9.53(-3)	9.48(-3)	9.05(-3)	8.40(-3)	7.91(-3)	6.96(-3)	4.69(-3)	1.73(-3)	1.96(-4)
1.25	1.23(-2)	1.22(-2)	1.17(-2)	1.09(-2)	1.03(-2)	9.18(-3)	6.36(-3)	2.53(-3)	3.46(-4)

α = .33

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	3.59(-3)	3.54(-3)	3.26(-3)	2.89(-3)	2.61(-3)	2.12(-3)	1.13(-3)	2.35(-4)	6.93(-6)
.364	5.99(-3)	5.93(-3)	5.49(-3)	4.89(-3)	4.46(-3)	3.67(-3)	2.06(-3)	4.90(-4)	2.07(-5)
.50	9.08(-3)	8.99(-3)	8.36(-3)	7.51(-3)	6.89(-3)	5.76(-3)	3.38(-3)	9.11(-4)	5.29(-5)
.662	1.27(-2)	1.26(-2)	1.18(-2)	1.07(-2)	9.83(-3)	8.31(-3)	5.06(-3)	1.51(-3)	1.14(-4)
.75	1.48(-2)	1.46(-2)	1.37(-2)	1.24(-2)	1.15(-2)	9.75(-3)	6.03(-3)	1.89(-3)	1.59(-4)
1.0	2.02(-2)	2.01(-2)	1.89(-2)	1.72(-2)	1.60(-2)	1.37(-2)	8.80(-3)	3.03(-3)	3.25(-4)
1.25	2.55(-2)	2.54(-2)	2.40(-2)	2.19(-2)	2.04(-2)	1.77(-2)	1.17(-2)	4.33(-3)	5.59(-4)
1.76	3.60(-2)	3.58(-2)	3.40(-2)	3.12(-2)	2.93(-2)	2.57(-2)	1.76(-2)	7.20(-3)	1.19(-3)
2.25	4.50(-2)	4.47(-2)	4.26(-2)	3.93(-2)	3.70(-2)	3.28(-2)	2.29(-2)	1.01(-2)	1.94(-3)
2.75	5.39(-2)	5.36(-2)	5.12(-2)	4.74(-2)	4.47(-2)	3.98(-2)	2.84(-2)	1.30(-2)	2.81(-3)

†MeV/gm-sec = 65.9 μr/hr; 1 μr/hr = 7.65 mrad/yr.

TABLE 5 (Cont'd)

α = .50

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	4.56(-3)	4.50(-3)	4.11(-3)	3.60(-3)	3.24(-3)	2.60(-3)	1.36(-3)	2.74(-4)	7.98(-6)
.364	7.55(-3)	7.45(-3)	6.84(-3)	6.03(-3)	5.47(-3)	4.45(-3)	2.45(-3)	5.67(-4)	2.36(-5)
.50	1.13(-2)	1.12(-2)	1.03(-2)	9.19(-3)	8.39(-3)	6.93(-3)	3.98(-3)	1.05(-3)	5.97(-5)
.662	1.58(-2)	1.56(-2)	1.45(-2)	1.29(-2)	1.19(-2)	9.92(-3)	5.91(-3)	1.72(-3)	1.28(-4)
.75	1.82(-2)	1.80(-2)	1.68(-2)	1.50(-2)	1.38(-2)	1.16(-2)	7.02(-3)	2.14(-3)	1.77(-4)
1.0	2.48(-2)	2.45(-2)	2.29(-2)	2.06(-2)	1.91(-2)	1.62(-2)	1.02(-2)	3.41(-3)	3.59(-4)
1.25	3.11(-2)	3.08(-2)	2.89(-2)	2.61(-2)	2.42(-2)	2.08(-2)	1.34(-2)	4.85(-3)	6.14(-4)
1.76	4.33(-2)	4.30(-2)	4.05(-2)	3.69(-2)	3.44(-2)	2.99(-2)	2.00(-2)	7.98(-3)	1.29(-3)
2.25	5.38(-2)	5.34(-2)	5.05(-2)	4.61(-2)	4.32(-2)	3.78(-2)	2.59(-2)	1.11(-2)	2.09(-3)
2.75	6.41(-2)	6.37(-2)	6.04(-2)	5.54(-2)	5.19(-2)	4.57(-2)	3.19(-2)	1.43(-2)	3.02(-3)

α = 1.0

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	6.47(-3)	6.36(-3)	5.69(-3)	4.88(-3)	4.33(-3)	3.40(-3)	1.71(-3)	3.32(-4)	9.42(-6)
.364	1.05(-2)	1.04(-2)	9.33(-3)	8.06(-3)	7.21(-3)	5.74(-3)	3.03(-3)	6.76(-4)	2.74(-5)
.50	1.57(-2)	1.54(-2)	1.40(-2)	1.21(-2)	1.09(-2)	8.84(-3)	4.88(-3)	1.23(-3)	6.86(-5)
.662	2.15(-2)	2.12(-2)	1.93(-2)	1.69(-2)	1.53(-2)	1.25(-2)	7.16(-3)	2.01(-3)	1.45(-4)
.75	2.47(-2)	2.44(-2)	2.22(-2)	1.95(-2)	1.77(-2)	1.46(-2)	8.46(-3)	2.47(-3)	2.00(-4)
1.0	3.32(-2)	3.28(-2)	3.01(-2)	2.65(-2)	2.42(-2)	2.01(-2)	1.21(-2)	3.91(-3)	4.02(-4)
1.25	4.13(-2)	4.08(-2)	3.76(-2)	3.32(-2)	3.04(-2)	2.56(-2)	1.58(-2)	5.51(-3)	6.81(-4)
1.76	5.68(-2)	5.62(-2)	5.21(-2)	4.63(-2)	4.26(-2)	3.63(-2)	2.33(-2)	8.98(-3)	1.41(-3)
2.25	6.98(-2)	6.91(-2)	6.43(-2)	5.74(-2)	5.30(-2)	4.56(-2)	3.01(-2)	1.24(-2)	2.28(-3)
2.75	8.25(-2)	8.18(-2)	7.64(-2)	6.84(-2)	6.32(-2)	5.47(-2)	3.68(-2)	1.59(-2)	3.27(-3)

TABLE 5 (Cont'd)

α = 10.0

E (MeV) \ h (m)	0	.1	1	3	5	10	30	100	300
.25	1.39(-2)	1.34(-2)	1.05(-2)	8.10(-3)	6.86(-3)	5.01(-3)	2.28(-3)	4.11(-4)	1.13(-5)
.364	2.20(-2)	2.13(-2)	1.68(-2)	1.30(-2)	1.11(-2)	8.28(-3)	3.96(-3)	8.22(-4)	3.21(-5)
.50	3.19(-2)	3.08(-2)	2.47(-2)	1.92(-2)	1.66(-2)	1.25(-2)	6.27(-3)	1.48(-3)	7.93(-5)
.662	4.27(-2)	4.15(-2)	3.36(-2)	2.62(-2)	2.27(-2)	1.75(-2)	9.08(-3)	2.37(-3)	1.65(-4)
.75	4.86(-2)	4.72(-2)	3.84(-2)	2.99(-2)	2.60(-2)	2.02(-2)	1.07(-2)	2.91(-3)	2.27(-4)
1.0	6.36(-2)	6.19(-2)	5.11(-2)	4.00(-2)	3.48(-2)	2.74(-2)	1.50(-2)	4.53(-3)	4.50(-4)
1.25	7.74(-2)	7.56(-2)	6.30(-2)	4.96(-2)	4.33(-2)	3.44(-2)	1.95(-2)	6.33(-3)	7.57(-4)
Plane Source									
.25		2.09(-2)	1.29(-2)	9.13(-3)	7.55(-3)	5.37(-3)	2.38(-3)	4.23(-4)	1.15(-5)
.364		3.27(-2)	2.05(-2)	1.47(-2)	1.22(-2)	8.88(-3)	4.15(-3)	8.56(-4)	3.40(-5)
.50		4.69(-2)	2.98(-2)	2.15(-2)	1.80(-2)	1.33(-2)	6.50(-3)	1.51(-3)	8.07(-5)
.662		6.25(-2)	4.01(-2)	2.92(-2)	2.46(-2)	1.85(-2)	9.36(-3)	2.41(-3)	1.67(-4)
.75		7.07(-2)	4.56(-2)	3.34(-2)	2.82(-2)	2.13(-2)	1.10(-2)	2.97(-3)	2.31(-4)
1.0		9.21(-2)	6.00(-2)	4.46(-2)	3.76(-2)	2.89(-2)	1.55(-2)	4.62(-3)	4.57(-4)
1.17		1.05(-1)	6.91(-2)	5.17(-2)	4.36(-2)	3.38(-2)	1.85(-2)	5.79(-3)	6.38(-4)
1.25		1.12(-1)	7.38(-2)	5.55(-2)	4.67(-2)	3.63(-2)	2.01(-2)	6.44(-3)	7.61(-4)
1.33		1.18(-1)	7.79(-2)	5.88(-2)	4.95(-2)	3.86(-2)	2.15(-2)	7.04(-3)	8.73(-4)
1.76		1.48(-1)	9.85(-2)	7.57(-2)	6.37(-2)	5.01(-2)	2.90(-2)	1.03(-2)	1.57(-3)
2.25		1.77(-1)	1.19(-1)	9.30(-2)	7.83(-2)	6.18(-2)	3.68(-2)	1.40(-2)	2.47(-3)
2.75		2.07(-1)	1.39(-1)	1.11(-1)	9.32(-2)	7.38(-2)	4.51(-2)	1.81(-2)	3.61(-3)

TABLE 6

PERCENTAGE OF TOTAL EXPOSURE RATE DUE TO SKYSHINE-EXPONENTIALLY DISTRIBUTED SOURCES

	Source	h = 1 meter	h = 100 meters
α = .33	.364 MeV	17.6%	23.1%
	.662 MeV	13.9%	18.6%
	1.25 MeV	10.1%	13.3%
Plane* Source	.364 MeV	11.8%	23.1%
	.662 MeV	9.5%	18.0%
	1.25 MeV	8.0%	12.9%

*$\alpha \to \infty$ corresponds to an infinite plane source.

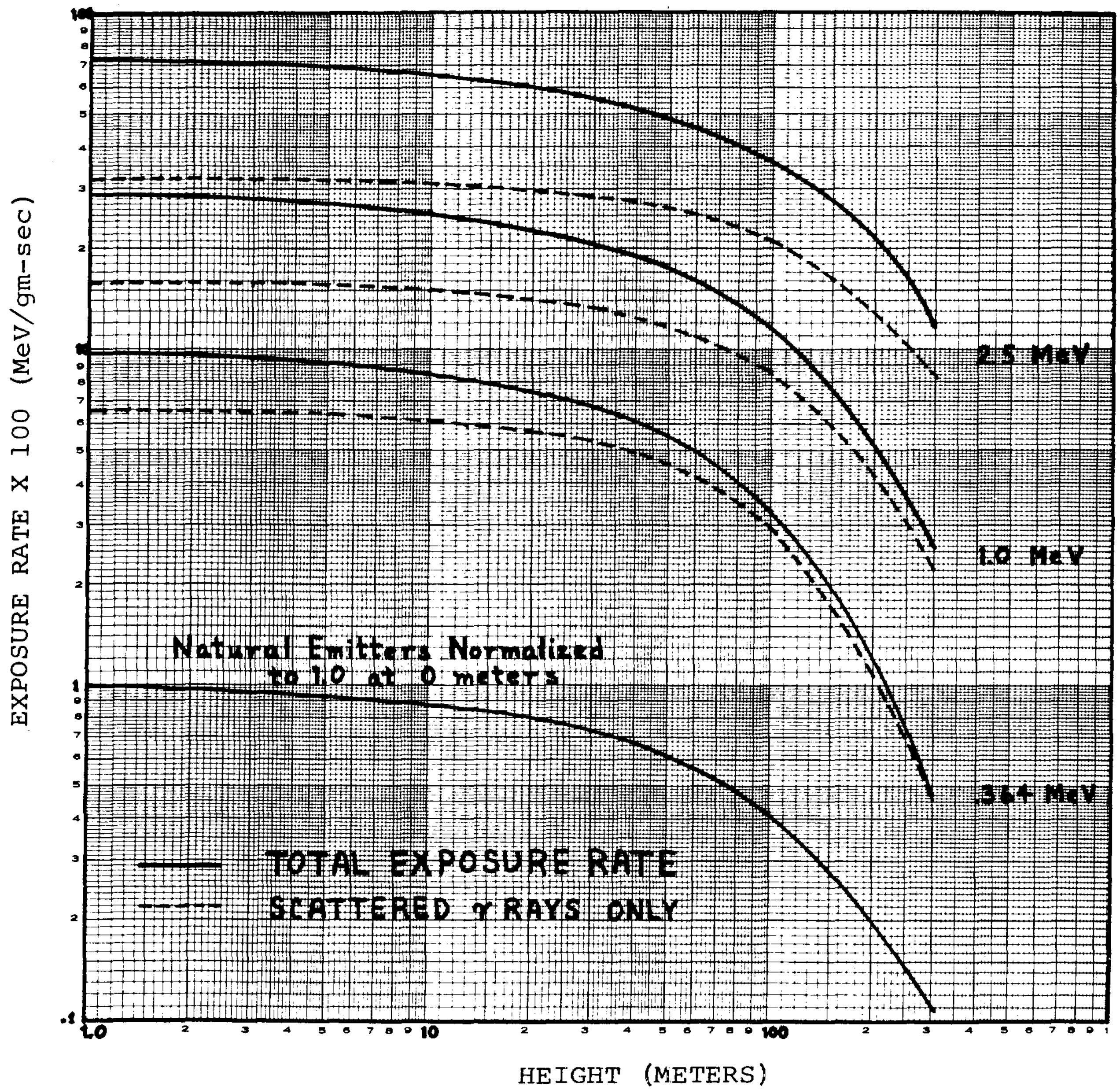

Figure 1. Total and scattered exposure rates versus height for uniformly distributed sources with energies of .364, 1.0 and 2.5 MeV and the single normalized curve of exposure rates for natural emitters.

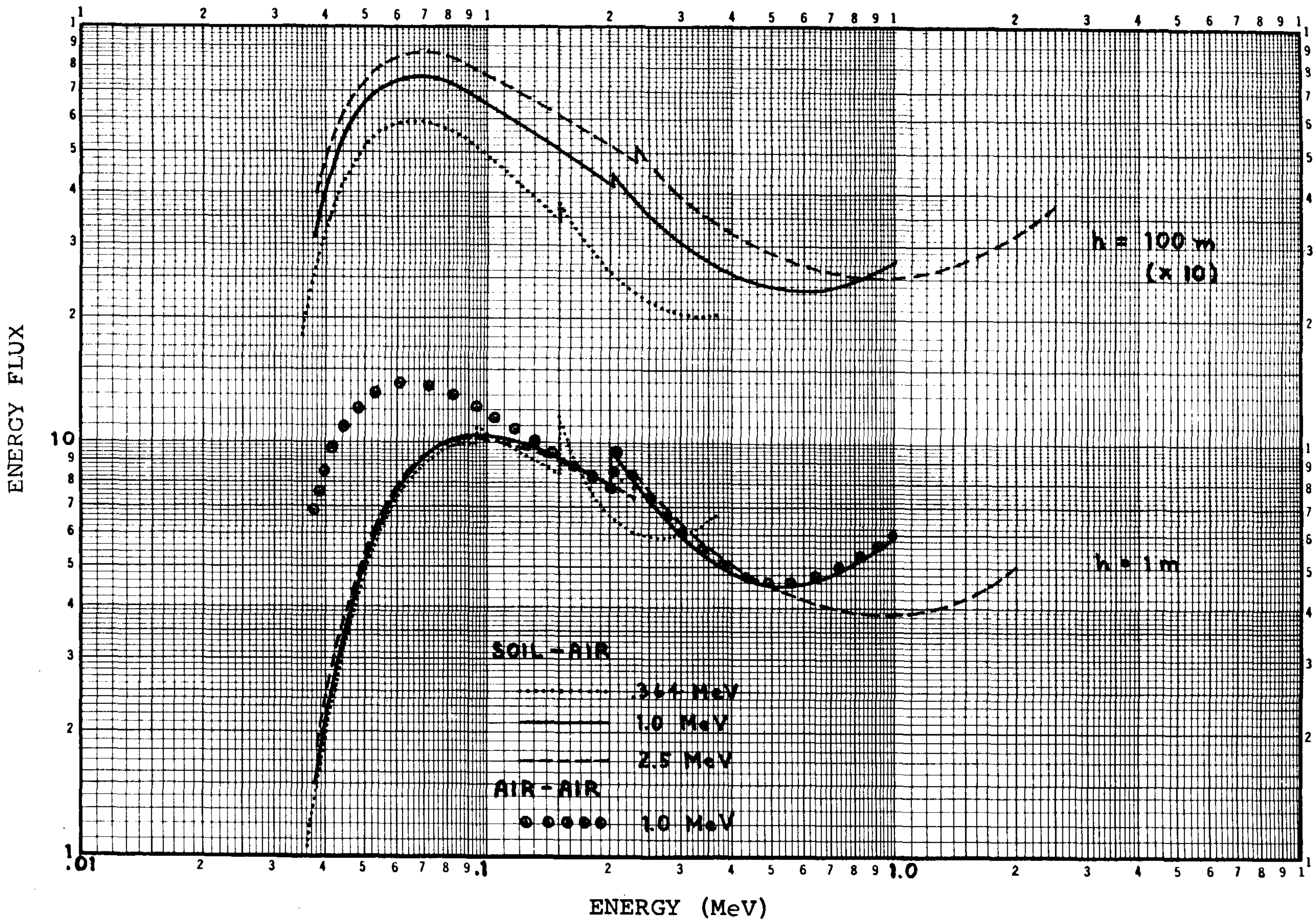

Figure 2. Differential energy spectra of the scattered energy flux (flux x energy) for three source energies at heights of 1 and 100 meters for a soil-air medium. Also shown for comparison, is the spectrum at 1 meter for a 1 MeV source in an infinite air medium.

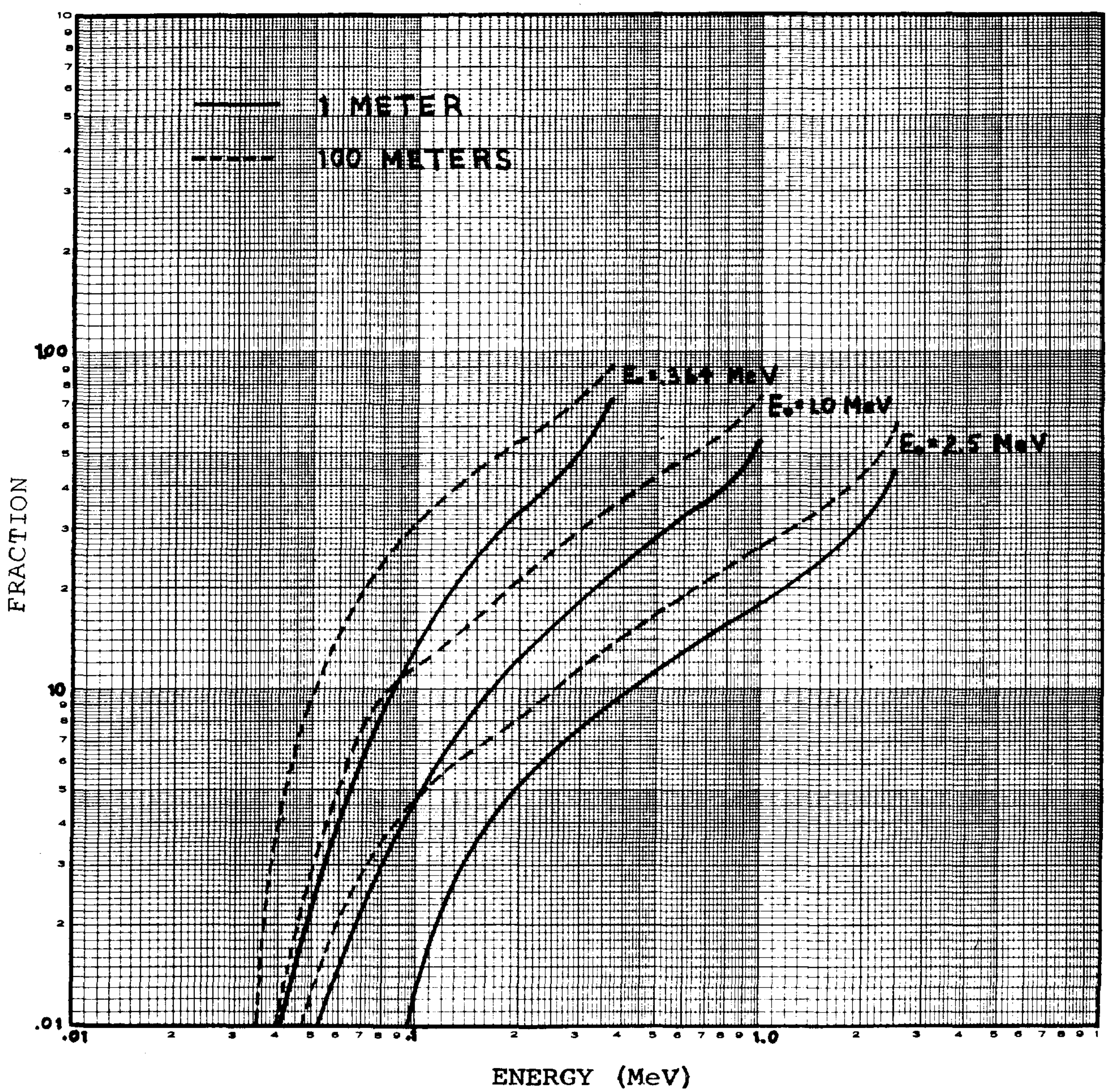

Figure 3. Integral exposure rate spectra (fraction of the total exposure rate due to gamma-rays of energy less than E) at 1 and 100 meters for uniformly distributed sources.

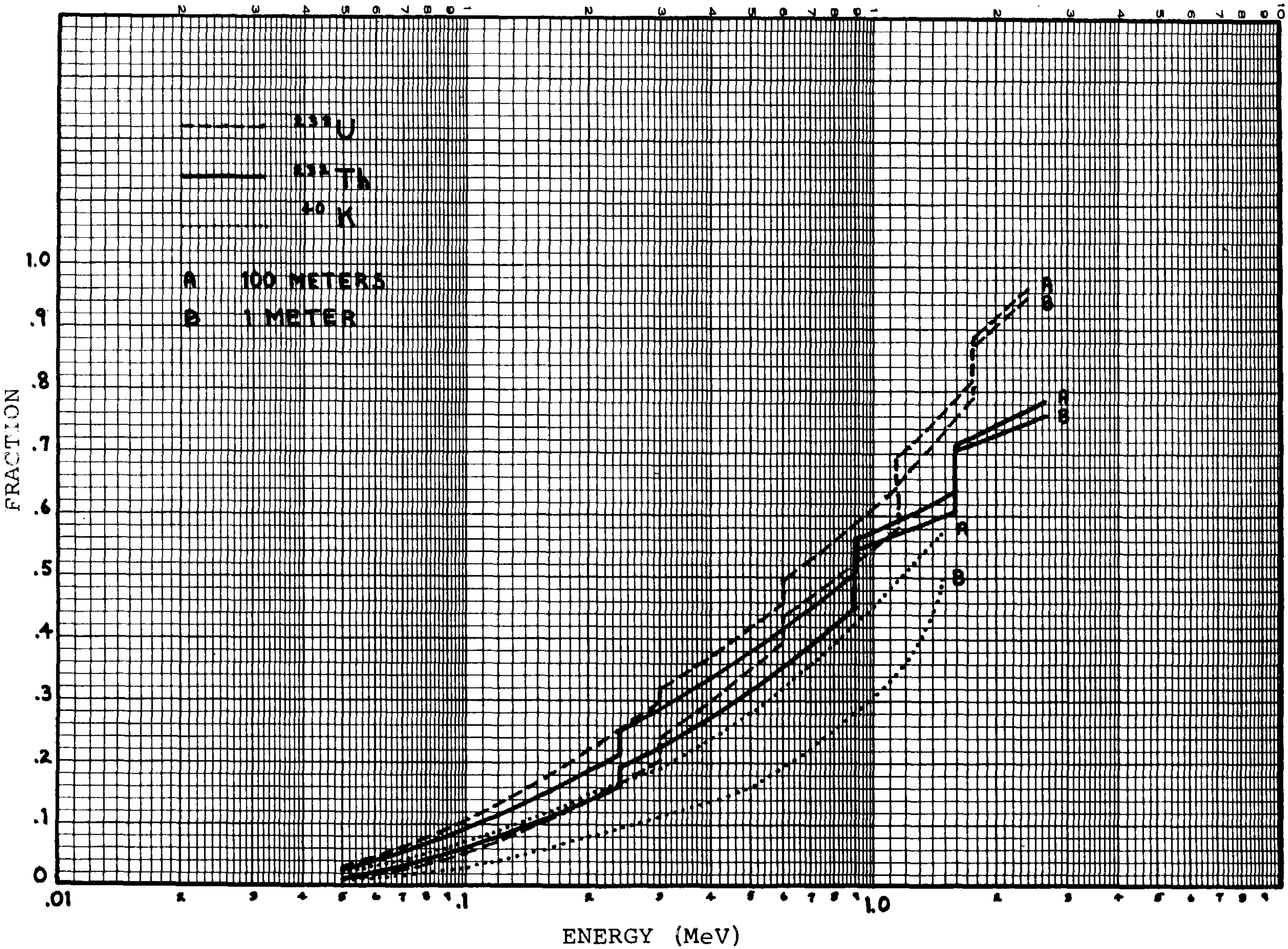

Figure 4. Integral exposure rate spectra (fraction of the total exposure rate due to gamma-rays of energy less than E) for the natural emitters ^{40}K, ^{238}U, and ^{232}Th, at 1 and 100 meters for uniformly distributed sources.

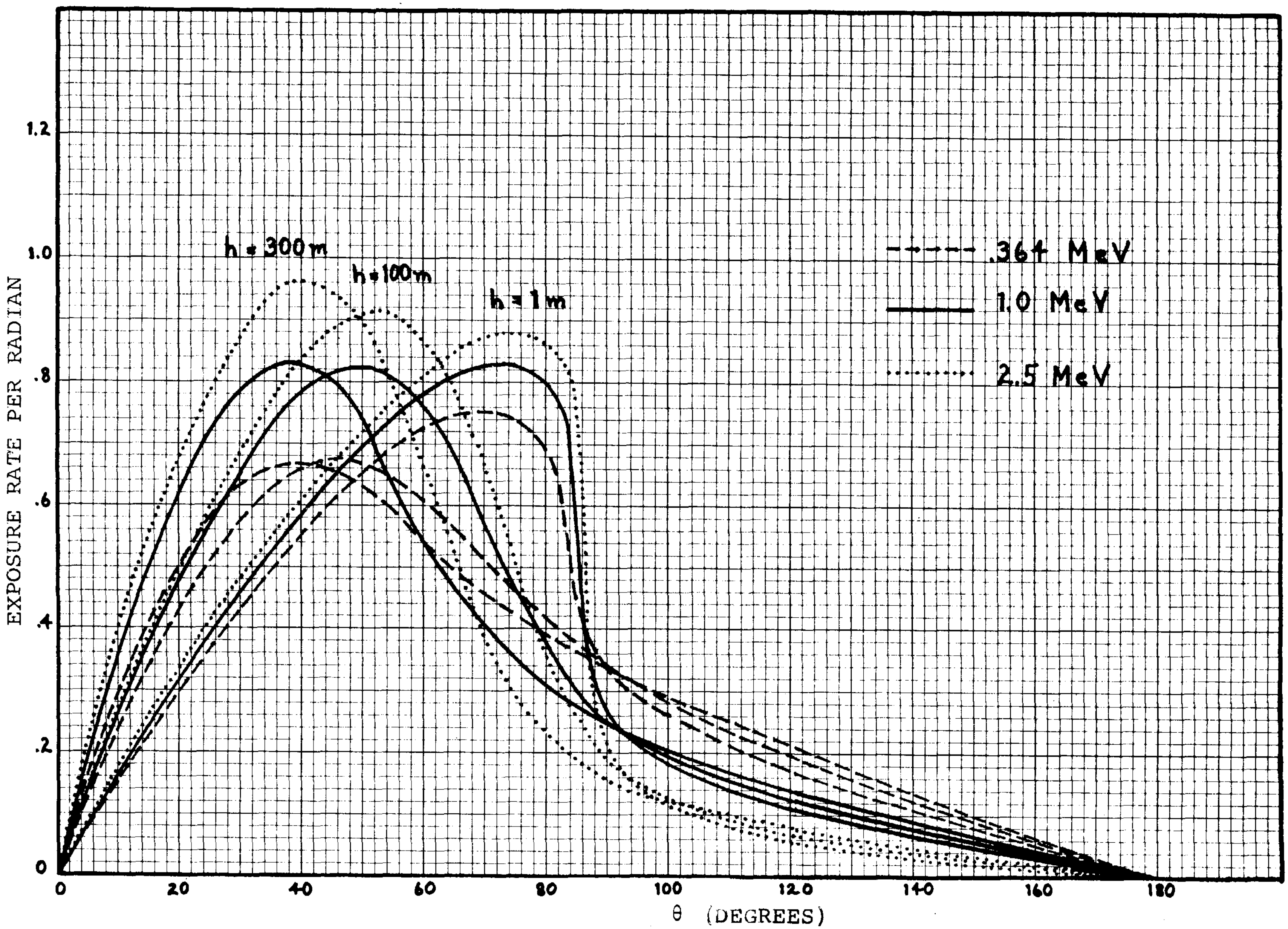

Figure 5. Differential angular exposure rate per radian (normalized to a total exposure rate of 1.0) at 1, 100, and 300 meters for uniformly distributed sources.

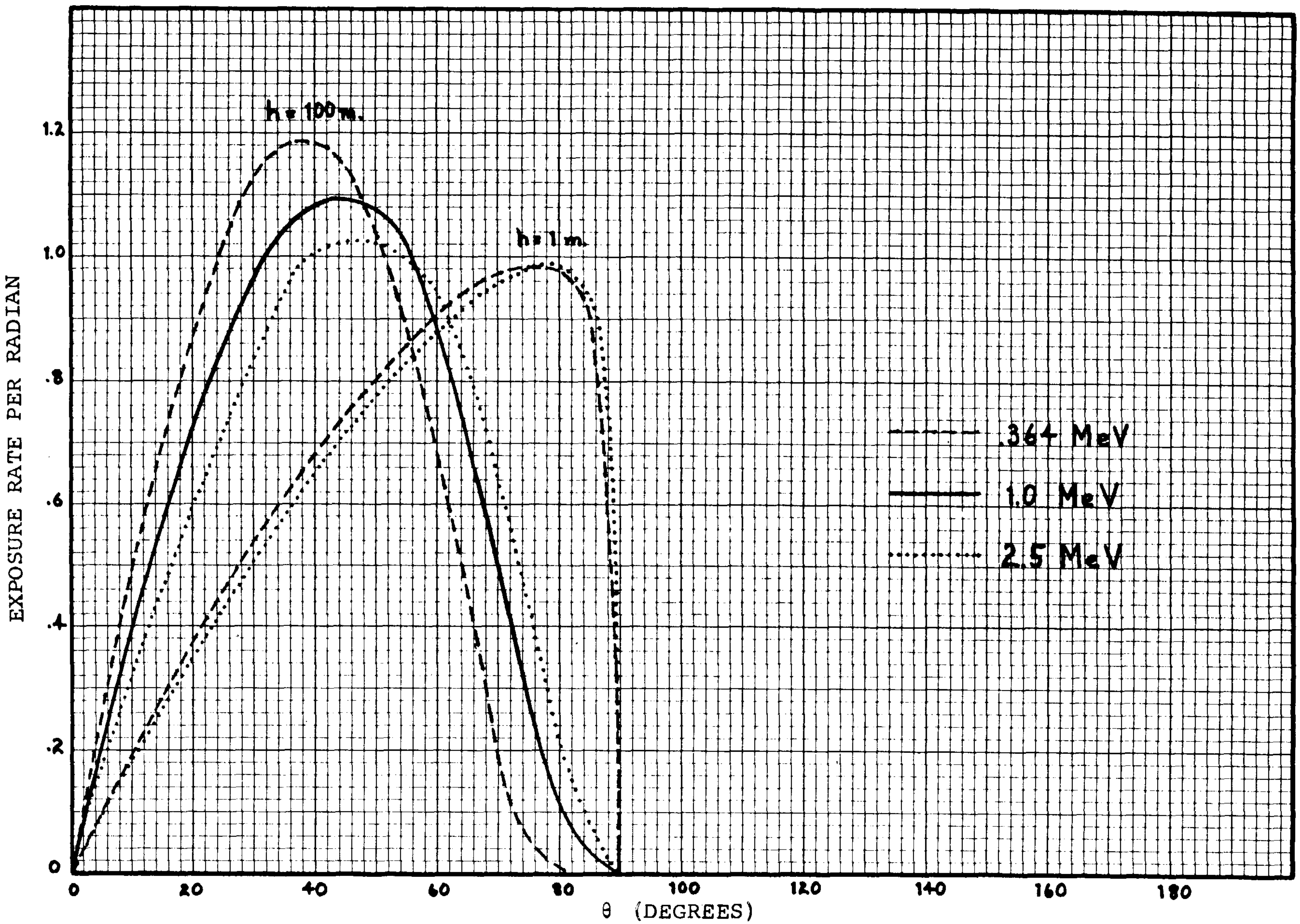

Figure 6. Differential angular exposure rate per radian for unscattered gamma-rays only (normalized to unscattered exposure rate of 1.0) at 1 and 100 meters uniformly distributed sources.

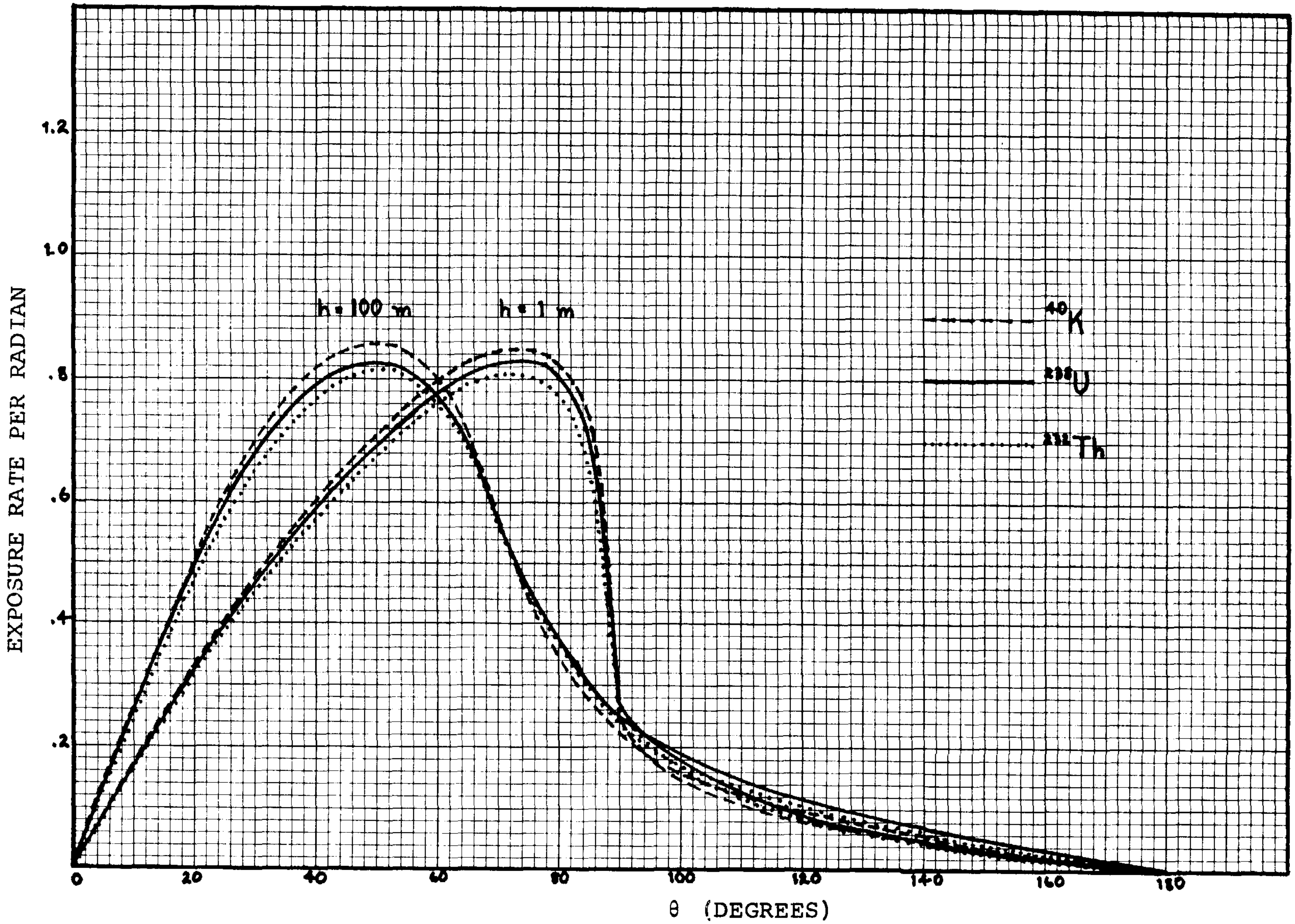

Figure 7. Differential angular exposure rate per radian for natural emitters (normalized to a total exposure rate of 1) at 1 and 100 meters.

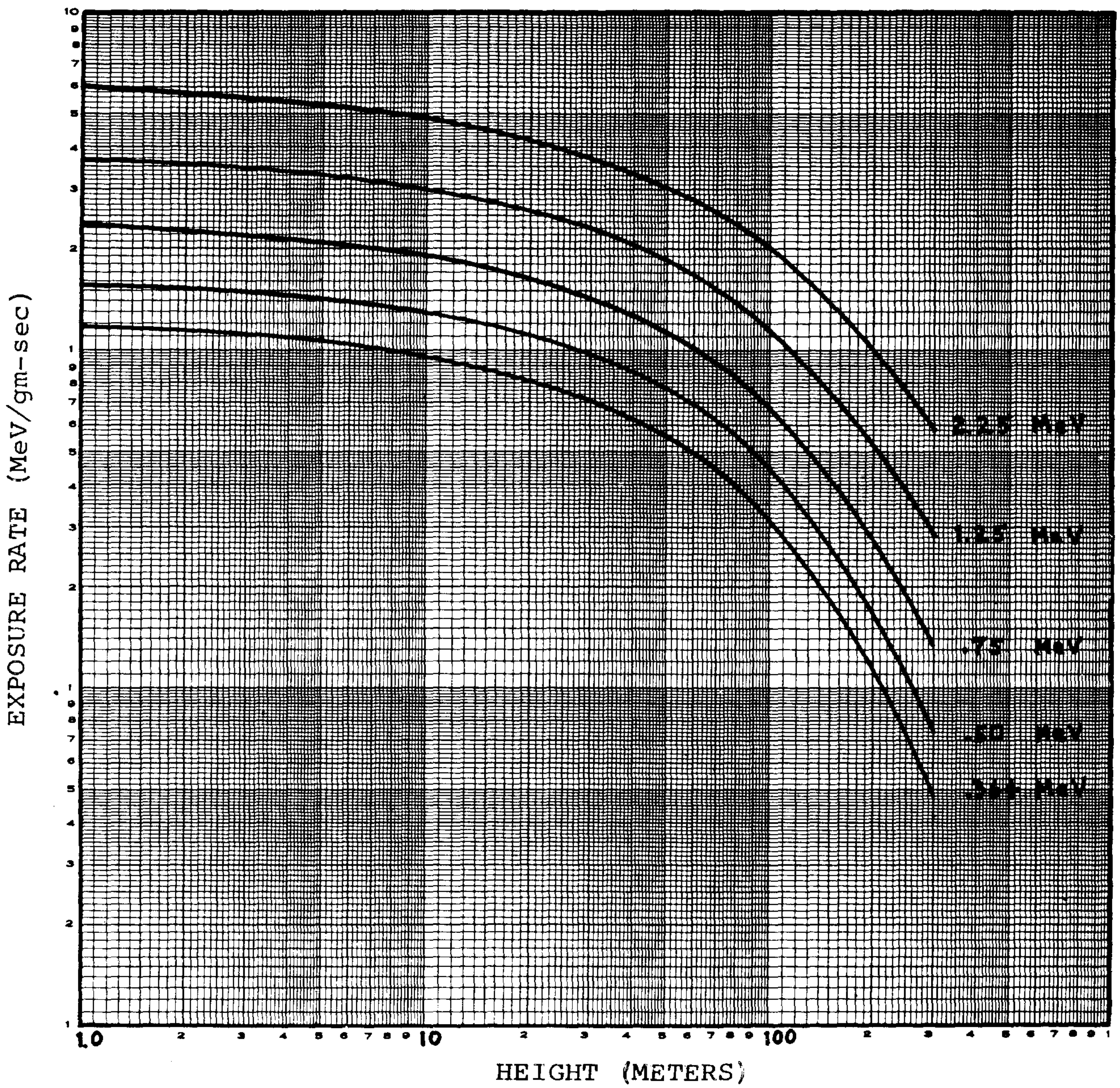

Figure 8. Total exposure rate for an exponentially distributed source ($\alpha = .33$) for various source energies as a function of height.

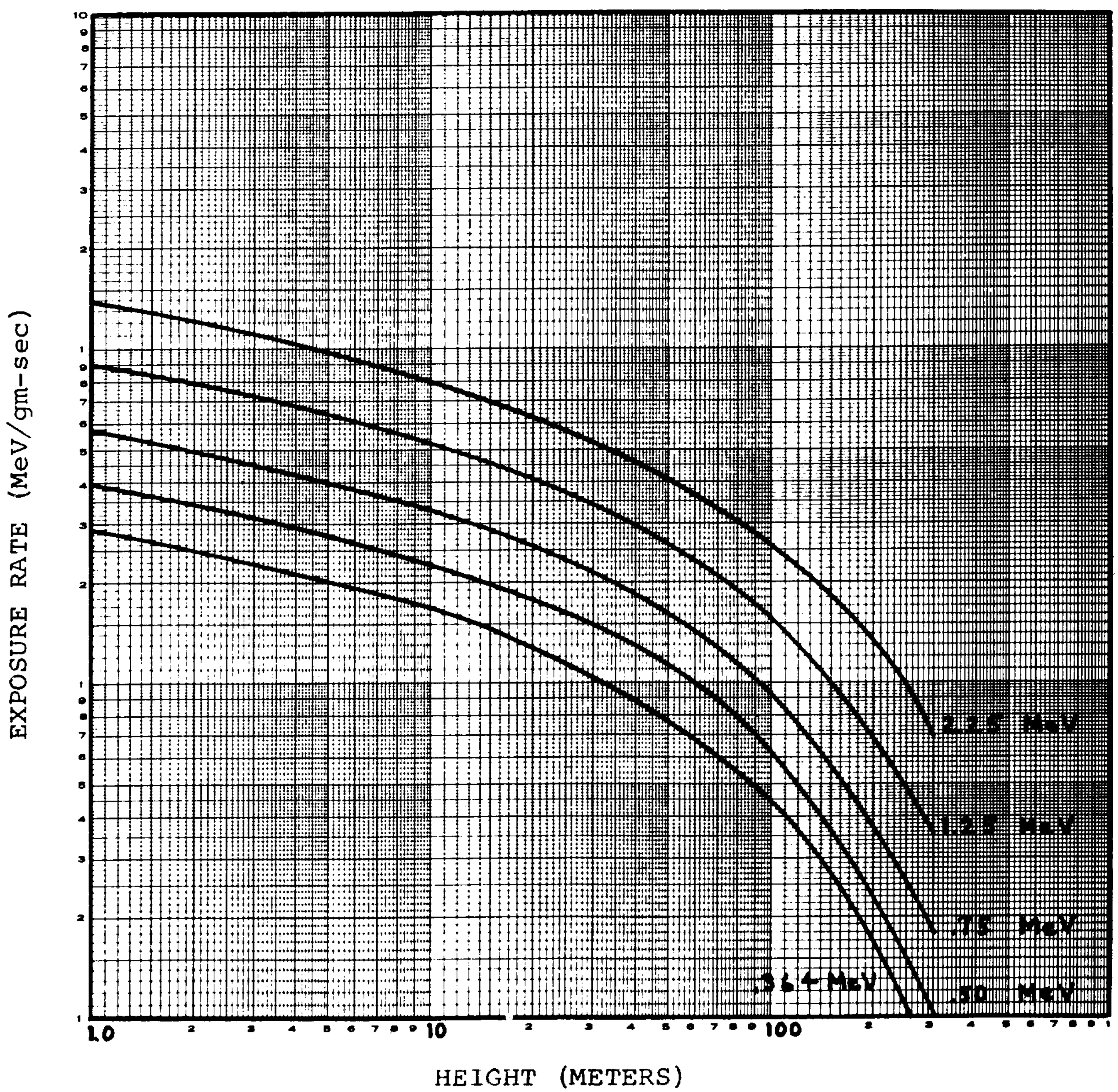

Figure 9. Total exposure rate for plane sources of various energies as a function of height.

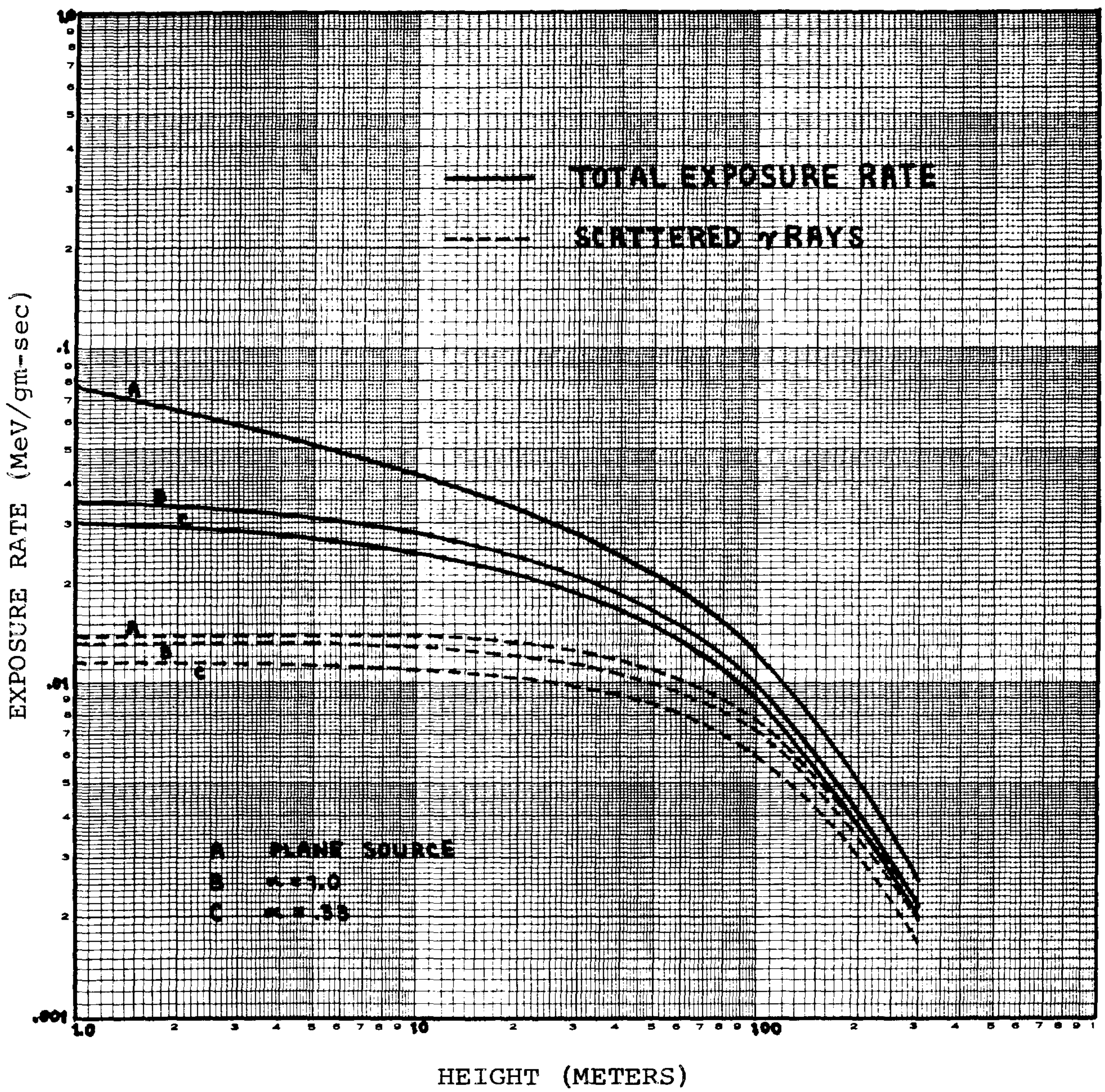

Figure 10. Total and scattered exposure rates as a function of height for various exponentially distributed sources, energy = 1 MeV.

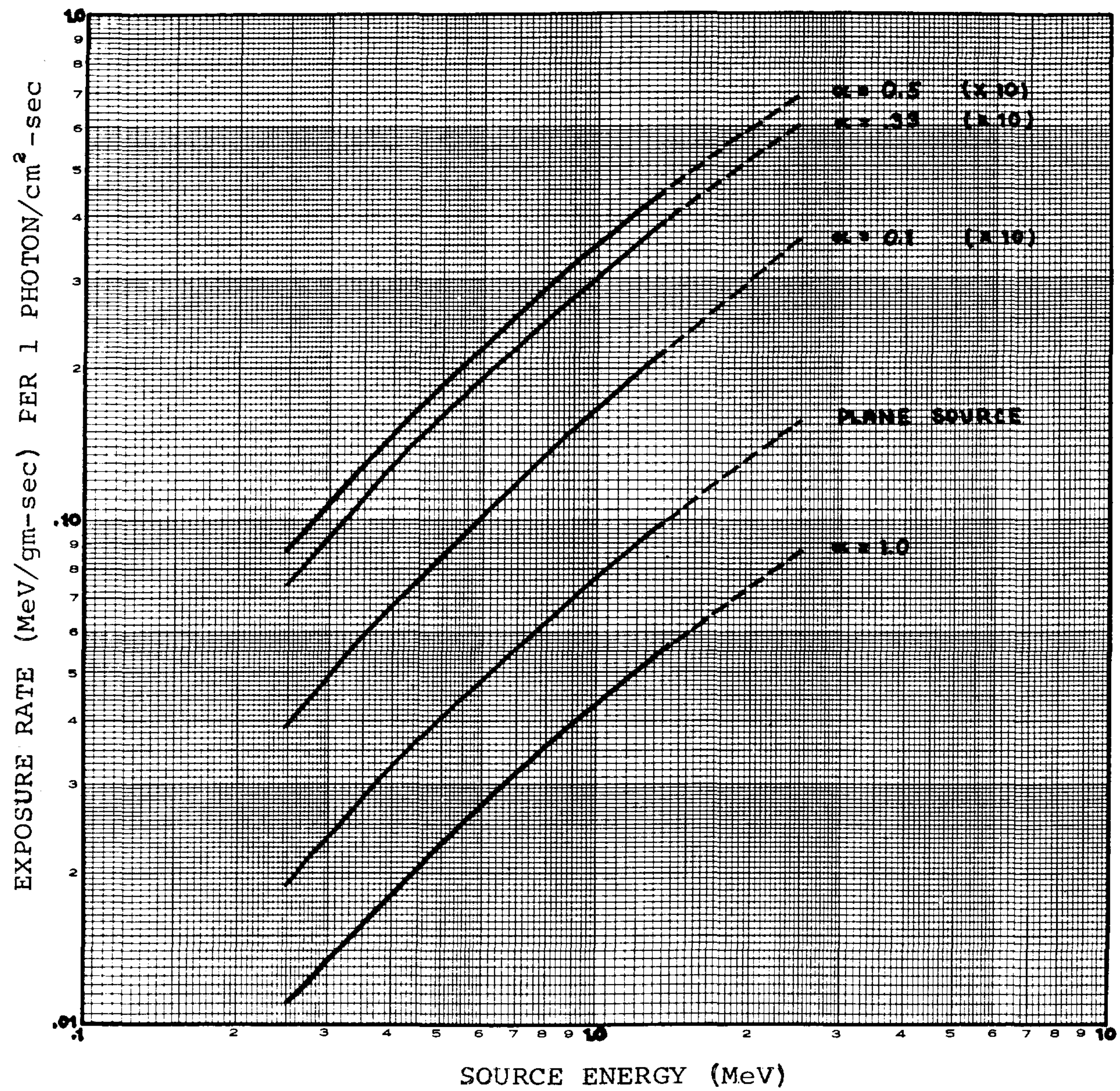

Figure 11. Total exposure rate as a function of energy at 1 meter for various depth distributions.

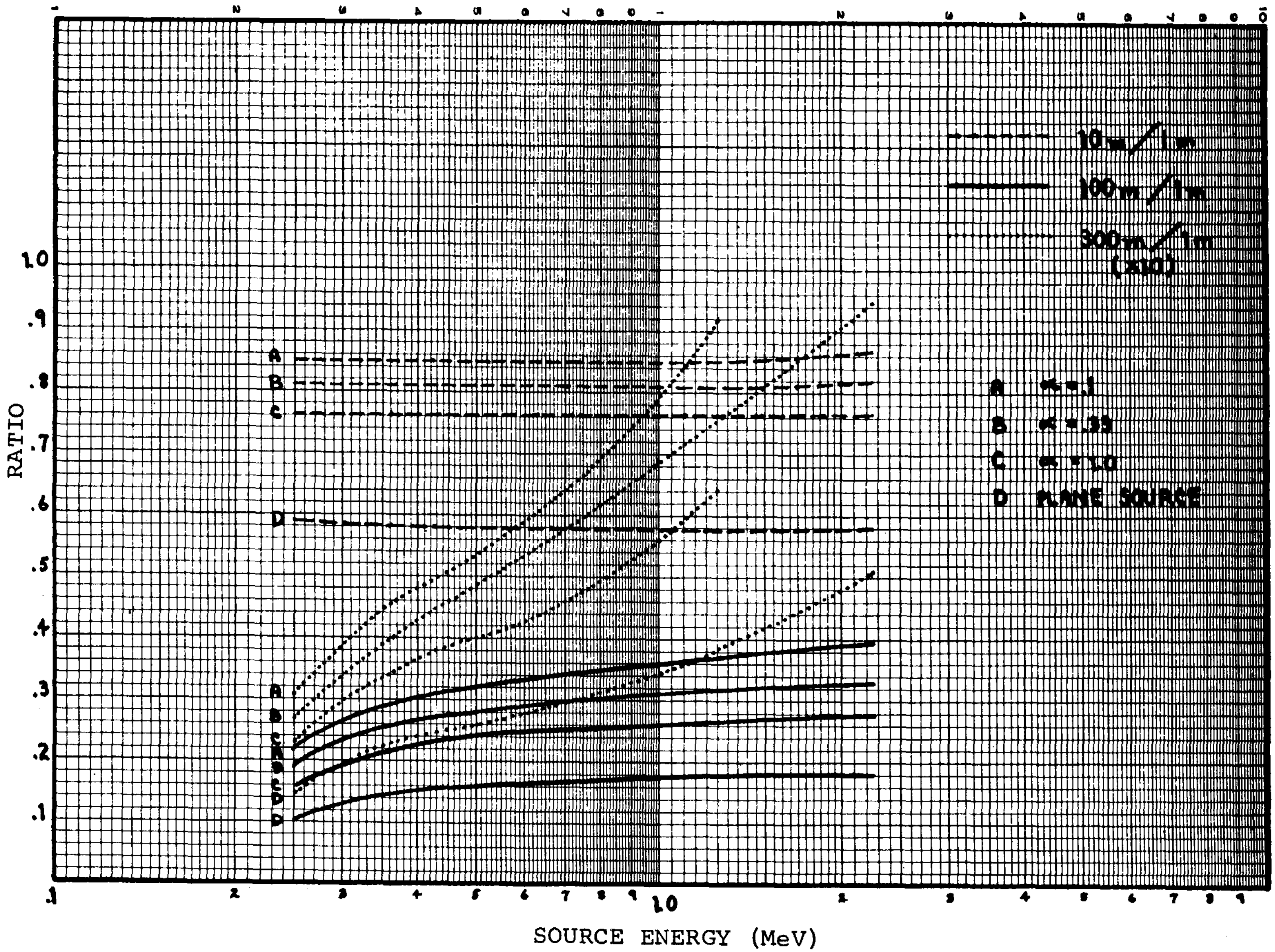

Figure 12. Effect of source depth distribution on total exposure rate at 10, 100, and 300 meters, relative to the total exposure rate at 1 meter.

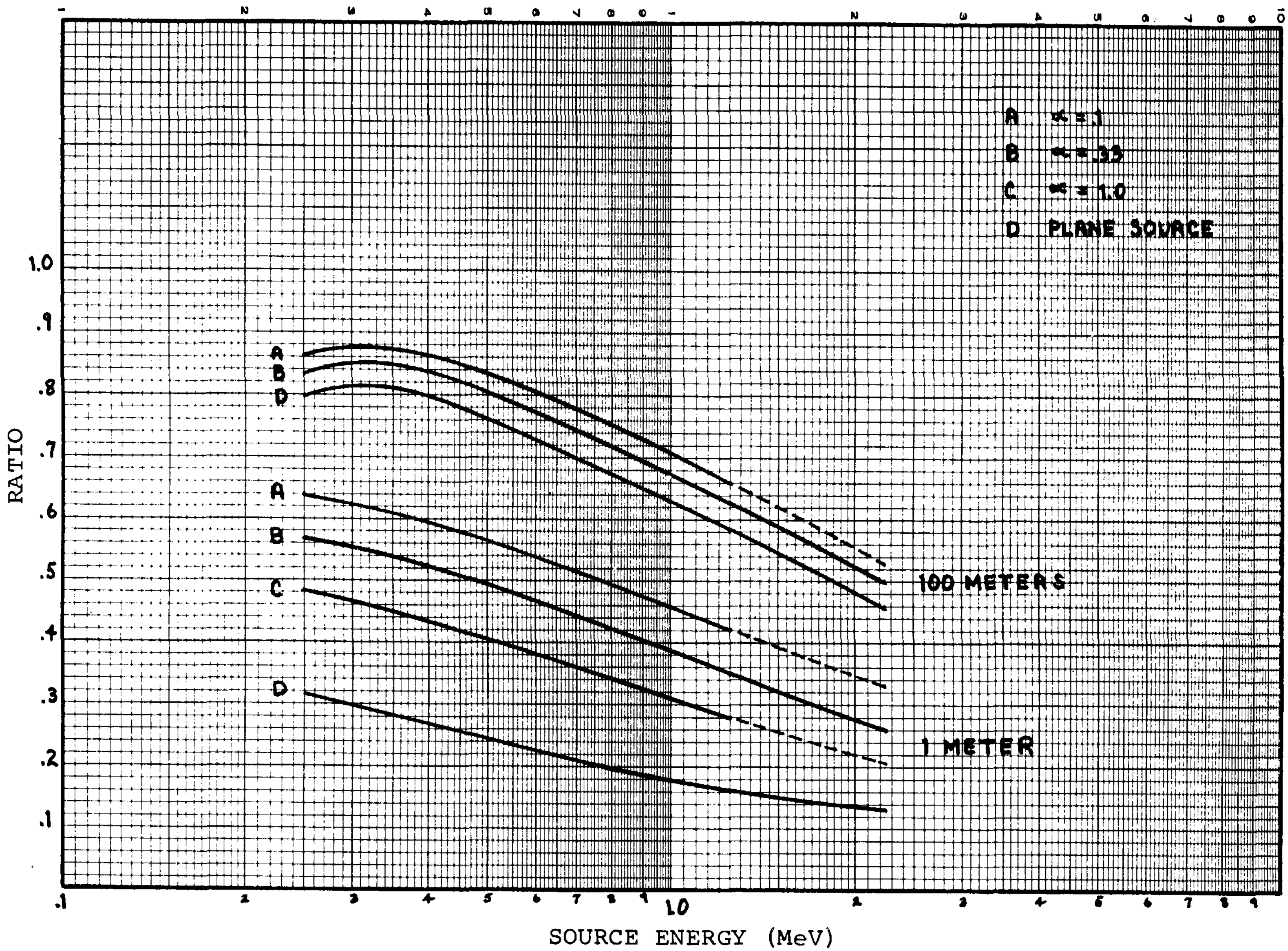

Figure 13. The ratio of the exposure rate due to scattered gamma-rays to total exposure rate at 1 and 100 meters for various depth distributions as a function of source energy.

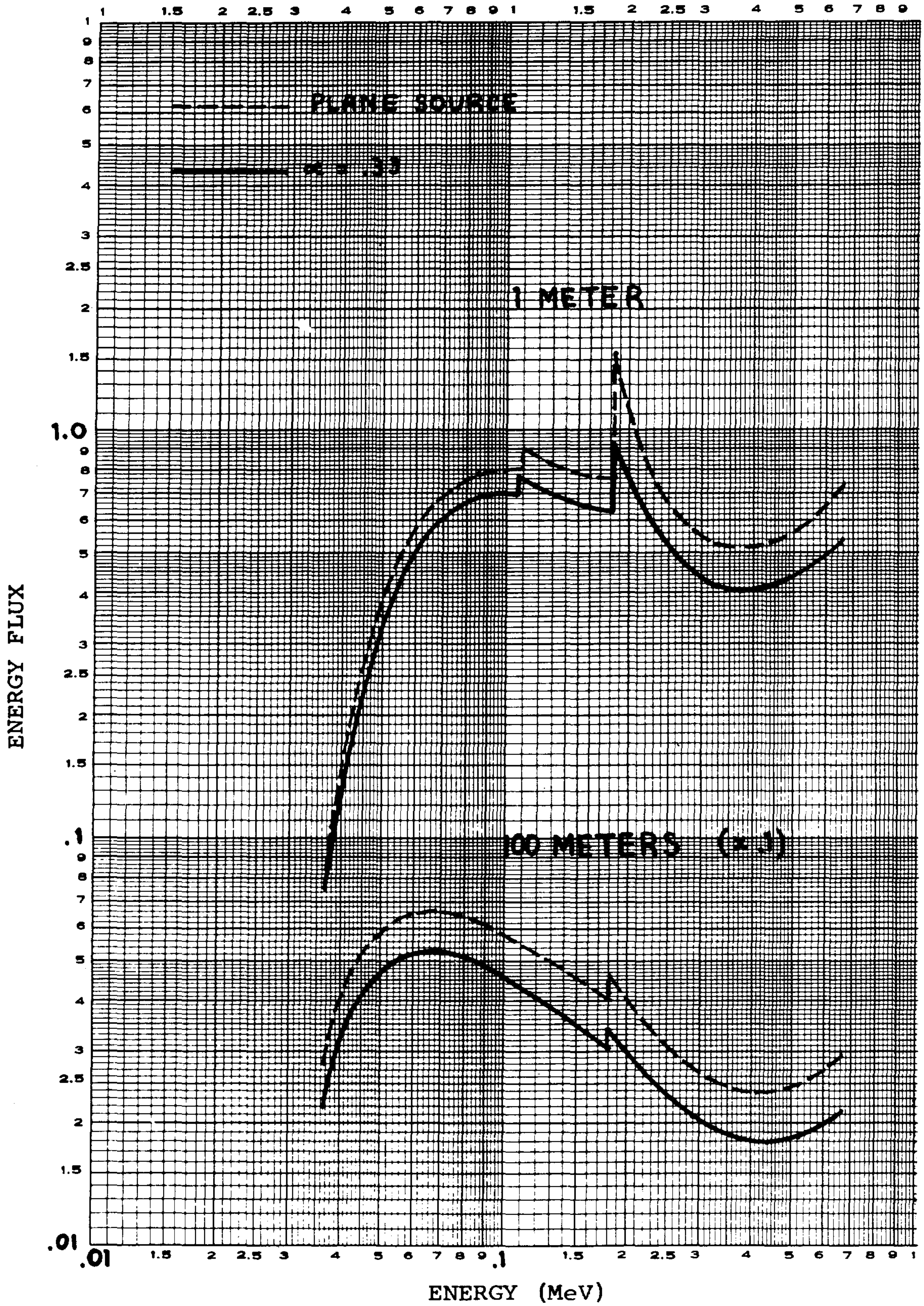

Figure 14. Differential energy spectra of the scattered energy flux at 1 and 100 meters for a .662 MeV source (^{137}Cs).

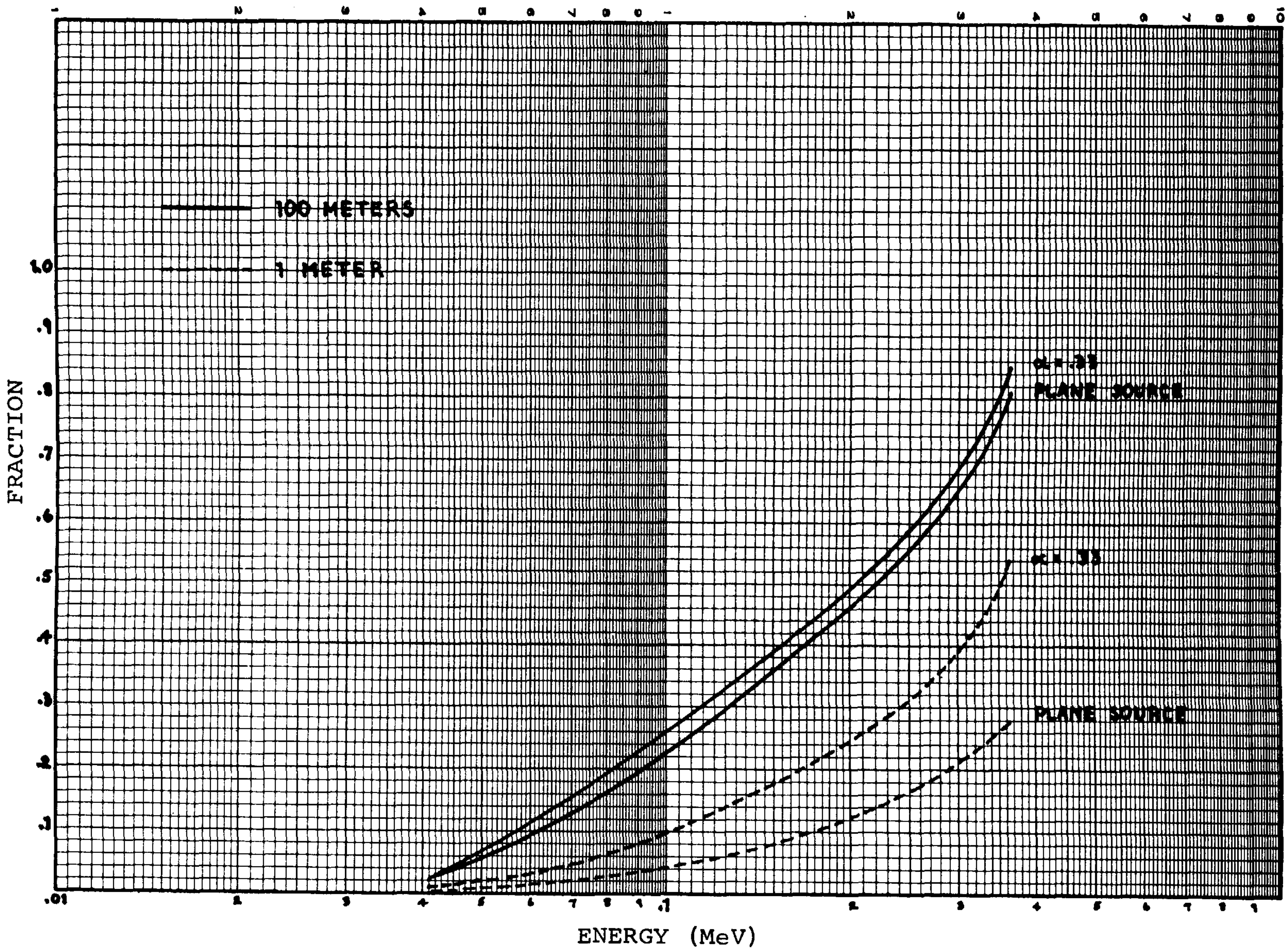

Figure 15. Integral exposure rate spectra (fraction of total exposure rate due to gamma-rays of energy less than E) for a .364 MeV source at 1 and 100 meters.

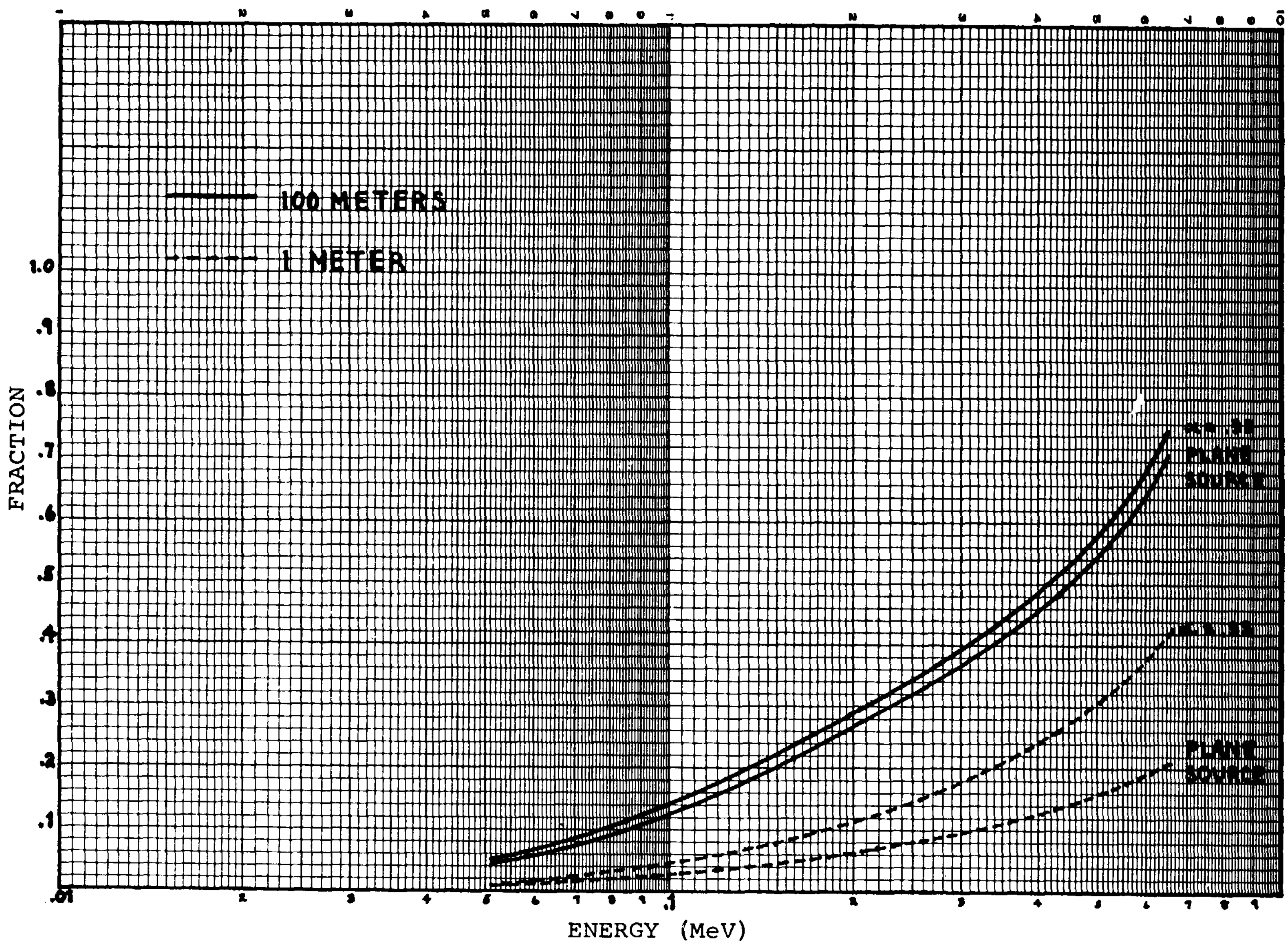

Figure 16. Integral exposure rate spectra (fraction of total exposure rate due to gamma-rays of energy less than E) for a .662 MeV source at 1 and 100 meters.

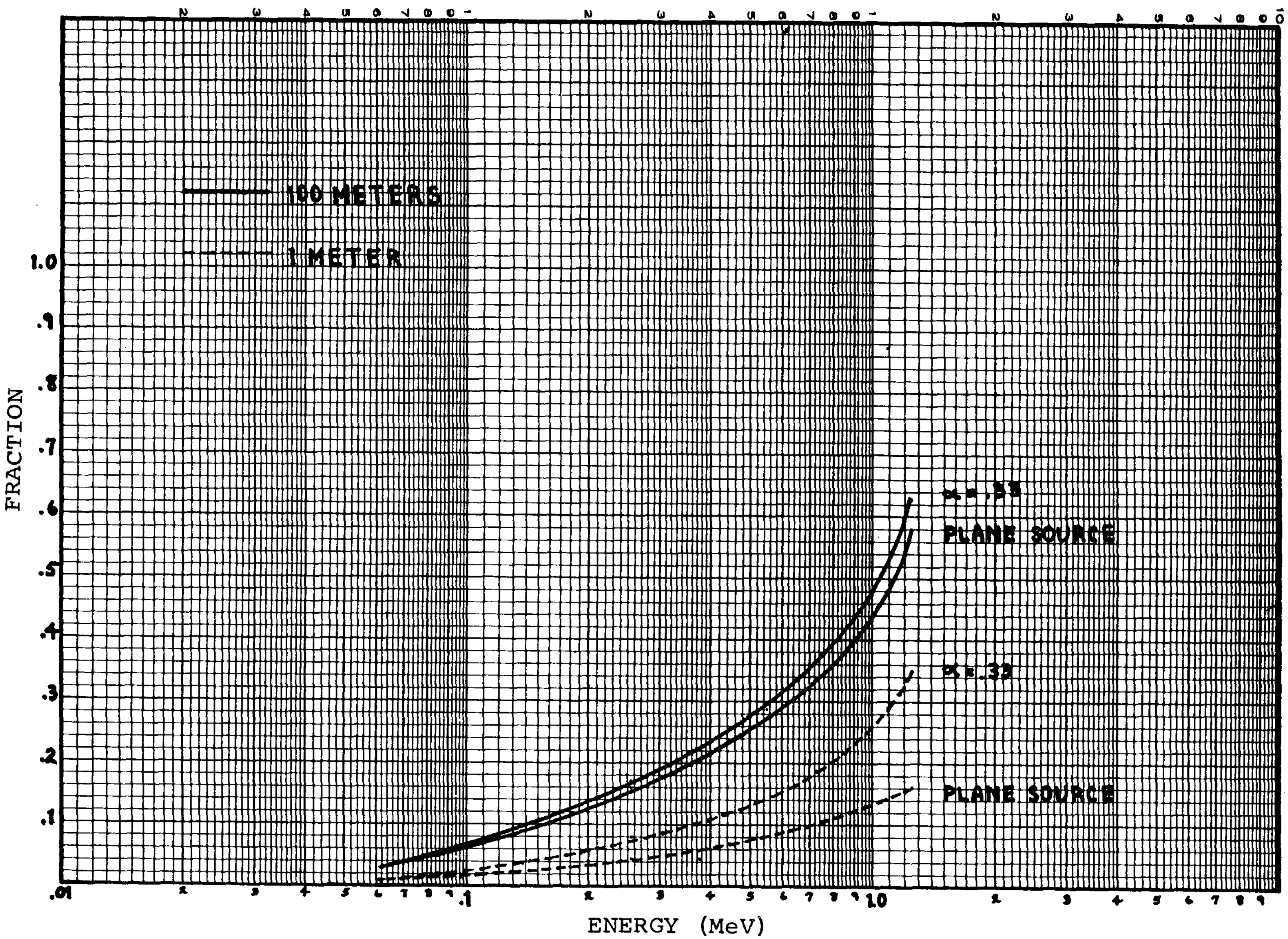

Figure 17. Integral exposure rate spectra (fraction of total exposure rate due to gamma-rays of energy less than E) for a 1.25 MeV source at 1 and 100 meters.

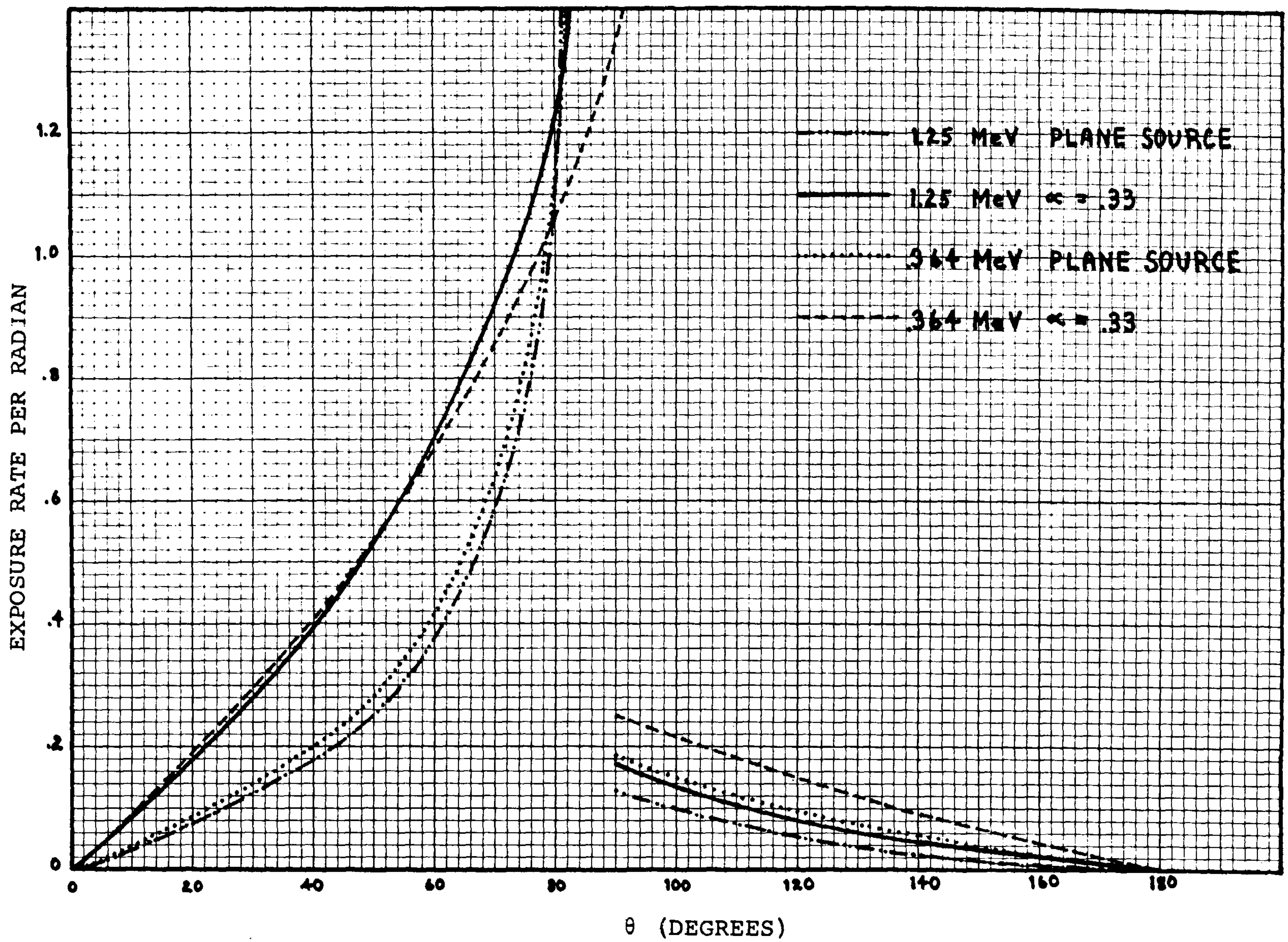

Figure 18a. Differential angular exposure rate distributions for plane and exponentially distributed sources at 1 meter (normalized to a total exposure rate of 1.0).

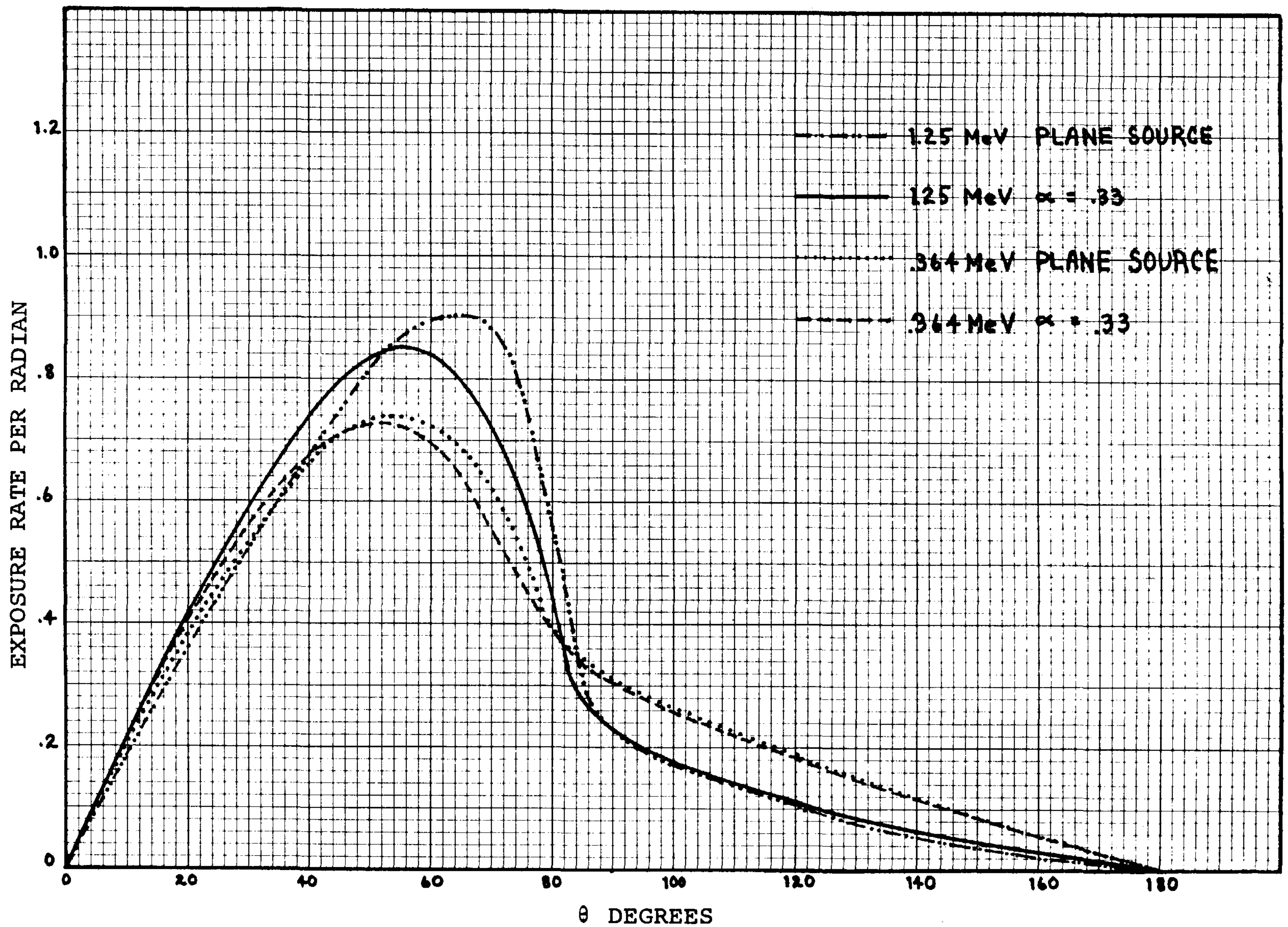

Figure 18b. Differential angular exposure rate distributions for plane and exponentially distributed sources at 100 meters (normalized to a total exposure rate of 1.0)

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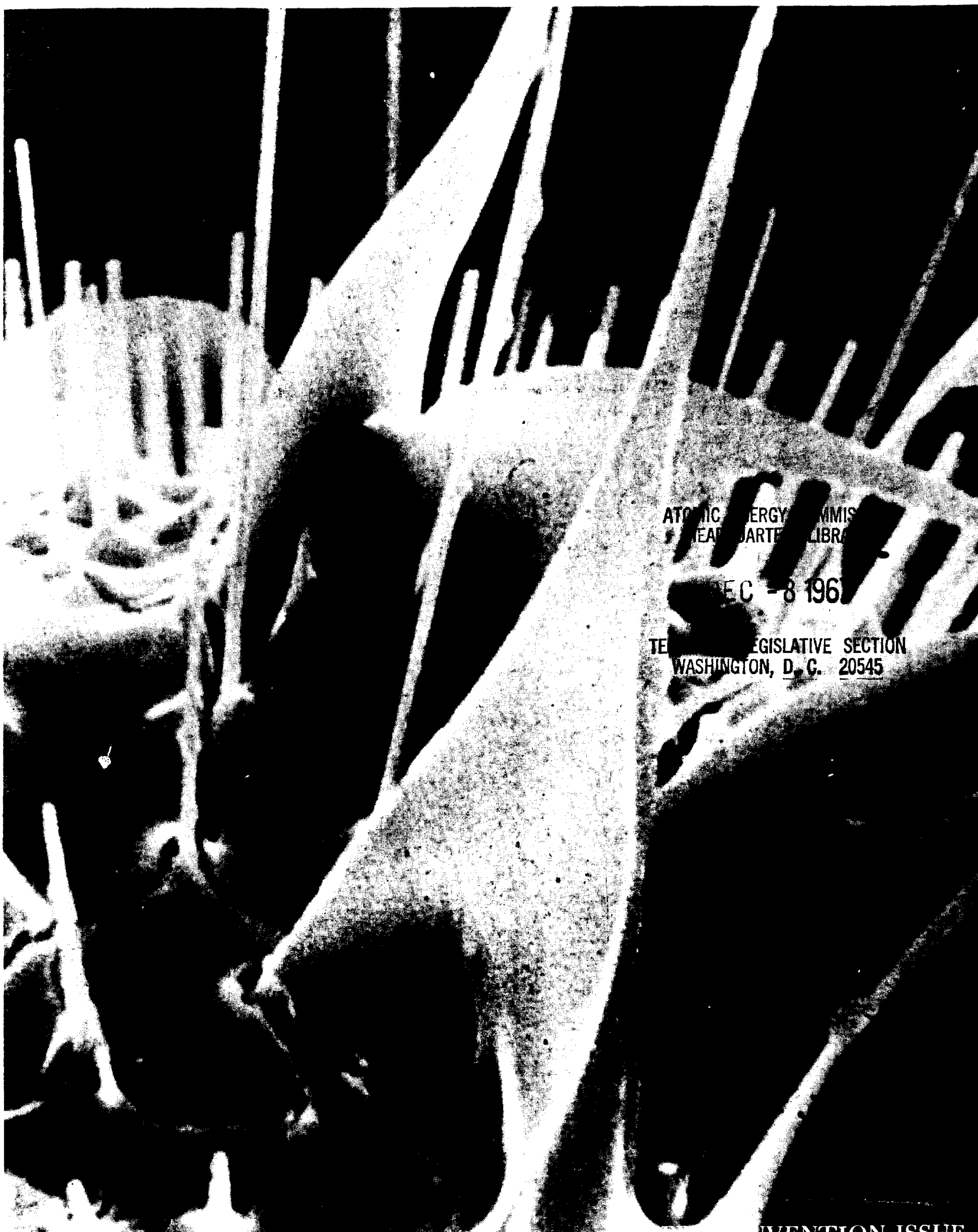

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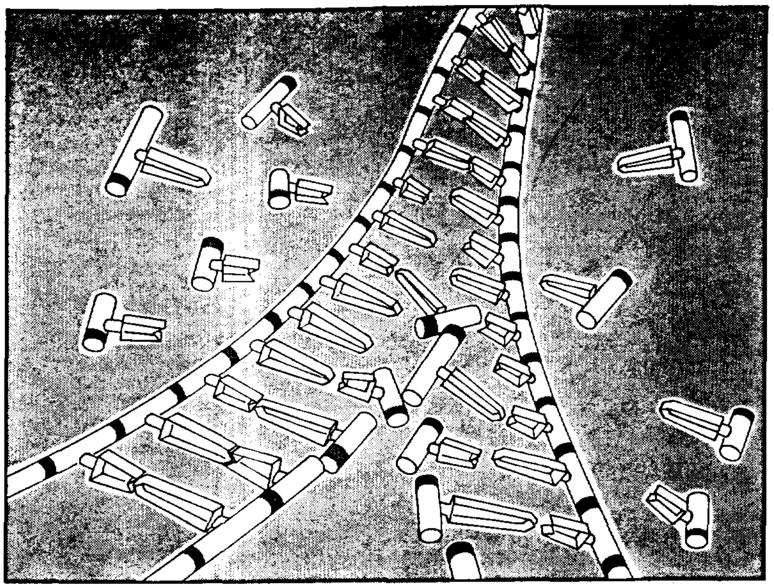

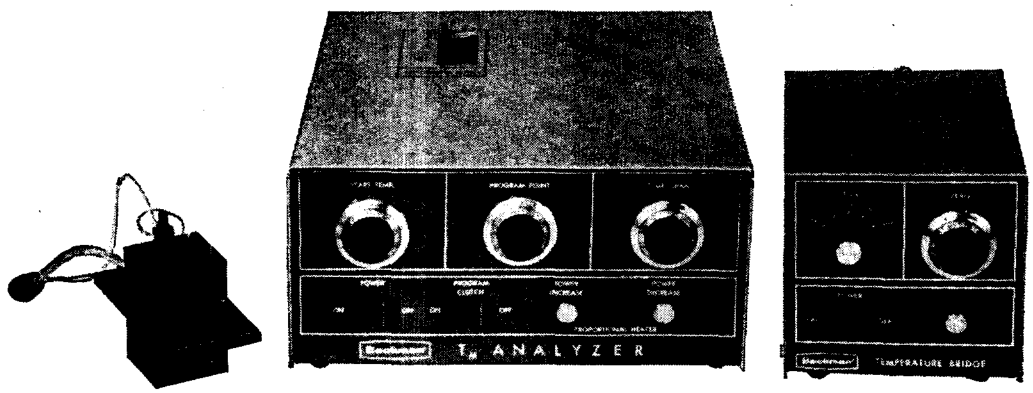
ANALYZER

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SCIENCE

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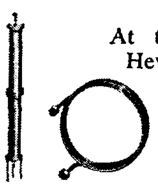
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

COVER

Globigerina bulloides (d'Orbigny), Recent, from 200-meter depth on the Scotian Shelf. Details of spinal development on the ultimate chamber adjoining the apertural opening of the shell (× 3500). The new scanning electron microscope ranges in magnification from × 50 to greater than × 100,000. See page 1318. [G. A. Bartlett, Bedford Institute of Oceanography]

A close look at the pill and other molecules ...with effective instruments

The Art of Making Fine Chemicals



At the 1965 Pittsburgh Conference, Hewlett-Packard introduced to the chemical industry a large-scale preparative gas chromatograph. Where prep GC had previously been limited to producing, at best, a few *milliliters* of high-purity chemicals during a long day's operation, this new H-P instrument easily separated a *liter* of equally pure materials in a few hours.

As is often the case with technological advancements that suggest a commercial value, incredulity ensued—partly because claims about the instrument were misunderstood, partly because the largest element of the scientific community is from Missouri. Large-scale prep GC became one of 1965's chemical controversies. Yet today, a scant 3 years later, H-P's large-scale prep GC is a fixture in scores of chemical companies around the world, on the basis of its *demonstrated* rather than claimed capabilities.

The characteristic elements of the H-P instrument are the 4-inch diameter column whose relative capacity ratio is more than 100 times greater than conventional prep columns; and the flow homogenizer, an ingenious piece of hardware that removed the last barrier to the use of such large columns, i.e., non-uniform carrier gas flow leading to loss of resolution. Because of these two elements, the instrument has a gargantuan appetite for performing high-purity separations. For example, it separated a gallon of rectified turpentine (that's almost 4 liters) into 1733 milliliters of α-pinene, 701 milliliters of β-pinene, both with a purity of over 98%; instrument running time was 30 hours. In a 7-hour run, the instrument separated 970 milliliters of C_8, C_9 and C_{10} methyl esters, collecting 906 milliliters in the following purities: C_8 and C_{10}, 99.8%; C_9, 99.2%. The same work would have taken 6 months on a conventional prep GC.

Based on these and many similar separations, the importance to the chemist of the H-P prep GC is easily described: it produces high-purity chemicals so fast, so conveniently, and so economically that every chemist who needs them—analytical, organic, biomedical—can now prepare his own, whether he needs a microliter or several liters of a pure substance . . . for use in reaction studies, for analysis, or even for commercial purposes. Of course if all three types of chemists work in the same lab, the H-P prep GC also creates a new problem: who gets to use it first. For help in solving most prep GC problems except this one, write for Data Sheet 775/6.

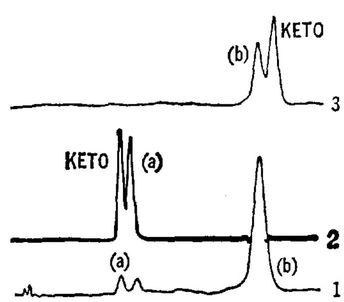
Pandora's Pill Box

Although five to seven million American women have already consumed more than four billion oral contraceptives, there is still much uncertainty concerning their long-term effect on the human body.

The issues are scientific and the questions involve chemistry, biochemistry and physiology . . . endocrinology, pharmacology, and gynecology. The answers are in widespread research in every scientific discipline concerned.

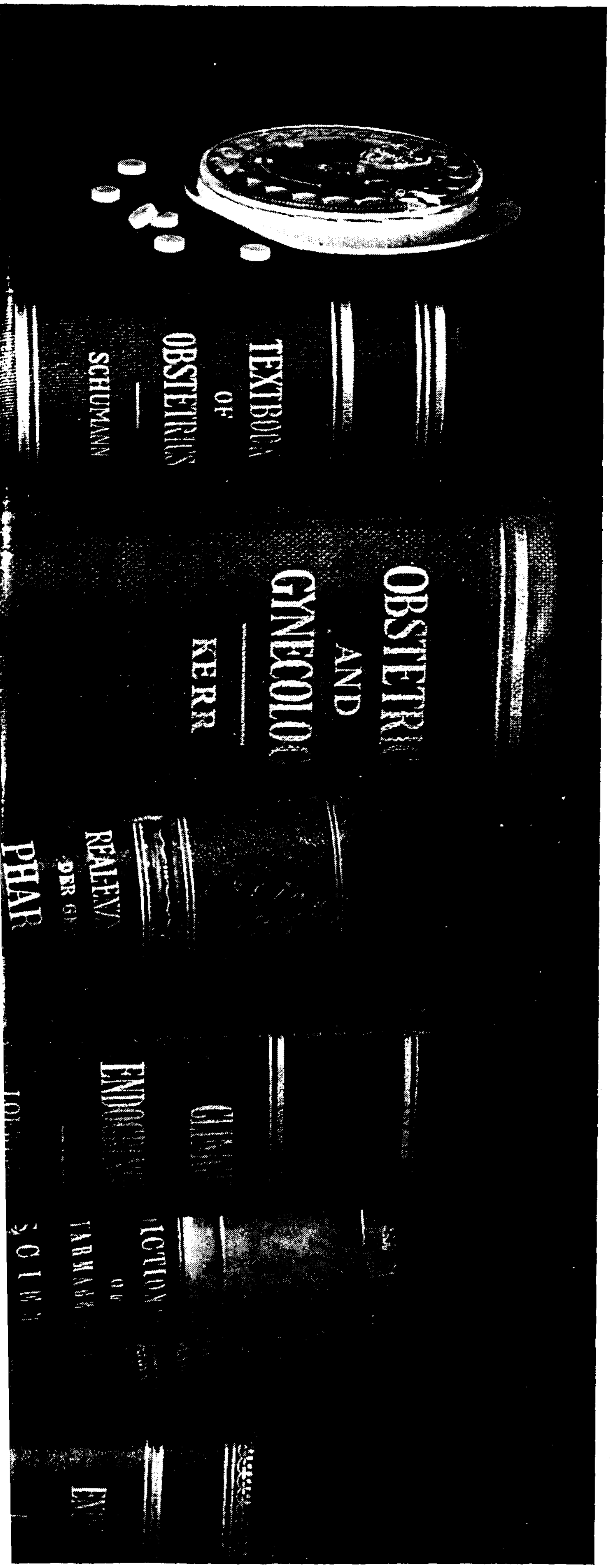
It is in the chemical and biochemical disciplines that Hewlett-Packard assumes its concern with the massive anti-fertility drug research program, specifically, through its Gas Chromatography Applications Laboratory, in Avondale, Pa. Thus far, Avondale's involvement has centered around two of the most widely used synthetic hormones: *Norethindrone* and *Mestranol.* Both are labile steroids, subject to thermal degradation. When these steroids break down—whether during manufacture, in the human environment, or during analysis—they form a keto analog so similar in chemical structure to the original molecule that it is extremely difficult to differentiate one from the other. The rub is that the scientist *must* be able to tell them apart since the steroid is an effective anti-fertility agent while the keto analog is not.

Thus there can be no confidence in any chemical analysis of the pill unless it is first demonstrated that the analytical procedure can separate the steroid from its keto analog . . . and that it can preserve the chemical integrity of the two types of molecules during the analysis.



As far back as 1964, our application chemists proved that the Model 402 High-Efficiency Gas Chromatograph has both capabilities. The proof is presented here in the form of three chromatograms. The first, an analysis of a sample containing the two steroids, shows the presence of *Norethindrone* (b) and *Mestranol* (a), and the absence of their keto analogs: this is proof that the 402 respects the chemical integrity of the steroids. If the Model 402 were causing degradation of the steroids, the chromatogram would show the presence of at least some quantity of the keto analogs. The second chromatogram shows the presence of both the steroid *Mestranol* and its keto analog, thus demonstrating the 402's ability to separate one from the other when the two coexist in a sample. The same is true of the third chromatogram, this time with respect to *Norethindrone.*

Lest it become obscure at this point, the noteworthiness of these analyses is twofold: they demonstrate the 402's ability to detect the labile steroids used in anti-fertility drugs without causing degradation during the analytical procedure; and its ability to separate compound pairs of such steroids one from the other and from their keto analogs. Extrapolating from these points, the 402 can be seen as a fast means for quality control in anti-fertility drug preparation, as the basis for investigation of its clinical progress and beyond that as a possible means for *in vivo* patient monitoring. A report of the anti-fertility drug analysis as it was originally presented in *Facts & Methods,* Vol. 5 No. 3, is available on request.


OF
SCHUMANN
AND
KERR

Report from

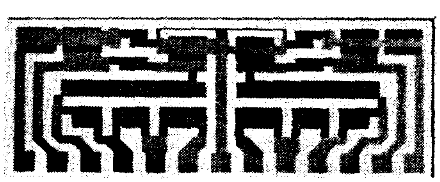
BELL LABORATORIES

Thin films: faster by computer

Arthur G. Gross and Harry M. Kalish of Bell Telephone Laboratories have developed a computer program whose end product is a set of correctly sized photographic "masks" for making prototype thin-film networks. The masks control the deposition and shapes of various widths and thicknesses of conductive, resistive, and dielectric materials that make up such circuits. (These frequently begin as tantalum, deposited onto a glass or ceramic substrate and chemically treated to produce desired electrical properties.)

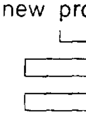
Controlled by the new program, a computer feeds a precision microfilm plotter which prints the masks on 35mm film (photo above).

With this system, a prototype can be ready in a day, as against the weeks that may be involved in making high-precision masks for volume circuit production. Usually, for example, a draftsman must make rough sketches and prepare a list of numbers (coordinate points) accurately describing the geometry of the final circuit. Then the actual shapes—greatly enlarged—are cut into plastic sheets on a "coordinatograph." Later, the plastic patterns are photographically reduced to circuit-sized masks, perhaps ½ by 1 inch.



An experimental thin-film filter network—in actual size—made from 35mm film masks. In the top photo, A. G. Gross (left) and H. M. Kalish hold three of the masks used. Each mask controls the formation of a layer of conductive, resistive, or dielectric material. The circuit is built up of a number of such layers.

In addition to reducing time and handling, Bell Laboratories' new program relieves the engineer of another tedious job: designing the meandering lines that constitute resistors in these circuits. And the computer resistors are "optimized" . . . fitted into the smallest possible area.



To give the engineer freedom to use irregular plane shapes, the program includes a subroutine which closely approximates geometric figures used in making thin-film circuits.

Bell Telephone Laboratories
Research and Development Unit of the Bell System

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Letters

UFO Consensus

I agree with Markowitz ("The physics and metaphysics of unidentified flying objects," 15 Sept., p. 1274) that extraterrestrial control of UFO's is unlikely. Nevertheless I find his arguments unconvincing.

First, a minor point—he seems to imply that Hynek is inconsistent when he states that UFO's *have* been seen by "scientifically trained people" but have *not* been seen by "trained observers." I think the distinction here is reasonably clear.

In this age of lasers, superpower microwaves, and superconducting magnets, his appeal to the law of Stefan-Boltzmann seems curiously unimaginative, as does his dependence upon solid surfaces to deflect high-energy particles. He arrives at a power required for interstellar flight of 3×10^{13} watts, noting that it is 30 times the world's electric generating capacity. An equally pertinent comparison would be to note that it is *only* 300 times the power of a single Saturn V, and that *only* a single decade of development effort separates that vehicle from its 300 times smaller predecessor! In any case, why does an interstellar vehicle need an acceleration of 1*g*?

On the other hand, a ship for such a voyage would probably weigh much more than 5000 kilograms. So in the end, one must agree that a satisfactory interstellar propulsion system is quite beyond the capability of our present technology. But his arguments in no way prove or imply that it is beyond someone else's—or even beyond what *we* will have 100 years from now. As far as proving that interstellar flight violates the laws of physics, his arguments are simply irrelevant.

His argument that the ground should be seared and radioactive where a UFO has touched down also seems irrelevant. Isn't it probable that such voyagers would use "excursion modules" just as we propose to do? And why use a specific impulse of 3×10^7 seconds to lift off the earth when 1000 seconds or less would do? In short, the use of an interstellar space ship to explore within our atmosphere seems about as likely as the use of airliners to explore the bottom of the sea.

Why suggest that a 1000-year trip duration should make the voyagers anxious to meet us formally? An alternative deduction would be that another hundred years, more or less, is of little consequence to them. The fact that Columbus did not hesitate to talk to the Indians was not without consequences that were unfortunate for Europe and tragic for the Indians. Perhaps our interstellar visitors have learned to be more cautious—and considerate.

Finally, the suggestion that "hard-data" cases should be published for all of the technical community to peruse, just like observations of any other interesting phenomena, seems constructive. But why insist, on the other hand, that the Air Force should completely drop the matter? The only valid argument against extraterrestrial visitors is, I believe, a statistical one. The probability of there being a civilization advanced enough, near enough, and diligent enough to find us is simply not very high.

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I acknowledge Markowitz' analysis of the UFO problem, and wish him well in the next field to which he lends his attention, since he has apparently finished this one. He cannot depart quickly enough, however, to escape the objections of those he left standing amid the shambles. His entire argument against the possibility of extraterrestrial control of UFO's rests on theoretical grounds, and bears no relationship to the contents of UFO reports. The one link between Markowitz' theoretical argument and UFO reports is the fact that objects have been reported to land and take off. Having arbitrarily settled on a design for a ship employing annihilation of matter for power and a horribly inefficient photon drive for thrust, Markowitz proceeds to imagine this starship entering the atmosphere of a planet and landing on its surface, using the full fury of its interstellar drive, a process akin to docking the Forrestal by running it up onto a beach. Since the obvious results of such foolishness have never been observed, Markowitz concludes, "Hence, the published reports of landings and lift-offs of UFO's are not reports of spacecraft controlled by extraterrestrial beings, if the laws of physics are valid." The *non sequitur* is blatant: Markowitz has proven only that his own design does not explain reports of takeoffs or landings. He has revealed his own haste to arrive at a particular conclusion.

When Markowitz "assumes for purposes of discussion" the existence of technically advanced beings, one might expect that this assumption would play a part in the discussion, but evidently the implications of such an assumption have escaped his notice. A technically advanced race just a cosmic clock-tick ahead of us in achievement would not only have inconceivably advanced scientific ability, but technological skill beyond our comprehension. Such beings would effectively command immense wealth; what would seem to us impossibly ambitious, ruinously expensive, and even frivolous undertakings would be carried out with a casualness that would shock our poverty-stricken souls. It is no more possible for us to expand our minds enough to encompass what will be the truth in a thousand years than it would have been for Charlemagne to speculate on the present gross national product of France, without even a word for 10^9. The contrast between the notion of an advanced civilization's mode of transport (as one may legitimately attempt to imagine it) and Markowitz' sketchy design for a starship is ludicrous.

Of course there may not *be* any advanced civilization, or any starships. Nobody can go beyond premise-bound speculations on those subjects, and even our speculations are denied the use of physical principles and effects that remain undiscovered.

WILLIAM T. POWERS
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. . . Markowitz' failure to find detailed reports in print is puzzling. That he should base his arguments on the minor Chiles-Whitted case (of which it is true that my evaluation is at variance with Hynek's) or such a brief observation, made under unfavorable conditions, as the Tombaugh case, tends to indicate that he is not really interested in the best documented sightings; on the contrary, he is deliberately selecting borderline cases in an effort to cast doubts on the validity of current official and private attempts at systematic data-gathering. Otherwise, how can we understand that the Forcalquier photographs (taken by a professional astronomer) or the observations made at Toulouse and Mount Stromlo observatories, or the Loch Raven Dam and Socorro cases, all of which are extensively documented in print, should have escaped his attention? He goes as far as stating that no unexplained physical trace has ever been left after the observation of an unknown aerial phenomenon, while one of the books he quotes in his bibliography describes at length the investigations conducted by Soviet physicists at the site of the Siberian explosion in 1908, which come very close to meeting the conditions Markowitz himself has set for "evidence."

Elsewhere, commenting on my survey of the observations of unknown celestial objects gathered and studied by Le Verrier, he kindly reminds me that the intra-Mercury planet theory is an impossibility, as if I had ever suggested that the objects in question were such a thing.

Thus, Markowitz is guided by one and only one idea: that one may not consider the "intelligent control" hypothesis unless one is willing to abandon entirely the rational processes upon which science is based. It is a disturbing fact that such grossly irrational arguments should still enjoy popularity in the scientific world. . . .

JACQUES F. VALLEE
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. . . If scientists avoided topics which involve possible violations of the inviolable laws of physics we should have unsung memorabilia like these: "Marie, this phosphorescence violates the First Law; let's study barium sulfate instead." "Xenon can't react; it has a closed shell. Ask any theoretician." "Conservation of parity is one of the immutable laws of physics, therefore it is impossible that . . ."

I doubt very much that UFO's are under extraterrestrial control, but if they *were* so controlled I am sure we primitive bipeds could prove the contrary by citing *our* laws of physics.

THOMAS R. P. GIBB, JR.
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Markowitz has closed the door on UFO's and space travel by showing that interstellar vehicles can never have visited Earth because neither he nor any Congressional committee has seen one. Only unreliable witnesses see UFO's which might be extraterrestrial. (An unreliable witness is anyone who reports a UFO that isn't an obvious natural or aerial phenomenon.) The scientific journals would, of course, be full of observational accounts, if any credible ones were presented, and scientists would be as eager to study them as they were Velikovsky's work 15 years ago. The evidence against UFO's as space vehicles, based on Simon Newcomb's recent (1895) proof that an intra-Mercury planet cannot exist, is as convincing as Newcomb's demonstration, following accepted physical laws, that aircraft can't fly. . . .

PHILIP C. STEFFEY
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While reading Markowitz' article, I could not help thinking about some words I believe were written by Isaac Asimov: that when a respected scientist said something was probable, he was probably right, and if he said that something was impossible, he was probably wrong.

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I was amused and somewhat shocked by Markowitz' reference to Aristotle's "Physics" and "Metaphysics." The idea that "metaphysics" is equated with the notion that "the laws of physics are not valid" is not only misleading as it relates to Aristotle, but threatens to make the philosopher who specializes in metaphysics some sort of buffoon. . . .

GEORGE COHEN
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Smoke-Filled Friendships

As the first three couplets of the following verse attest, I share Turbeville's aversion to tobacco smoke (Letters, 20 Oct.), though, as the last couplet shows, I do not often express my objections.

A cigarette's what the smoke from all goes
From wherever it is to a nonsmoker's nose.

Smokers are who, if at parties they're there,
I must later change clothing and shampoo my hair.

A nonsmoker's who, when it's too thick to see,
If you hear someone coughing, it's probably he.

Friendship is what, though I gag, weep, and choke,
I would much rather have it than absence of smoke.

Smokers often ask a stranger, "Do you mind if I smoke?" If the stranger does not smoke, he probably minds, and is then faced with the poor choice of being rude or perjuring himself. I suggest that smokers ask instead, "Do you smoke?" and refrain if the answer is "No."

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Buffalo River Endangered

Carter's article, "Dams and wild rivers: looking beyond the pork barrel" (13 Oct., p. 233), is most timely. Here in Arkansas we have reason to be keenly aware of the dam-building pork barrel through our efforts to preserve the beautiful Buffalo River in the Ozarks of northern Arkansas. The Buffalo is one of the few free-flowing streams remaining in the state. For years it has been threatened with impoundment by the Corps of Engineers.

The National Park Service recommends preservation of the Buffalo as Buffalo National River. The great majority of the people of Arkansas support preservation of the Buffalo. Bills are pending in the U.S. House and Senate which would establish the Buffalo National River, but these have not yet come up for consideration. Despite the growing realization of the economic and ecological losses resulting from unnecessary impoundments, strong pressures for unjustifiable projects continue.

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A Revolt against Time and Effort Reports

I believe the following considerations should be brought to the attention of the academic scientific community. They concern time and effort reports required in connection with government research grants. In October 1966, the Association of Graduate Deans passed the following resolution:

Be it resolved that the Association of Graduate Schools instruct its President to call upon the Association of American Universities to join in addressing to the President of the United States our respectful requests: 1. that the present requirement for reporting of effort by individual members of the professional staff be suspended immediately because it admits no meaningful compliance.

This resolution is reproduced on page 126 of the *Journal of the Proceedings* of the AGS, 1966, with further explanations as follows:

The earlier motion on individual effort-reporting had proposed involving CGS in the attempt to get a revision, and had not proposed immediate suspension of the present requirement while negotiations were being undertaken. Dean Halford feared that if negotiations alone were proposed the results would be delayed two to four years, and that AGS had the most at stake in this area whereas most of the institutions in CGS were not deeply involved in this problem. Furthermore, as the presidents of AAU had expressed interest in working with the AGS in implementing specific recommendations of the Policies Committee report, and since there are on many campuses separate officers other than the graduate deans who serve as research coordinators, the group decided to address the AAU presidents in these matters. Dean Halford announced that in the event that this invitation to the presidents is not acted upon by them, the dean would be informed by mail as to some alternate course of action.

[*After adjournment of the AGS meeting, President McCarthy transmitted this resolution to President Grayson Kirk and President Nathan Pusey, President and Secretary of AAU respectively. On December 2, 1966 he was informed that President Kirk had appointed a committee to consider the issues raised in this resolution. Its members were Herbert E. Longenecker of Tulane as chairman; President Fred H. Harrington, Wisconsin; President James A. Perkins, Cornell; Dean Ralph S. Halford, Columbia; and Dean Joseph L. McCarthy, University of Washington.* —ED.]

I am informed that the committee appointed by the presidents has never met. But, in any case, what did the presidents expect after the problem had been considered by a body like the Association of Deans? As I have emphasized repeatedly, the threat to unfettered academic support does not only arise from certain pressures in the government, but from inadequate representation of academic interests by some university administrators (Letters, 17 Feb.). I regard the inaction of the presidents, members of the AAU, as a failure in the exercise of academic responsibilities.

By their inaction, the presidents will lose the confidence of the professors, and they have allowed a bad situation to deteriorate still further. The professors will lose confidence in normal channels of administration, and seek other channels for redress. As an example, the Council of the American Mathematical Society on 29 August passed the following resolution:

> The Council of the American Mathematical Society urges responsible university officers to take immediate action to have time and effort reports and similar documents pertaining to faculty members' time eliminated, because it considers that such documents are incompatible with academic life and work. The council reiterates the traditional view that teaching and research are inseparable and that accounting procedures in universities must take account of their unitary character.

Simultaneously, the Council instructed the president of the AMS to appoint a committee "to work toward mutually acceptable modifications with appropriate Government administrators." This committee has been appointed (G. W. Mackey, Harvard; R. S. Palais, Brandeis; Alex Rosenberg, Cornell).

Under the circumstances, I don't see how deans with any self-respect can continue to pass on for signing to their faculties the time and effort reports. And furthermore, I don't see how the professors can agree to sign them.

As for the larger picture, the universities are becoming more and more dependent financially on the government. At a time when policies governing the universities are being determined for the foreseeable future, it is extraordinarily important that our administrators should insure, in their dealings with the government, that traditional academic values and standards are upheld. Ultimately, it is also the responsibility of the professors to refuse to submit to requirements which destroy these standards.

SERGE LANG

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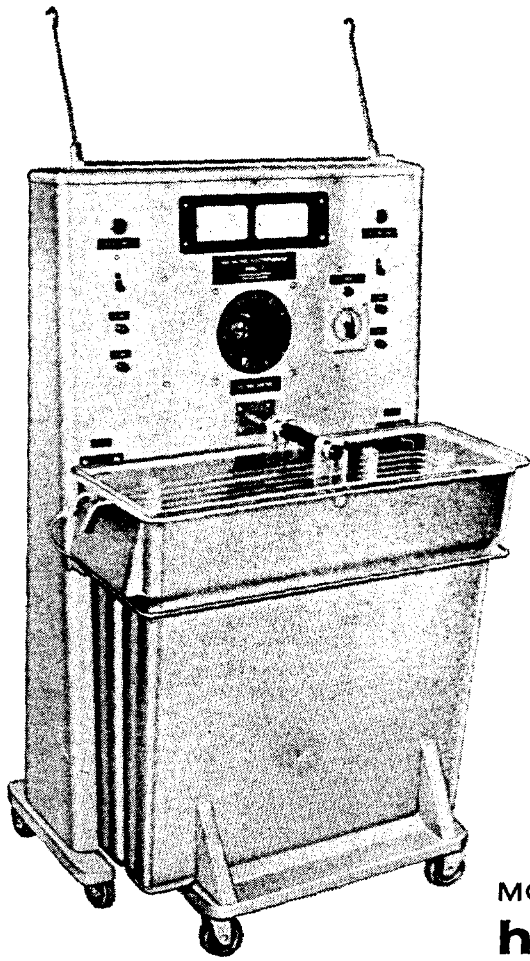

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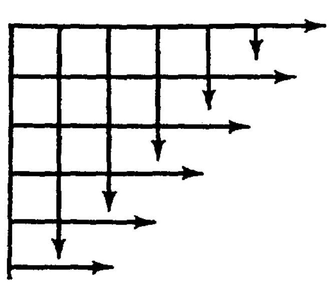

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8 December 1967, Volume 158, Number 3806

SCIENCE

Selective Service Solution

At the end of the current academic year the pool of men eligible for Selective Service induction will suddenly be swelled by the addition of 1968 college graduates, men who receive graduate degrees in June, and those who complete their first year of graduate work. Under existing regulations the oldest men in this pool must be inducted first. The result will be that the Army will receive very few inductees in the preferred 19-to-20 age range and will find from 50 to 75 percent of draft calls being filled by men with college degrees or with a year or more of graduate work—a prospect that pleases neither the Army, the employers of engineers and other professional manpower, nor persons interested in the continuity of graduate education.

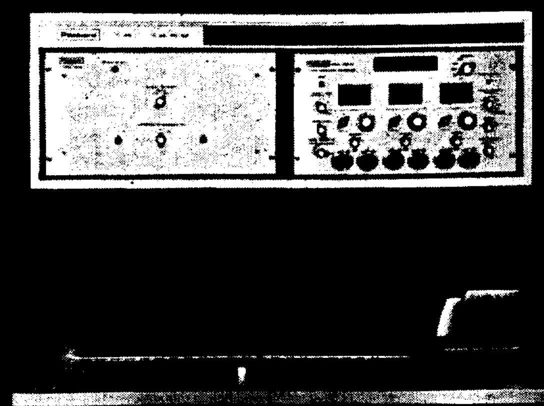
The present regulations must be changed. The changes should be announced soon and should be designed to retain flexibility in the size of draft calls; provide the Army with a better age mix of inductees; and reduce the uncertainty concerning induction that now makes it difficult for young men (and also for others, such as graduate school faculties) to plan with reasonable confidence for a year or more ahead.

There is substantial but by no means unanimous support for the proposition that, when not all young men are required to enter military service, those who are required to do so should be selected by some random method. The President proposed this idea to Congress, but did not spell out the details. Lacking a specific plan, Congress refused to approve, but invited the President to submit new legislation later. It now seems unlikely that new legislation will be adopted in time to be of much help in 1968; there are too many other items on the congressional docket. Legislation, however, is not necessary; the Executive already has the authority necessary to accomplish most of what is needed.

One kind of "lottery" could be used without new legislation. The existing law would permit reversing the present oldest-first method of selection by designating a specific age group—probably the 19-year-olds—as the "prime age group" for induction. Older men who have been deferred—for example, men allowed to enter graduate school this past fall—would be treated when their deferment ended as if they were just reaching age 19. The prime age group would therefore include men who who were actually 19 and older men being treated as if they were 19. Selection would still have to be on an oldest-first basis, but the "oldest," under these circumstances, would be those born in the earliest months of the year. Thus the "lottery" of birth dates 19 or more years ago would now be used to determine order of induction.

This system would call a large number of college graduates and graduate students into military duty next year, but would leave a larger number free to continue graduate work or to enter essential occupations. It would provide the Army with a better age mix in 1968 than existing regulations would, and a still better mix in following years. And it would give all of the young men involved a better opportunity to plan realistically, for each could estimate with some degree of assurance whether and when he was likely to be called for induction.

These arrangements would not solve all of the problems; for example, there are still uncertainties as to which graduate students should be deferred. The arrangements may not be permanent in all details; for example, we are unlikely to continue to penalize those with January birthdays year after year. But the proposed regulations would allow orderly planning for the year ahead. They can be introduced quickly and without new legislation. They offer the best immediate solution of an urgent problem.—DAEL WOLFLE



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SCIENCE

Ultraviolet Spectra of Stars

The ultraviolet spectra of stars are discussed from both theoretical and observational viewpoints.

Anne B. Underhill and Donald C. Morton

From the shape, strength, and wavelength of stellar absorption lines, one can deduce information about the composition, density, temperature, and state of motion of the gas forming a stellar atmosphere. If emission lines are observed, further particular conclusions can be drawn about the physical characteristics of the outer parts of the stellar atmosphere. Ground-based observations of stars, with spectrographs illuminated by light collected with large telescopes, permit one to study spectra from 3000 to 6800 Å and into the infrared in the parts of the spectrum that are not obscured by absorption bands originating in the earth's atmosphere. Extension of the observations into the infrared is done with recording devices sensitive to low levels of light for stars that are rather cool and so produce much radiation at long wavelengths. In practice, most stellar spectroscopy is done between the lower limit of wavelength, 3000 Å, imposed by the ozone absorption bands of the earth's atmosphere and about 6800 Å —the long limit of wavelength of most panchromatic photographic emulsions. The stellar spectra are usually recorded photographically; thus one may use most efficiently the limited amount of observing time that is available for high-resolution spectroscopy with large telescopes.

Dr. Underhill is professor of astrophysics at the University of Utrecht, The Netherlands. Professor Morton is a research astronomer at Princeton University Observatory.

Rockets and satellites provide means of transporting telescopes and spectrographs above the ozone of Earth's atmosphere. Once an instrument is above the ozone layers, one may expect to record stellar spectra from 3000 Å to the Lyman limit of hydrogen at 911.6 Å. Since interstellar space contains neutral hydrogen atoms, radiation emitted from stars more distant than the sun is absorbed strongly at wavelengths shorter than 911.6 Å. At extremely short wavelengths (soft x-rays), interstellar space becomes again fairly transparent, but normal stars are not expected to radiate a measurable amount of energy at such wavelengths. It is practical and convenient to define the ultraviolet spectrum of stars as lying between 911.6 and 3000 Å.

Two questions arise: (i) Which stars are expected to radiate in the ultraviolet spectral range at a detectable level? (ii) Is it reasonable to expect the spectral lines observed in the ultraviolet to contribute information not already available from the normally observed spectral region?

To answer these questions we must consider the theoretical models used to represent stellar atmospheres, and the validity of our theory of the formation of stellar spectra. One should remember that stellar atmospheres consist of gas (atoms, ions, and molecules) through which a stream of radiation is flowing. The atoms, ions, and molecules interact with the radiation to produce absorption or emission spectra. We know from laboratory studies the chief spectral lines produced by each species in the range of wavelengths from 911.6 to 6800 Å. Our predictions of the ultraviolet spectra of stars are based on the idea that any theory and model, representing well the part of the spectrum of a particular atom or ion observed in the spectral region 3000 to 6800 Å, should be also valid for prediction of the spectrum in the ultraviolet spectral region. No atom, ion, or molecule in a gas ever radiates only part of its spectrum, although we frequently observe only part of the spectrum because of the restrictions imposed by our observation techniques (untransparent windows, including the earth's atmosphere; insensitive recording devices at some wavelengths; and suchlike).

An important point is evaluation of the reliability of our theories of the formation of stellar spectra. Some weaknesses are well known, and deviations between predictions made with the imperfect theory, and observations can be interpreted qualitatively. One can gain new information about the stellar atmosphere by study of spectral lines when the deviations between observed and predicted line profiles and line strengths are largest. From our studies of stellar spectra with ground-based spectrographs we think we know what sort of spectral lines yield the most information. Naturally, surprises greet us in the ultraviolet spectral region, but they are a bonus that comes with a successful program of observation—they are not the primary reason for making the observations.

Before looking at the answers to the questions just posed and at the available observational material, we should remark that the light reaching the earth from the stars has passed through vast distances in interstellar space. The gas and dust lying between the earth and the stars absorb stellar light and form interstellar absorption lines in a stellar spectrum. These interstellar spectral features are expected to give much information about the physical conditions in interstellar space, but we shall not discuss them. Interstellar absorption lines can be distinguished from stellar absorption lines by the fact that, in a multiplet, only the component that arises from the ground state is observed. The dilute radiation and low particle density in interstellar space cannot excite atoms and ions even by 0.01 ev.

Models of Stellar Atmospheres

In the case of normal dwarf or main-sequence stars, the geometric extent of the layers through which the line spectrum is formed is small in comparison to the radius of the star. Consequently it is sufficient to consider that the stellar atmosphere consists of plane parallel layers of gas in hydrostatic equilibrium under the local acceleration of gravity. On the surface of a main-sequence star, gravity is about 10^4 centimeters per square second. The composition of the stellar atmosphere is constant throughout the relevant layers. The theoretical spectra to be presented have been computed for models having a fractional abundance, by weight, of hydrogen equal to 0.68; of helium, 0.32. The fractional abundance by weight of all other elements is small (1.41×10^{-4} for Fe, for instance), and it is usually neglected when a model is constructed. When the line spectrum is computed, a representative abundance, relative to hydrogen, for each element is adopted according to the results of abundance analyses of stellar spectra.

The condition that hydrostatic equilibrium should exist gives a relation between gas pressure and geometrical depth in the atmosphere. The relation between temperature and depth in the atmosphere is found by requiring that a constant flux of energy flow through the model. As the radiation field in all frequencies from 0 to ∞ passes through each layer of the model, no energy is lost or gained, but the energy is redistributed in frequency as a result of the interactions with the atoms and ions in the atmosphere. In principle this redistribution may be followed by solution of an equation of radiative transfer appropriate to the physical situation encountered. In practice these interactions between atoms, ions, and radiation are represented in a somewhat schematic manner that is complex enough to describe the major

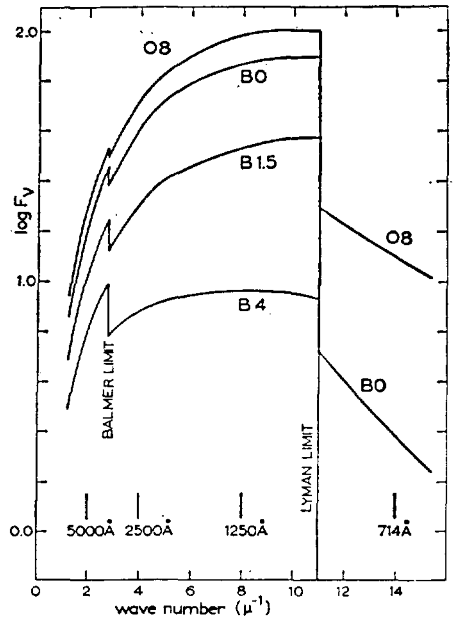


Fig. 1. The continuous spectrum of OB stars, predicted without attention to the blocking of radiation by the ultraviolet lines. The unit of flux is 10^{-4} erg per square centimeter per second per unit frequency interval.

trends of the processes that occur but simple enough for expeditious handling by a large computer.

Preliminary studies have indicated that only stars classified, according to empirically selected spectroscopic criteria, types O or B may be expected to produce an ultraviolet flux of energy comparable to that in the normally observed spectral region; they are among the hottest known. Consequently the results we present have been calculated with equations suitable for atmospheres in which the electron temperature varies between 8000° and 60,000°K.

In brief, the monochromatic flux emerging from the stellar surface has been calculated by use of the Milne-Eddington transfer equation. This equation represents the postulates that the radiation is removed from the beam by absorption in the continua of H, H^-, He I, and He II and in lines, and as a result of coherent isotropic scattering by electrons; and that energy is returned to the beam by reemission, as though the gas were in thermodynamic equilibrium at the local electron temperature, and as a result of coherent isotropic scattering by the electrons. The methods of constructing model stellar atmospheres and of computing the line and continuous spectrum have been described (*1*).

Theoretical Spectra from Models

When the first model atmospheres were constructed, the radiation-blocking effects of the strong stellar lines in the ultraviolet spectral region were ignored. These models, for stars of types O to B2, predicted a rather bright continuous spectrum in the ultraviolet spectral region (Fig. 1). Even so, it may be seen that only stars of spectral types O to B4 will produce a greater flux between 3000 and 911.6 Å than they produce in the spectral region observed with ground-based instruments (*2*). The predicted ultraviolet fluxes below 1500 Å will be reduced considerably when the absorption by the ultraviolet lines is taken into account; only O-type stars will produce a significant flux of energy at wavelengths shorter than the Lyman limit.

A few models have been constructed that take into account the line blanketing (*3*). An example of the resultant changes in the overall intensity distribution of the emergent spectrum appears in Fig. 2; both models shown may be classified type B1.5 according to the size of the Balmer jump. For main-sequence B-type stars a single-valued empirical relation exists between spectral type and the intensity jump at the Balmer limit of hydrogen; since this relation is rather insensitive to gravity and to the electron pressure in the atmosphere, it may be used to obtain a first approximation of the equivalent spectral type of a model atmosphere. In practice, spectral types are assigned to stars according to the relative intensity of a few empirically selected strong absorption lines.

Including the strong lines in the procedure for constructing the model is physically more correct than ignoring them. One result is that the effective temperature is reduced by about 10 percent from its value in an unblanketed model having the same Balmer jump and thus nominal spectral type. The temperature-pressure structure is not significantly changed in the deeper layers of a blanketed model from that in an unblanketed model of the same spectral type. However, in the extreme outer layers of a blanketed model, the temperature for a given value of the pressure is lowered from its value in an unblanketed model. This difference between models having the same nominal spectral type will be important only for interpretation of lines so strong that they are formed effectively in the outermost layers of the model. In this case however, one may be certain that the equation of transfer that has been adopted to represent line formation is no longer tenable; furthermore, that it is not appropriate to calculate degree of ionization and level of excitation by the equilibrium relations known as Saha's and Boltzmann's laws. In solving the problems of the monochromatic transfer of radiation through the outer parts of the stellar atmosphere one should take into account what are called "non-l.t.e. effects"—that is, departures from the equations representing local thermodynamic equilibrium.

In order to obtain a first prediction of the ultraviolet spectrum from OB stars, these important physical considerations have been ignored and the spectrum has been predicted by use of the existing thermal-equilibrium theory of line formation. When observed line profiles are compared with predicted line profiles, attention must be paid to isolation of discrepancies due to (i) departures from the adopted simple theory of line formation; (ii) departures of the state of motion, of the gas in the plane parallel layers, from the thermal motions appropriate to the local temperature, which are the only motions taken into account in the theory; and (iii) the fact that the stellar atmosphere may indeed be so extensive that it cannot be adequately represented by a plane parallel layer, but must be represented as a sphere or other geometric form.

An important concept for visualization of what occurs in the stellar atmosphere, and where it occurs, is the "depth of formation" of the spectrum at frequency ν. Whether this frequency lies in the continuous spectrum, or in a line, is immaterial; what is significant is that numerical work has shown that F_ν, the emergent flux in frequency ν, is approximately equal to B_ν, the value of the Planck function at this frequency, at the layer in the model in which the *monochromatic* optical depth t_ν is about equal to 0.4. In a very opaque spectral region the position at which t_ν equals 0.4 will occur in the outermost layers of the star; in a transparent spectral region t_ν will equal 0.4 at much greater depths. In the first case, the local temperature will be low; in the second it may be higher by 10,000° or 15,000°K. Clearly, in an opaque spectral region such as the centre of a strong line, one is observing a part of the star different from the one seen in a transparent spectral region, such as in the continuous spectrum or in weak lines. A large part of the ultraviolet brightness (Fig. 1), in comparison to the brightness at 4500 Å, is due to the fact that in these calculations the spectrum at 1300 Å comes from considerably deeper layers than does the spectrum at 4500 Å. Important in determination of the depth of an absorption-line profile at any spectral region is the factor of whether the selected frequency range lies on the steep side of the Planck function for the relevant temperatures or on the long-wavelength tail. In the latter case (at wavelengths greater than 3600 Å in B stars) even the stronger lines are not deep; at wavelengths shorter than 3000 Å, the strong lines become very deep, especially at very short wavelengths.

The foregoing qualitative explanation does not tell the full story (especially for resonance lines, where line-formation by scattering processes must be important), but it does demonstrate that the presence of strong lines in the ultraviolet spectral region causes greater reduction of the expected emergent flux, from the flux for the case of no lines, than would ever occur in the normally observed spectral region between 4000 and 5000 Å. The interplay of these various factors causes the two different spectral distributions shown in Fig. 2.

Expected Ultraviolet Absorption Lines

The ultraviolet spectrum of O and B stars divides into two regions. In the section 911.6 to 1900 Å there occur many resonance lines and strong lines from low-lying levels of the first, second, and third ions of the elements He to Ca; many of these lines are predicted to be exceedingly strong. The only important spectra not having resonance lines in this region are those of He I and II, O II and III, Ne I and II, and Mg II. Morton (*4*) has predicted the profiles of some of the stronger lines formed in an unblanketed model atmosphere of type about B1.5, using the simple theory of line formation sketched above. The results in the neighborhood of 1200 Å appear in Fig. 3; the great width and depth of the resonance lines are evident. The central parts of these lines are formed

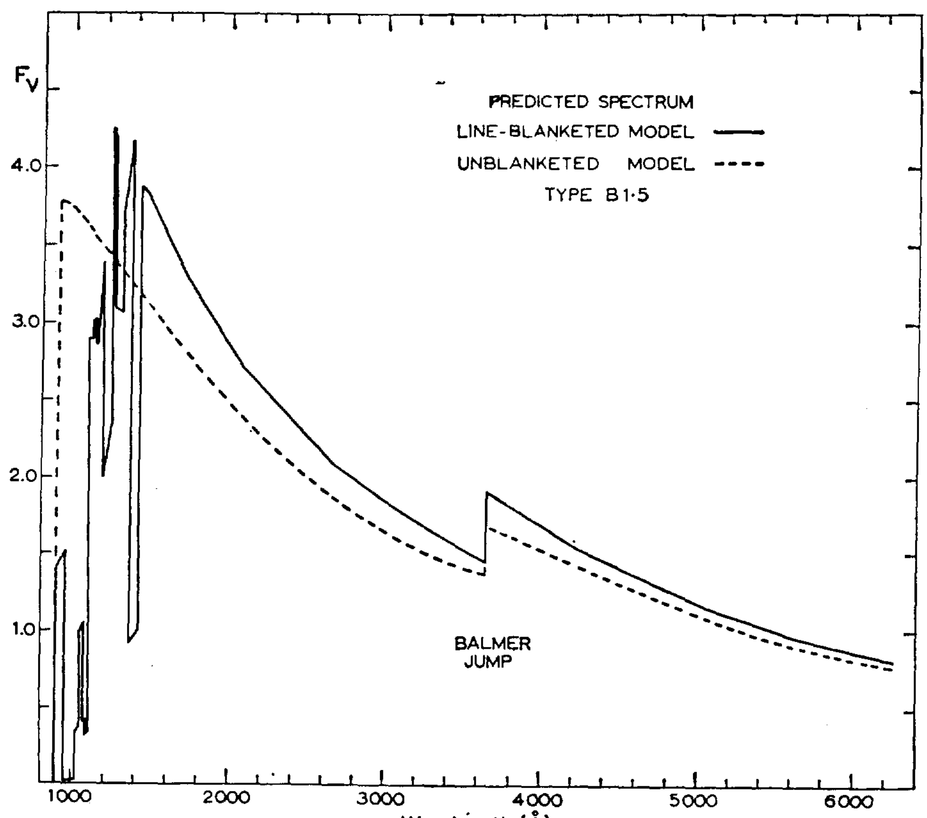


Fig. 2. The difference in spectral distribution between a line-blanketed model calculated by C. Guillaume and an unblanketed model calculated by one of us (A.B.U.). The unit of flux is 10^{-8} erg per square centimenter per second per unit frequency interval.

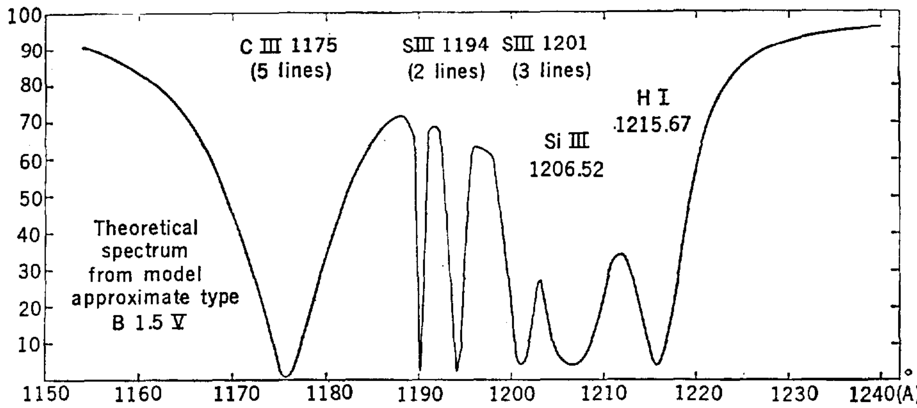


Fig. 3. Predicted strong stellar lines in the neighborhood of 1200 Å.

in the outermost layers of the models. Thus study of the observed profiles and displacements of the strong resonance lines should yield information about the electron temperature and pressure and the velocity field in the outermost parts of the stellar atmosphere, especially whene an improved theory of line-formation is used. Morton's calculations show that it is quite unreal to expect observation of a continuous spectrum from O and B stars (Fig. 1) at wavelengths between 911.6 and 1500 Å; rather the spectrum of main-sequence stars will be cut up by many deep absorption lines—some of which are shown schematically in Fig. 2.

The wavelength region between 1900 and 3000 Å has been studied at Utrecht. The only resonance lines expected are those of Mg II at 2800 Å. Calculations suggest that these lines will be quite strong in B-type spectra although less strong than the resonance lines of C IV and Si IV. This region contains a few strong lines of Si III and C III and very many lines of the second and third spectra of the metals. Estimates of the strength and profiles of the latter lines (*5*, *6*) have shown that the lines of the second spectra will be weak, but that the lines of the third spectra of the metals will be deep and as wide as 1 Å. The spectra of B stars between 1900 and 3000 Å are expected to look rather like spectra of F stars in the spectral region observed with ground-based instruments; many weak lines and a moderate number of moderately strong, deep lines will be present; typical line profiles appear in Fig. 4. The lines from the third spectra of the metals should be easily observed, with a spectral purity of the order of 0.5 to 1 Å.

The line profiles shown in Fig. 4 have been calculated with a so-called microturbulence equal to three times the thermal Doppler broadening. Observation has shown that the spectral lines of the standard "sharp line" stars are not really sharp, and that predicted profiles most easily can be made to fit the observed profiles by introduction of the arbitrary parameter microturbulence. The adopted motions are small, the root-mean-square velocity of an atom or ion being about 12 kilometers per second instead of 3 kilometers per second as is characteristic of heavier atoms at the temperatures in B1.5 atmospheres.

There are many ways in which such a velocity distribution could arise in a stellar atmosphere. Trial computations have shown that the adopted velocity field, which is used in description of the shape of the line-absorption coefficient, has far more influence on the shape and strength of lines predicted at wavelengths longer than 2000 Å than have differences in the temperature-pressure structure of the models due to the inclusion or omission of line blanketing in the process of construction of models.

Observation and interpretation of the line spectra of B stars in the wavelength region between 1900 and 3000 Å should lead to new and improved estimates of the abundances of the metals (Fe, Mn, Cr, Ti) in the atmospheres of B stars. These estimates should be quite reliable because the line spectrum in the region between 1900 and 3000 Å is formed through exactly the same parts of the atmosphere as is the part of the spectrum observed with ground-based instruments. (This statement appears obviously true from the relative value of the continuous-absorption coefficient in the region between 1900 and 6800 Å.) Thus good models for the relevant layers of the atmosphere can be established and controlled by normal ground-based observation.

The reason the abundances of the metals in B stars cannot be estimated easily from the parts of the spectrum that are observed by ground-based instruments is that too few lines of sufficient strength occur in the accessible spectral region to permit successful applications of the usual methods of spectrum analysis. It will be interesting to

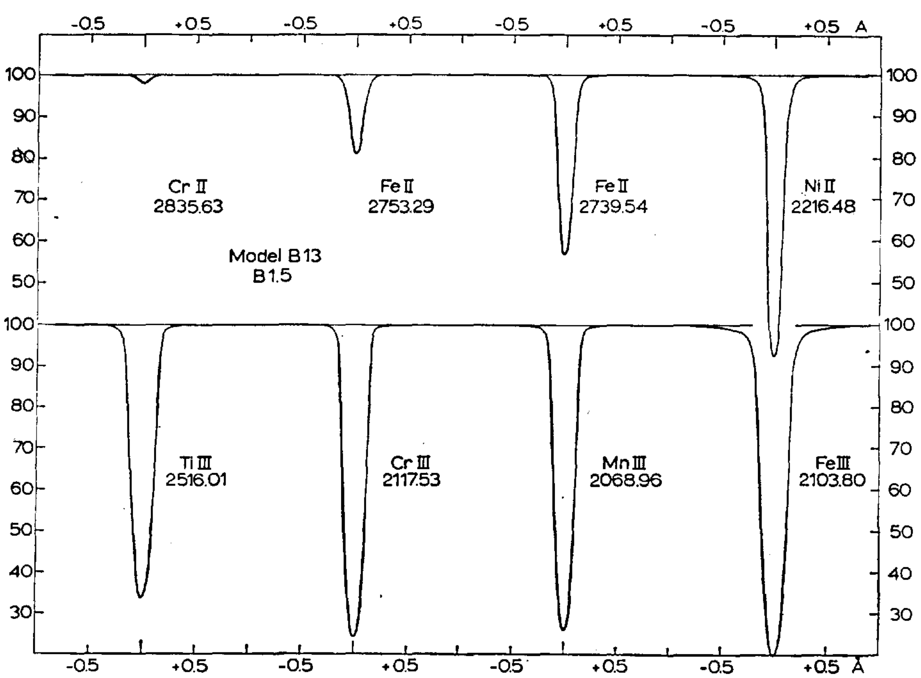


Fig. 4. Predicted lines from the second and third spectra of the metals in the spectral region 1900 to 3000 Å.

discover whether there are "strong line" and "weak line" B stars such as are known among the A, F, and G stars. The "strong line" or "weak line" characteristic is assigned chiefly according to the apparent strengths of the lines from the metals.

Should the ultraviolet spectra of stars be observed with photometers of narrow or wide band-pass, the effect of all the lines lying in the passband will reduce the measured intensity from what it would be if no lines were present. Elst (*6*) has estimated the line-blocking for each 100 Å between 1900 and 3000 Å in the spectrum of one model atmosphere; the results appear in Fig. 5, the blocking being expressed as a magnitude difference Δm. Clearly, to a narrow-band photometer, the ultraviolet spectrum of a B star will not appear smooth. In the spectral region below 1900 Å where the wide, deep resonance lines occur, the photometer response will vary even more irregularly with central wavelength and width of the passband, as a result of line blocking.

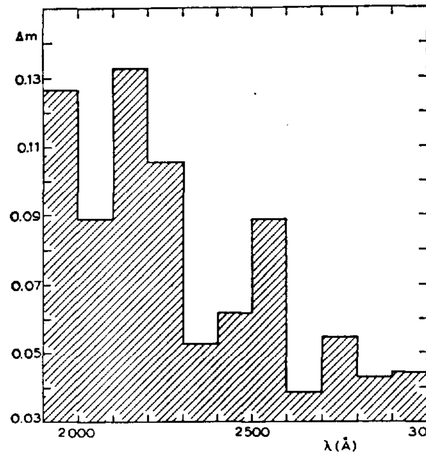


Fig. 5. Line blocking, in the region 1900 to 3000 Å, in the spectrum of a model atmosphere of type B1.5.

The Observations

Broad-band photoelectric observations of O and B stars in the ultraviolet have been made by several groups. Much interest was raised when it was reported that bright nebulosities in the direction of Spica and other hot stars had been detected by rocket-borne instruments recording in a wavelength band from 1225 to 1350 Å. However, subsequent flights found nothing unusual, so that the suspected nebulosity is now considered probably spurious (*7*).

Chubb *et al.* (*8*) have measured absolute fluxes from many hot stars in bands 60-, 70-, and 200-Å wide at 1115, 1314, and 1427 Å, respectively; relative to the fluxes at 5560 Å, determined from ground-based observations, the ultraviolet was fainter than expected, according to unblanketed models, by factors of 2 to 10. Morton (*4*) has shown that part of the discrepancy can be removed by inclusion of the strong absorption lines falling within the detector bandwidths in the calculation of the predicted fluxes. The differences are further reduced because the latest blanketed models predict lower fluxes in the relevant ultraviolet spectral regions and higher fluxes near 5560 Å than unblanketed models predict. The remaining discrepancies are no greater than may be expected from the possible systematic errors in the observations, the omission of weak lines in the models, and the effects of interstellar reddening.

It is certain that line blanketing plays an important role in establishing the emitted spectrum at wavelengths less than 1600 Å; this fact is borne out by the very recent results for 96 stars having spectral types from O7 to A2 obtained (*9*) with a satellite-borne photometer. After correction for interstellar reddening, the observed ratio of ultraviolet to visual fluxes is consistently below the prediction by unblanketed models, but in reasonable agreement with the Mihalas-Morton blanketed B1.5V model.

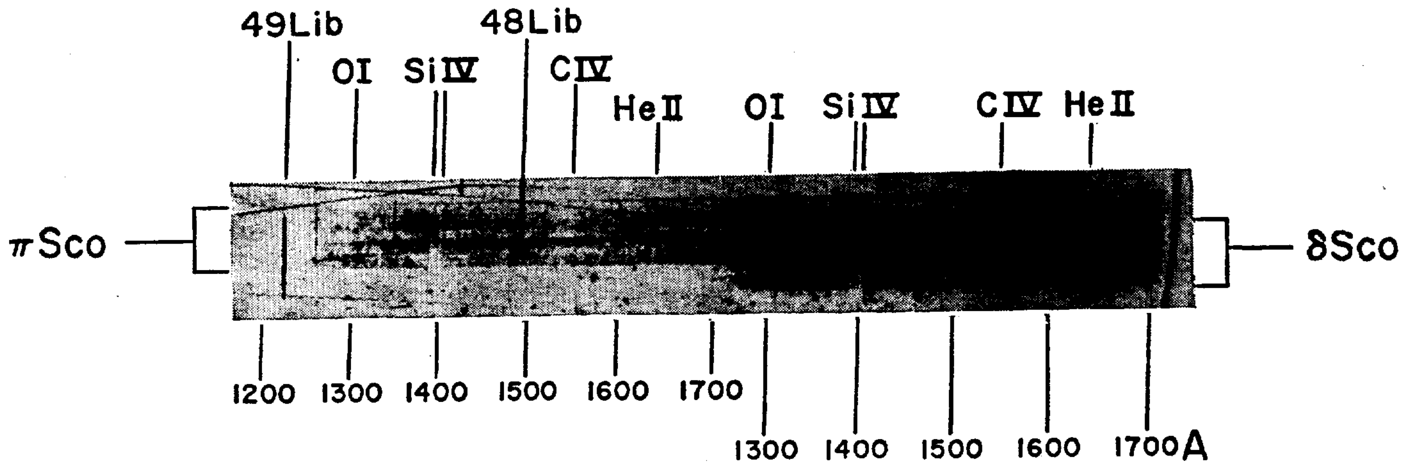
A rocket (*10*) scanned 22 early-type southern stars at 1900 Å with detectors of 400-Å half-width; the results indicated that the B stars were only 50 to 33 percent as bright at this wavelength as was expected from unblanketed models, but unfortunately there was no absolute calibration of the flight photomultipliers. Other (*11*) rocket-borne photometers have found fluxes at 2120 Å, in a passband with half-width of 188 Å, that were about 0.75 times those expected from models lacking lines. A few observations at 2200 and 2600 Å have been reported (*12*); no comparisons have been made with model atmospheres, but these data were used for estimation of the effects of interstellar reddening at these wavelengths. Fluxes from some 100 stars in bands of 400-Å half-width, centered at 2100, 2500, and 2800 Å, have been measured (*13*); when compared with the visual fluxes, these ultraviolet observations agree with the predictions by unblanketed models within 0.5 mag. Unfortunately, all published reports of the flights covering the range longward from 2000 Å are rather brief, so that it is difficult to judge the quality of the data; nevertheless it seems that the discrepancies can be resolved if we allow for the effects of interstellar reddening and the errors in the observations—if we make the comparison with the predictions from line-blanketed models.

Scans of seven stars between 1700 and 4000 Å were made with 50-Å resolution by use of a rocket-borne spectrometer (*14*). At wavelengths greater than 2600 Å the shapes of the observed spectra closely resembled those predicted from model stellar atmospheres, but at shorter wavelengths the fluxes decreased rapidly. This sudden decline does not accord with normal theories of stellar spectra. Later observations with the same type of spectrometer seem to give reasonable agreement with the models, suggesting that the earlier abrupt decline in flux may have been instrumental in origin.

The first ultraviolet line spectra of stars other than the sun were obtained (*15*) by use of Aerobee rockets; objective-grating spectrographs were used with *f*/2 Schmidt cameras having fields of view of 10 degrees. An active gyro system with gas jets oriented the rocket toward the desired target. The ± ¼-degree limit-cycle jitter in the dispersion direction was reduced to ± 16 seconds of arc by pivoting the spectrographs in the direction of the dispersion and by attaching to them a large gyro rotor gimbaled about a perpendicular axis. Torques in the dispersion direction resulted in precession of the gyro, with the end result that fine stabilization in one coordinate was achieved by a purely mechanical system.

On 2 June 1965 spectra of the main-sequence stars δ Scorpii, B0, and π Scorpii, B1, were photographed with a camera having a calcium fluoride corrector that transmitted wavelengths longer than 1265 Å (Fig. 6); wavelength resolution was about 1 Å. No fine stabilization was provided normal to the dispersion, so that the residual rocket motion widened the spectra, causing them to overlap in part; such widening increases confidence in the identification of features. The spectra of δ and π Scorpii are much as anticipated—continuous emission, with absorption lines.

The zero-order images of 48 and 49 Librae permit one to determine a wave-



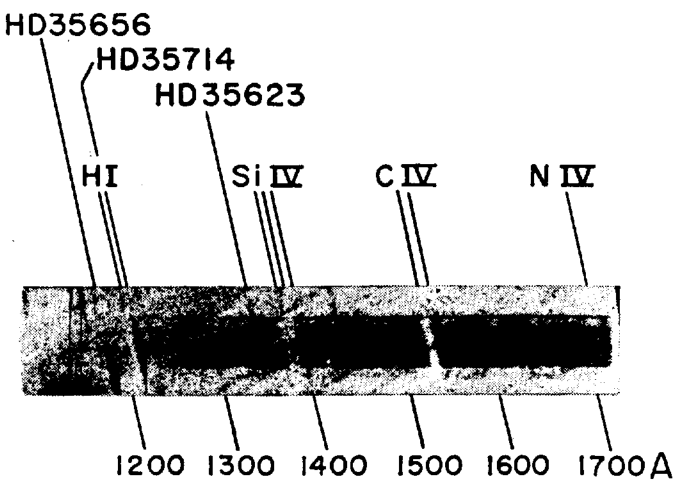


Fig. 6 (above). The ultraviolet spectra of π Scorpii (above) and of δ Scorpii (below).

Fig. 7 (left). The ultraviolet spectrum of ζ Orionis.

length scale to an accuracy of 1 Å, so that the spectral features can be identified. Both stars show the resonance lines of C IV and Si IV and an excited line of He II; also present are several excited multiplets of C III, which have yet to be studied in detail in the laboratory. Of particular interest in these stars are absorption lines of O I, C II, Si II, and Al II, which are all rather low states of ionization for such hot atmospheres; the lines, probably originating in the interstellar medium, give the first direct information on the abundances of these elements between the stars (*16*).

Spectra, longward from 1200 Å, of six OB stars in Orion were obtained on 13 October 1965 with a camera having a lithium fluoride corrector. The spectrum of the O9.5Ib supergiant ζ Orionis is reproduced in Fig. 7; the zero-order images at the left show that the pointing was not quite so good as on the first flight; the resolution is about 3 Å. Nevertheless several remarkable features are visible. The Lyman-α line due to interstellar absorption by hydrogen atoms may be seen beside one of the zero-order images; the position of this line confirms the wavelength scale determined from the zero-order images. The width of the Lyman-α line corresponds to only one-tenth the number of H atoms expected from the 21-cm radio emission in this direction.

The resonance-absorption doublet of Si IV and the unresolved doublet of C IV appear further to the right. Emission lines appear on the long-wavelength edges of these absorption lines; it is the wavelengths of the emission lines that agree with the laboratory values. The absorption lines are shifted to shorter wavelengths by some 9 Å; this shift corresponds to a velocity of 1900 kilometers per second toward the earth. These resonance lines must be formed in an expanding shell of gas around the star, the implication being that the star is losing mass, returning to it the interstellar medium from which the star once formed.

The other two supergiant stars, δ Orionis, O9.5 II, and ε Orionis, B0Ia, which with ζ Orionis form the belt of Orion, also show the displaced Si IV and C IV absorption lines. Consequently we suggest that this observed loss of mass was not by chance and that the loss is a continuous phenomenon typical of all hot supergiants. The presence of expanding atmospheres around the B0- and O-type supergiants had been suspected earlier (*17*) from several weak and very broad features observed in the part of the spectrum accessible to ground-based instruments. Nevertheless the ultraviolet observations are of tremendous value in confirming unmistakably the earlier inferences and permitting a quantitative estimate of the rate of mass ejection. The full implications of these ultraviolet spectra are yet to be worked out in terms of models for the outermost layers of O and B stars.

Within the past year additional ultraviolet stellar spectra have been obtained by several investigators using various techniques. During the flight of Gemini 11 on 14 September 1966 the astronauts photographed a number of stars longward of 2200 Å, with 15-Å resolution. According to Henize, Wackerling, and O'Callaghan (*18*) Canopus

(F0Ib) shows absorption lines of Mg I, Mg II, Si I, Fe I, and Fe II below the earth's atmospheric cutoff, while in Sirius (A1V) the main feature is the Mg II resonance doublet. On 20 September 1966 Jenkins and Morton (*19*) flew an all-reflective *f*/2 spectrograph on an Aerobee rocket, and obtained spectra of eight stars in Orion with about 1-Å resolution. These photographs confirmed the earlier results of the wavelength shifts in the C IV and Si IV absorption lines and the unexpectedly weak interstellar Lyman-α lines. The wavelength range was extended to 1130 Å and revealed absorption lines of N V, Si III, and C III also shifted to shorter wavelengths in δ, ϵ, and ζ Orionis. During four Aerobee flights Stecher (*20*) has scanned the spectra of at least ten hot stars with 5- and 10-Å resolution longward of 1100 Å. He also has found the C IV and Si IV resonance lines to be in emission with absorption components to shorter wavelengths in some of the stars. On an Aerobee launched on 16 March 1967 Carruthers (*21*) used a windowless image intensifier to photograph spectra of some 12 stars from 1030 to 1400 Å with 2- to 3-Å resolution. He confirmed the shifts of some of these lines in ζ Orionis and found the same phenomenon in ζ Puppis, γ Velae, and ι and κ Orionis. Both the spectral data and photon counters lead him to suggest that the photon flux decreases shortward of 1150 Å even in the hottest stars.

Summary

According to theories of model stellar atmospheres only stars of spectral types from O to about B3 may be expected to be bright in the ultraviolet-wavelength region. Observations of the strong resonance lines between 911.6 and 1900 Å will yield new information permitting construction of better models for the outermost layers of OB stars. However, an adequate theory of line-formation, including non-l.t.e. effects, should be used if an accurate physical representation is to result. Already it has been demonstrated beyond doubt that O and B0 supergiants are surrounded by expanding atmospheres.

The spectrum between 1900 and 3000 Å is formed chiefly in the same layers of the star as is the part of the spectrum observed with ground-based equipment; consequently, ground-based observations can be used to establish an adequate model. With such a model, observations of the absorption lines due to the first and second ions of the metals should permit new and reliable determinations of the abundances of Fe, Cr, Mn, and Ti in B stars.

The photometric and the spectral observations so far available of O and B stars do not generally conflict seriously with the predictions of theory, provided that we use line-blanketed models for the comparison and that we correct for the effects of interstellar reddening when necessary.

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Causality, Consciousness, and Cerebral Organization

Walter R. Hess

Psychology has been largely, if not exclusively, regarded as being in the domain of philosophy, and, until recently, reference to the brain as the substrate of psychological function was infrequent. It should be admitted that regional differences of approach exist; for example, in the United States psychological concepts are influenced more by the natural sciences than they are in tradition-bound Europe. The works of Herrick (*1*), Lashley (*2*), and Hebb (*3*), the publications of the experimentally oriented Canadian neurosurgeon Wilder Penfield (*4*), and more recent noteworthy works of Klüver (*5*), Ploog (*6*), Delgado (*7*), MacLean (*8*), and others are significant in this connection. On the other hand, it is surprising that the physiologists show some reluctance to teach psychological concepts. More than a minimum knowledge of the relationship between brain and psychological function is essential for students in biology and medicine, both because this function plays a role in the biology of men and the other higher mammals and because such knowledge is necessary for an understanding of mental illness. For all these reasons, an effort to survey psychological problems in biological perspective seems justified.

If a series of events relating to our past experience comes to our attention, we feel compelled to look for a causal

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link. In other words, it seems that an innate tendency to integrate simultaneous and successively induced perceptions leads us to an awareness of a causal relationship. The achievement of insight into cause and effect brings a feeling of satisfaction and relieves psychic tension. A simple example may illustrate this psychophysiological assertion. From my desk I see on the horizon a dark bank of clouds coming nearer and nearer. Suddenly lightning from the cloud strikes the earth. A little later I hear the thunder. Momentarily ignoring earlier experiences of this nature, I am confronted with a visual, followed by an auditory, experience. The two phenomena manifest themselves independently of one another. Continuing to watch, out of curiosity, I see after some time another flash of lightning and hear again, later, a clap of thunder. Repetitions of these essentially identical sensory experiences lead inescapably to the interpretation that the optical and the subsequent acoustical phenomena are somehow related.

With increasing frequency of repetition analogous successions are established as associative links, so that the conjecture of a causal relationship ultimately assumes the character of a certainty. Strictly speaking, no certainty exists but, at best, a high degree of probability. In everyday life one is, to be sure, surprisingly ready to assume a causal relationship. Obviously such a "short circuit" ordinarily suffices as a basis for adaptive behavior. In the case of a scientific investigation, one requires a higher number of identical successions before being ready to accept the intuitively conceived causal relationship as an established reality. Even then, in the area of biology at least, the causal relationship remains basically conjectural as long as the number of repetitions is not infinite. Nevertheless, we have to admit that, even in the pursuit of scientific interest, the number of repetitions required before the impression of pure coincidence is eliminated is relatively soon reached. After all, the willingness to think *post hoc, propter hoc* depends to a considerable degree on the personality of the observer. Irrespective of the number of repetitions, the persuasive power of the repetitions depends on conditional factors. There are men, for example, with a strong inclination to associate a comparatively short series of successive similar data with one another in the sense of a causal relationship. On the other hand, one knows laymen and researchers of outspoken skepticism who will not integrate successive similar data into an inferred causal chain even when the probability of an accidental succession is low. In the tendency to integrate or not to integrate, the individual's temperament, his previous experiences, his physical health, and his biological constitution play a not unimportant role. When the probable causal relationship offers a reward, he may be more likely to accept it. Further, mental age is a factor —as is seen, for example, when the child experiences a fairy tale as reality. The young, still inexperienced observer instinctively attempts to find a causal relationship, while the mature person is critical and does not exclude accidental succession so quickly. In the end, none of these arguments alters the fact that reality provides no objective criteria for arriving at a construct of causal relationships.

The Physiological Basis of Consciousness

The waking human being or higher animal has a large number of sense organs for making contact with the internal and external environment. The sensory cells function as receptors of organ-specific stimuli. Light flashes, for example, stimulate the rods and cones of the retina of the eye. Thereby the order of optic phenomena generated by the visual system is transformed into patterns of excitation of the visual pathways whose morphological organization is relatively well known (*9*)—for example, the projection of circumscribed retinal areas to corresponding elements of the visual areas in the occipital lobes of the brain. Far less advanced is exploration of the functional laws of the living brain. Actually, research in this sector of physiology is only now in process of development. The school of Jung (*10*) and the team of Hubel and Wiesel (*11*) have made significant contributions, particularly with respect to visual perception. Basic information is derived from observations concerning electrical stimulation of the visual cortex in man (*4*). Patients subjected to such stimulation in an effort to localize pathological foci in that area reported visual phenomena arising with the onset of stimulation. The sense of hearing was similarly involved when the stimulating electrode was applied to a certain region of the temporal lobe. Further, it has been experimentally established that the visual and auditory sensations experienced are associated with one another in the sense of a "causal" connection on the basis of temporal coincidence or spatial contiguity. In such cases consistent relationships between brain stimulation and subjective sensations (*4*) are as evident as those existing between natural stimuli and a determined flow of consciousness.

Findings such as the foregoing raise the question, How may the "causal" relationship between excitatory patterns of the nervous system and the development of conscious perceptions come about? Before we pose this problem, we must acknowledge that it is not now possible, and may not be possible in the future, to obtain such information. The subjective experience may be a direct expression of the condition of excitation of those centers which receive and integrate the sensory signals. In this case it would be only another aspect of the same process which one can objectify in the form of evoked potentials. An alternative explanation would be that of transmission of the integrated excitation pattern to a *specific system* whose principal activity is one of implementing release of the contents of consciousness. However, no criteria which would allow us to define such a process of transmission are, as yet, known. For the entire process which leads from the sensory stimulation pattern to the content of consciousness results exclusively in the mediating of relevant information. The process of transmission itself lies in an area into which we have no insight. Obviously reference to a reflex mechanism leads no further, so that physiology must give up the attempt to submit a comprehensive explanation. This is not to deny that there is a correlation between patterns of neural excitation and the release of corresponding contents of consciousness.

This situation is not unlike that existing with respect to verbal communication. The listener is unaware of the pressure changes acting upon his eardrum, and he does not perceive their transmission upon the sensory surface within the organ of Corti. Nor is he aware of the nervous impulses which are sent from the organ of Corti to the auditory centers of the brain.

Yet he can understand the meaning of a spoken message. This achievement is based upon associations which were developed between sensory stimulation and central patterns of nerve excitation at an early stage in the learning process. Whenever similar patterns of verbal stimuli are presented, the old memories and the corresponding contents of consciousness become reactivated and comprehended. Thus, there is no trace of a causal evolution of understanding of verbal stimuli by way of an uninterrupted chain of conscious correlates of the sensory mechanisms. Instead, central patterns of excitation are elicited as though by resonance when specific sensory messages arrive. However logical this may sound it does not explain the process of transformation itself, which seems to be a separate biological faculty. No road to its understanding seems open at present.

Subjective Experience and Neural Events

It has been known for a long time that light surface elements in the neighborhood of a dark field appear lighter than elements that lie away from the light-dark border. This difference in brightness is felt explicitly although objective checking shows that all the light fields are identical in tone. Therefore, until a short while ago the so-called simultaneous contrast had been interpreted as a subjective phenomenon. Recently this contrast effect was shown to be already manifest in the neural plane of the visual system (*12*). This was something of a surprise. The evidence discloses that contrast phenomena are basically produced by collateral inhibition involving neighboring elements at retinal as well as central levels. The physiological effect of this mechanism is the sharpening of the border between light and dark areas in the visual field. Thus the correspondence between subjective impressions and patterns of neural activity in the visual system is documented.

A second example of the close interrelationship between function of brain systems and mental processes is the well-known fact that consciousness is lost when critical areas of the brainstem are damaged (*13*). In contrast, consciousness remains unaffected when only parts of the cerebral cortex are damaged. At most, a limited defect may result, such as a scotoma of perceptive integration. In spite of this defect, the patient remains conscious of the situation and is capable of answering questions intelligently. His self-awareness and his orientation in space and time are undisturbed. With this, proof exists that specific psychic functions are bound to specific nervous structures. Still, the intervening process between stimulation of nervous elements and the formation of a conscious perception remains beyond our grasp.

A third example concerns the release of definite sensations through artificially induced stimulation of the brain. One recalls the activation of a characteristic behavior pattern in experimental animals (goats) after intradiencephalic injection of hypertonic saline. Their response was a massive intake of water (*14*). This behavioral reaction is identical to that induced by long-term deprivation of water. The electrolyte concentration in the tissue is increased, and the thirsty animal is impelled, as the human is under similar conditions, to quench its thirst by drinking. The observation implies that the stimulated area of the brain contains receptors which control osmotic pressure by regulating the water balance. The immediate impulse is normally given by the specific sensation of thirst in association with the positively conditioned satisfaction of removing the thirst sensation.

Another example of drive behavior elicited by stimulation of the diencephalon concerns food intake (*15*). Here, extreme voracity may develop under the influence of central excitation, resembling that seen after prolonged fasting or as a consequence of insulin-induced fall of the blood sugar level. Such increased intake of food (bulimia) is also seen in some psychically disturbed human subjects. Thus, physiological hunger, experimentally induced hyperphagia, and pathological bulimia appear interrelated inasmuch as they may be subserved by identical cerebral systems.

Another set of observations refers to manifestation of rage and fear elicited by stimulation of the hypothalamus in cats (*15*). With the onset of artificial stimulation the cat begins to snarl, hiss, and spit. It arches its back or crouches, it bristles, and it lashes its tail. Thus, the typical defense reaction develops, as in an animal threatened by an enemy—for example, a cat threatened by an attacking dog. The question is raised, Are these effects due to the direct stimulation of efferent pathways? This is obviously not the explanation. For, if the experimenter reaches toward the cat at the climax of excitment, it strikes at him angrily in a well-directed attack. At the onset of stimulation the animal may inspect the environment and, in its search for a refuge, may suddenly jump off the laboratory table and flee to a hiding place. These observations indicate strongly that the stimulation, induced attack, and flight reactions are not purely motor effects; rather, they represent interactions between highly integrated central patterns of motivational behavior and conscious visual perceptions of the environment.

The experiment with goats mentioned above is even more convincing (*16*). In the standard experimental procedure the animals are first acquainted with a well-defined source of water. After being deprived of water for a period they begin to seek water at this source. To reach it, they must surmount an obstruction and climb a ladder. After many trials the second part of the experiment begins—namely, electrical stimulation of specific structures of the diencephalon when the animal is hydrated. The trained animal uses the ladder promptly, goes directly to the familiar water vessel, and drains it. The short time between the beginning of stimulation and the action described leads to one conclusion: the effect of electrical stimulation of specific diencephalic structures manifests itself in the subjective sphere as a drive, thirst. This drive gives inducement and direction to the behavior, through which the tension of drive is relieved. Thus, it seems appropriate to conclude that, under the influence of brain stimulation, experiences stored in the memory are actively integrated with instant perceptions and released as behavioral responses.

Effects of Psychotropic Drugs

Electrical brain stimulation is not the only means whereby subjective experiences may be elicited or modified; they may be influenced considerably by the action of chemical agents. One of the best-known examples is the effect of ethyl alcohol. With moderate doses, the individual's mood is usually improved; he experiences an increased desire for adventure, including an urge for verbal communication. His euphoria is accompanied by a suppression of inhibition. For this reason the ventures of the inebriate lead all too often to catastrophe. Another group of substances, the amphetamine compounds, also increase initiative and give the individual the courage for risky undertakings. Certain drugs which influence mental disturbances are particularly interesting from the medical point of view. The effect of stronger doses of ethyl alcohol is revealing; such doses lead to a dimming of consciousness, even to total loss of consciousness. This observation indicates an important sensitivity of consciousness to chemical influences (*17*), which is further revealed in the action of anesthetics upon basic properties of cerebral elements. Such modifications show that chemically defined receptors, as constituents of nerve cells, are in play at the molecular level. Little is known about this field today; however, the means for further investigation are at hand—for example, through study of the effect of drugs on explants of clinical biopsy material.

In addition to drugs which suppress consciousness there are drugs whose action manifests itself in the psychic sphere in other ways. One of these, lysergic acid diethylamide (LSD), is an appropriate "research instrument." Even minimum doses produce very striking psychic effects—for example, primitive visual perceptions such as colored clouds and changes in brightness of visual patterns, like scintillations or flickerings. One psychiatrist (*18*) has described more complex visual impressions, such as spirals, ornaments, fern branchings, and wood carvings, which he experienced in a self-trial. Such imagery arises from latent memory traces. Even more impressive is the case where fragments of acquired knowledge appear in the visual field—for instance, images of benzene rings or chromosomes. Experiences of this nature are noteworthy because similar visual phenomena, such as stars, wheels, colored balls, and disks, are reported by the patient when the brain surgeon applies electrical current to the occipital cortex for purposes of diagnosis (*4*). Artificially elicited perception of the contents of consciousness, on the one hand through electrical stimulation and on the other hand through the administration of a chemically defined substance, is all the more arresting because this activity is based on excitation of elements that lie in the visual-projection areas of the brain. Thus the actions of LSD may be considered a modification of discharge of nervous elements of the visual system. As mentioned above, fragments of stored experience are often part of the activated pattern of excitation. An example is one subject's identification of a wall with a railway embankment. A hallucination was joined to this illusion; the subject believed that he saw an overhead electric line, which in reality was not there but which belonged to the full picture of the electrified Swiss train system. From this, it appears that the mechanism of hallucination may eventually become understood through a biologically oriented approach.

Causality and Motivation of Behavior

The behavior of a cat in an open field on the lookout for an enemy seems to be motivated by the imminent threat. The cat's watchfulness and active search for a refuge confirm this interpretation. While emotions may be the impelling force, the *waking consciousness* determines the organization of a flight reaction. For successful avoidance, coordinated muscular action is called upon. Such action occurs through excitation of precisely defined central mechanisms. To me it is clear that such an explanation can be deduced only from one's own experience. From the objective point of view one might take exception to this interpretation. On the other hand, scientific observers can be expected to be guided in their view by their specialized knowledge concerning the organization of brain and behavior—knowledge which has led to the recognition of principles applicable in both man and other higher animals. Such is the problem of motive and execution of acts controlled by the conscious will. Therefore, the question is, Where do the activating impulses originate?

One may say that this category of phenomena cannot be compared with the category discussed above. On the other hand, no one can deny that the display of behavior presupposes the action of forces, for, without them, nothing would be set in motion and there would be no resistance to be overcome. Voluntary acts are no exception. What is difficult is to determine the type of activating force. As the matter stands, one can only argue by exclusion. Certainly, conditions required for the release of nuclear forces are not present; gravitational forces also are excluded, for today it has been shown that psychic processes take place normally under conditions of weightlessness. The activating forces could be molecular or electromagnetic. Possibly, as yet undiscovered forces may be active which belong to none of the known categories, forces inherent in the living neuronal system of man and other higher animals. Such a concept may mean, to be sure, a revival of the long-departed vitalistic theory. This suggestion is not so absurd, since the experiments which seem to have ruled out vitalistic processes have concerned only somatic or organic functions. However, psychic functions are a reality for the living individual even though they cannot be objectified by outsiders.

Causality and Communication

The substitution of verbal symbols for perceptions of reality plays an important role in causal thinking. An example of such substitution is the reporting of a conference, with mention of the names of the participants. To this conference report only a few details need be added to convey meaningful information concerning the course of the transactions and the conclusions reached.

Acoustical and optical symbols are also used, moreover, and not only for communication between man and man. A dog reacts to the call of its name as a consequence of its education. It looks about, comes to its master, and responds when asked, through word and sign, to perform tricks it has learned.

In the human, basically complex information can be reduced to symbols of fixed, brief design which denote, nevertheless, wide-reaching conclusions. The highest development is found in the symbols of mathematics. Here, data can be expressed through ciphers and other signs which denote qualitative as well as quantitative aspects, and new insights can be developed.

Sense stimulations which are integrated into a pattern of neural excitation are transferred automatically to the environment by the receiving and perceiving subject. This transfer corresponds to the long-known rule of excentric projection. The consequence of this is that no clue concerning localization and organization of the nervous system comes to us from the cerebral process, which is induced through sense organs. On the other hand we receive through the resolving power of receptive systems information about the environmental source of stimulation. In visual perceptions derived from both eyes, for example, paralactic shift is utilized in composing an integrated stereo image. The impression that the sensory stimulation originates in the environment is confirmed through the directed motor reaction—for example, through the grasping of a visually localized object. The successful attempt to grasp the object confirms the correlation between perception and reality. Involved are consistent temporal and spatial relationships which produce the impression of causality (*19*).

Simple mechanisms for the preservation of life are genetically controlled and subject to phylogenetic selection. Important individual behavioral patterns are determined prenatally. Complex reactions, on the other hand, are learned postnatally, and their release is under the control of conscious will. Through frequent repetition, psychic functions become partially or totally automated. As a result, the desired success is achieved with more speed and more precision, and mechanisms of great complexity are mastered.

Summary

This article is based upon data which are suitable for the correlation of behavioral research and experimental neurophysiology. Causal thinking manifests a sort of integrative activity which brings simultaneous and successive patterns of nervous excitation into a subjectively meaningful frame of reference. While neuronal patterns determine the content of consciousness, they fail to provide clues concerning the transformation of such patterns into subjective experience.

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Arbovirus Infections of Laboratory Workers

Extent of problem emphasizes the need for more effective measures to reduce hazards.

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Prior to 1950, only an occasional report was concerned with the need for protection of laboratory personnel who came in daily contact with disease-producing agents. Sulkin and Pike (*1*) had collected data on viral infections contracted in laboratories in the hope that this information would be helpful in determining where the greatest caution must be exercised in working with viruses. The magnitude of the overall problem of laboratory-acquired infections, however, became evident in an extensive survey (*2*) which revealed over 1500 instances of laboratory-acquired infections resulting in 39 deaths. A standing Committee on Laboratory Infections and Accidents of the American Public Health Association (APHA/CLIA) (*3*) has maintained a file of cases of laboratory-acquired infections whether reported to the public or by private communication; so far, there have been over 2700 cases with 107 fatalities.

Molecular biologists interested in the relation of viruses to the metabolic systems of cells and in the structure of their nucleic acids may now be added to the many virologists who have long worked with a heterogeneous group of viruses known as arboviruses. The health hazard inherent in the manipulation of these viruses may not be well known to many of the newer investigators who lack clinically oriented training.

The arboviruses, a contraction of

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"arthropod-borne viruses," are so named because they are transmitted biologically by arthropods between vertebrate hosts. Of more than 200 viruses now classified as arboviruses, approximately 50 have been associated with disease in man, and many have caused overt laboratory infections. This high incidence may have resulted from the marked acceleration of studies of this group of viruses and from the increase in the number of persons who handle these agents.

This article, based on data from laboratories in 38 countries (*4*), reveals risks for those who work with arboviruses. The information obtained was related to the earlier records of the American Public Health Association Committee on Laboratory Infections and Accidents. We now report on the extent of the problem of accidental infection, without regard to recommended measures or devices, since guidelines for laboratory safety and references to specific procedures have been reported (*5, 6*).

Laboratory groups working with the arboviruses were asked to provide information concerning: (i) the number and nature of overt laboratory-acquired arbovirus infections by virus type, (ii) the circumstances that led to infection, (iii) practices in laboratories that may relate to detection and prevention of infections, and (iv) the number of people at risk.

Laboratories responding to the questionnaire ranged from 29 with less than five individuals employed to 13 with more than 15 persons on the staff. Over half of the 91 laboratories surveyed had five to 14 employees.

Of 428 overt laboratory-acquired infections due to arboviruses, 16 were fatal (Table 1). Information on 129 cases first became available through the recent survey. Of the 192 arboviruses currently registered in a catalog prepared by the American Committee on Arthropod-borne Viruses (*7*), 36 are reported to have caused illness acquired in the laboratory, and at least 14 induced illnesses of such severity that need for extreme precaution in laboratory manipulation was indicated (*6*). Most of the arboviruses known to have caused laboratory-acquired infections are in group B. The data do not necessarily reflect the risk of infection from each of the viruses listed because some cases tend to be concentrated in a single area or even in a single laboratory, some viruses are seldom used, and others are used in many laboratories. For example, 24 cases of Venezuelan equine encephalitis were the result of a single accident (*8*), and most of the cases of Kyasanur Forest disease virus infection occurred in two laboratories (*9*). Seven cases of vesicular stomatitus virus infection were reported by one institution (*10*), and all the infections from Colorado tick-fever virus occurred in a single laboratory (*11*). The viruses causing these infections may eventually be classified (for administrative purposes) according to their various propensities for causing laboratory infections. Many caused overt disease of such severity that hospitalization for periods of 2 days to 3 months was required; seven different viruses caused death. Although Kyasanur Forest disease virus has not been reported to be fatal for any laboratory personnel, it is highly infectious. Clinically apparent infections occurred in 65 laboratory workers, principally in India, New York, and Washington.

In several instances, an arbovirus was first found to be capable of producing disease in man as a result of infection of laboratory personnel. Six persons with laboratory-acquired disease due to louping-ill virus were the only known human cases until two instances of naturally acquired disease were reported in 1948 (*12*), and the first recorded case of Zika virus infection in man was a laboratory-acquired

Table 1. Overt laboratory-acquired infections with arboviruses. APHA/CLIA, American Public Health Association, Laboratory Section/Committee on Laboratory Infections and Accidents. ACAV/SLI, American Committee on Arthropod-borne Viruses/Subcommittee on Laboratory Infections. Numbers in parentheses represent cases for which information first became available through recent ACAV questionnaire.

Arboviruses	Information from: APHA/CLIA	Information from: ACAV/SLI	Total cases	Deaths
Group A				
Chikungunya	13	13 (6)	19	
Eastern equine encephalitis	2		2	
Mayaro	1	3 (2)	3	
Mucambo	2	2	2	
Venezuelan equine encephalitis	92	46 (26)	118	1
Western equine encephalitis	5		5	2
Group B				
Dengue	4	4 (2)	6	
Japanese B encephalitis	1	1	1	
Kunjin	2	1	2	
Kyasanur Forest disease	9	60 (56)	65	
Louping-ill	19	3 (2)	21	
Omsk hemorrhagic fever	2	1 (1)	3	
Powassan	1	1	1	
U.S. bat (Rio Bravo)	5	5	5	
St. Louis encephalitis	1		1	
Spondweni	2		2	
Tick-borne encephalitis	8	13 (10)	18	2
Wesselsbron	2	2 (2)	4	
West Nile	3	11 (8)	11	
Yellow fever	37	1 (1)	38	8
Zika	1		1	
Group C				
Apeu	1	1	1	
Marituba		1 (1)	1	
Oriboca		1 (1)	1	
Bunyamwera				
Bunyamwera	4		4	
Germiston	3		3	
Simbu				
Oropouche		2 (2)	2	
Tacaribe				
Junin	2	3 (3)	5	1
Machupo	1	1	1	1
Vesicular stomatitis virus				
Vesticular stomatitis	38	1	38	
Ungrouped				
Colorado tick fever	7	6 (1)	8	
Nairobi sheep disease	1		1	
Piry	1	3 (3)	4	
Rift Valley fever	28	1 (1)	29	1
18 AR 1742 (unidentified)		1 (1)	1	
AR 1792 (unidentified)	1		1	

Table 2. Comparison of number of reported infections with number of viruses handled by laboratories. Numbers in parentheses represent total number of laboratories checked.

Viruses handled (No.)	Laboratories reporting cases		Cases (No.)
	No.	Percent	
1–5	9 (31)	29	16
6–10	6 (14)	43	19
11–20	8 (20)	40	32
21–30	7 (11)	64	42
31–40	4 (6)	67	9
41	6 (6)	100	23
Unknown	1 (3)	33	1

infection (*13*). Several additional arboviruses (Germiston, Kunjin, Piry, and Nairobi sheep disease) are not known to cause disease in man through naturally acquired infection, but yet they have produced infections in the laboratory.

Acquisition of laboratory infections is not always similar to transmission of the disease when it occurs naturally. For example, none of the cases of encephalitis was believed to be transmitted by an arthropod, and only one case of yellow fever was thought to be due to the bite of an infected mosquito. Many persons have become infected while working with dried virus preparations which provide ideal circumstances for aerosol transmission. A case of St. Louis encephalitis and a fatal case of Russian spring-summer encephalitis apparently resulted from aerosol transmission of such materials (*14, 15*). Contaminated dust from mouse cages was apparently responsible for several infections with the virus of Venezuelan equine encephalomyelitis (*16*) and for a fatal infection with Machupo virus; thus, these infections were probably also acquired by the respiratory route.

Table 3. Proved or probable sources of laboratory-acquired arbovirus infections. Cases are distributed according to the one most probable source.

Probable source	Infections (No.)	Percentage of total
Experimentally infected animals	93	21.7
Not indicated	84	19.6
Aerosol	74	17.3
Agent handled	70	16.4
Accidents	43	10.0
Preparation of vaccines, antigens, and other	35	8.2
Experimentally infected chick embryos	9	2.1
Discarded glassware	9	2.1
Autopsy (including known accidents)	8	1.9
Clinical specimens	3	0.7

Although many pathogens decrease in their virulence for the natural host after several passages, a number of overt infections have been acquired in the laboratory by individuals working with "laboratory-adapted" strains of various arboviruses; hence, virus strains that have been passed through animals many times may be still pathogenic for man (*14, 17*). A serious laboratory infection with St. Louis encephalitis virus occurred in an investigator who had worked with a strain that had been passed through mice many times over a period of 16 years. Disease occurred in an individual who had worked with a strain of Rift Valley fever virus that had undergone over 150 mouse passages, and Japanese B encephalitis occurred in an individual who had worked with a strain that had been through six passages in a mouse brain and one passage in chick-embryo cell cultures.

The intensity of activity of the reporting laboratories may be indicated by the number of viruses with which they had been working (Table 2). The percentage of laboratories reporting infections increased directly with the number of viruses being studied in the laboratory. This was the only apparent relation between a characteristic of the laboratory (size of staff, length of operation, and number of viruses handled) listed on the questionnaire and number of infections (including subclinical) reported.

Failure of the size of staff to be directly related to the number of acquired infections may be due to the increase in the proportion of supportive personnel in such laboratories—individuals who have less exposure to infection. Unless the maintenance of records of acquired infection is an administrative routine of the laboratory and unless surveillance has been unchanging, one would not expect a retrospective query to obtain as many early as later cases of infection. The lack of relationship between number of infections and length of operation of laboratories may be ascribed in part to an inadequacy of reporting and in part to changing methodologies. Because of these variables, a man-year exposure index was not presented for any virus.

Over 80 percent of the currently classified arboviruses have been recognized since 1950. The steady increase

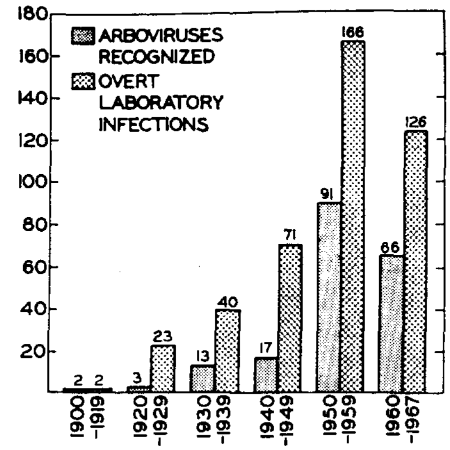

Fig. 1. Number of overt laboratory infections and recognition of new arboviruses by decade. In addition, 12 arboviruses have been added to the ACAV catalog; one virus, Canjam, was responsible for an overt mild febrile illness.

in the number of overt infections acquired in the laboratory correlates with the increase in the recognition of new arboviruses (Fig. 1). Changes in the kinds of agents involved in laboratory infections and in the circumstances resulting in infection to some extent reflect trends in areas of research and interest in certain agents (*18*). Prior to 1950, bacterial infections accounted for over one-half of known overt cases of laboratory-acquired infections, while viruses were responsible for about 20 percent of the total. Since 1950, there has been an increasing number of laboratory-acquired infections due to viruses, with more than half due to arboviruses. This is probably the result of the marked acceleration in research and diagnosis in connection with arboviruses and a consequent increase in the number of persons and laboratories handling such agents. A large proportion of the total number of infections due to arboviruses occurred since 1950 (Fig. 1). Relatively few laboratories worked with these viruses prior to 1941, and the agents causing laboratory infections at that time reflect the area of interest prevailing then.

The exact source of a laboratory-acquired infection is frequently obscure. Often it is known only that an individual had been working with a particular agent or that he had been in contact with infected animals. In other situations, it is known that the atmosphere of the laboratory had become contaminated. That an aerosol may be unwittingly produced by a variety of common laboratory procedures has been convincingly demonstrated (*19*). The potential source of infection has been more fully appreciated since the use of atmospheric sampling devices which show that such common and simple procedures as removing stoppers, expelling the last drop from a pipette, or removing plugs from a tube may produce aerosols near the laboratory bench (*20*). Filtration of infectious material may result in contamination of a vacuum line or pump unless adequate precautions are taken, and maceration of infected tissue by a variety of means may produce an infectious aerosol. Blenders for mechanical disruption of infected tissue have been designed to minimize the chance of leakage and to provide a means of drawing off fluid without removing the top (*21*). If, in addition, the operation is performed in a sterile chamber with a plastic cover over the apparatus, there should be little hazard. The opening of sealed glass ampules containing lyophilized active viral material constitutes a serious inhalation hazard in the laboratory. Special techniques have been recommended for opening such ampules.

Sources of laboratory-acquired arbovirus infections are shown in Table 3. In many instances, it was known only that the individuals had been working with the agent and that the source was probably aerosol inhalation. In addition to those classified as due to an aerosol, a number of infections under other headings were probably transmitted by aerosols. Known accidents resulting from situations that could have been avoided accounted for about 10 percent of the total.

The survey of laboratory-acquired infections has provided information concerning the number of cases and the identity of viruses that cause infections. Regular reporting of laboratory-acquired infections to the American Arbovirus Committee or American Public Health Association would stimulate the development of more effective measures to reduce the hazards in arbovirus laboratories. Regular testing of all members of the laboratory staff for antibodies to all viruses that they handle should be encouraged as a means of assessing the effectiveness of safety procedures. The greatest hope of preventing laboratory-acquired illness lies in the recognition of the sources of infection; the unrecognized sources constitute the greatest problem.

While there is no evidence that use of immunizing substances such as serum from convalescents or specific immunoglobulin is of any value after symptoms of arbovirus infection appear, a rationale based on studies in experimental animals has been developed for use of such substances for passive immunization immediately or soon after accidental exposure. Because of the numbers of laboratory workers required to handle an increasing number of arboviruses in diagnostic and research studies, efforts are being made by the National Communicable Disease Center and the World Health Organization to collect, pool, and accumulate serums of convalescents from specific arbovirus infections. These serums are being processed into specific immunoglobulins and will eventually be available on a restricted basis for use after certain types of laboratory accidents.

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NEWS AND COMMENT

Federal Research Funds: Science Gets Caught in a Budget Squeeze

As the first session of the 90th Congress draws to a close, it is clear that President Johnson's legislative program has been badly gutted. A number of factors—the rising economic and emotional costs of the Vietnam war, a general fiscal squeeze, poor Democratic congressional leadership, a stronger conservative coalition, and growing antipathy between the legislative and executive branches—combined to produce a Congress this year that ignored or drastically altered many of the President's legislative requests. The closing months in particular have been marked by an economy wave that engulfed virtually all non-war-related spending requests, from foreign aid to urban rejuvenation. In the scramble to save another nickel, few targets proved more tempting than federal support of research and development. As Representative Frank T. Bow (R–Ohio) expressed it: "R & D spending is a prime area for economy."

Such attitudes made it certain that the budget and appropriations process for fiscal year 1968 would provide no bonanza for science. Thus there are probably two main points to be made in any analysis of how science fared this year: One is that science received rougher-than-usual treatment at the hands of congressional appropriations committees—though things could have been worse; the other is that things are certain to get worse, thanks to the latest budget-cutting scheme announced

What Congress appropriated (millions of dollars).*

Agency	FY 1967 appropriation or allocation	Administration budget request	FY 1968 appropriation or allocation
National Science Foundation	480.0	526.0	495.0
Atomic Energy Commission	2,199.0	2,646.1	2,509.1
Plant and capital equipment	276.0	476.2	369.1†
Operating expenses	1,923.0	2,169.9	2,140.0
Physical research	255.3	272.0	273.5
High-energy	108.1	116.5	118.0
Medium-energy	11.0	11.1	11.1
Low-energy	28.3	29.4	29.4
Math and computer	6.1	6.2	6.2
Chemistry	52.9	55.0	55.0
Metallurgy	26.3	27.6	27.6
Controlled thermonuclear	22.6	26.2	26.2
Biology and medicine	86.0	90.5	90.5
Training, education, information	16.2	17.9	16.4
Reactor development	467.7	521.1	507.5
Weapons	663.5	700.5	715.5
Plowshare	13.3	21.9	20.7
Health, Education & Welfare Department			
Public Health Service	2,618.1	2,907.9	2,817.4
National Institutes of Health	1,123.2	1,187.8	1,178.9
Cancer Institute	175.7	183.4	183.4
Heart Institute	164.8	168.0	168.0
Institute of Dental Research	28.3	30.3	30.3
Institute of Arthritis & Metabolic Diseeases	135.7	144.0	144.0
Institute of Neurological Diseases & Blindness	116.3	128.6	128.6
Institute of Allergy & Infectious Diseases	90.7	94.4	94.4
Institute of General Medical Sciences	145.1	160.3	160.3
Institute of Child Helath & Human Development	65.0	68.6	68.6
Regional medical programs	45.0	64.3	58.8
Environmental health sciences	24.3	20.6	17.3
General research and services	68.5	81.1	81.1
Construction, health research facilities	56.0	35.0‡	35.0‡
National Institute of Mental Health			
Mental health research and services	225.1	246.7	246.7
Community resource support	50.0	100.2	100.2
Construction, health education facilities	160.7	203.0	203.0
Health manpower education, utilization	149.7	170.4	164.7
Food & Drug Administration	64.8	67.9	67.2
Office of Education	3,924.8	4,004.7	3,903.2
Elementary and secondary education	1,464.6	1,692.0	1,677.9§
Teacher training institutes	37.3	42.8	37.3
Teacher Corps	11.3	33.0	13.5
Research and training	91.1	99.9	90.9
Higher education	1,179.4	1,173.2	1,158.2
Construction, 2-year facilities	99.7	89.7	100.0
Construction, 4-year facilities	353.3	300.3	300.0
Construction, graduate facilities	60.0	50.0	50.0
Elementary-secondary teacher fellowships	30.0	35.0	35.0
College teacher fellowships	80.8	96.6	86.6
Developing institutions	30.0	30.0	30.0
Undergraduate instructional equipment	14.5	14.5	14.5
College library resources	25.0	25.0	25.0
National Aeronautics & Space Administration	4,968.0	5,100.0	4,588.9
Research and development	4,235.1	4,352.0	3,925.0
Physics and astronomy	129.8	147.5	141.5
Bioscience	41.6	44.3	41.8
Basic research	21.5	23.5	21.5
Sustaining university program	31.0	20.0	10.0
Defense Department			
Research, developments test, evaluation	7,093.5	7,273.0	7,108.6
Basic research	404.0	399.3	361.5
Advanced Research Projects Agency ‖	270.9	241.1	223.1
Commerce Department			
Environmental Science Services Administration	156.8	182.5	163.1
National Bureau of Standards	33.3	40.5	32.5
Patent Office	37.1	40.0	38.2
State technical services	5.5	11.0	6.5
Interior Department	1,579.6	1,710.3	1,624.0
Geological Survey	81.6	88.2	85.5
Federal Water Pollution Control Administration	234.7	306.0	295.8
Bureau of Mines	50.7¶	55.5¶	51.5¶
Office of Saline Water	29.9	23.3	9.8**
Office of Water Resources Research	6.9	12.7	11.1
Office of Coal Research	8.2	9.7	11.0
Agriculture Department			
Agricultural Research Service††	213.2	238.2	231.1
Soil Conservation Service	237.6	240.5	238.1
Office of Science & Technology	1.2	1.8	1.5
National Foundation on Arts & Humanities	9.0	16.4	12.2
Arts endowment	6.0	8.8	7.0
Humanities endowment	2.0	6.0	4.0

*The bewildering detail of the federal budget makes its presentation in tabular form an exercise in frustration. This table in no way pretends to be definitive. It is offered primarily as a guide to trends. Some figures have been adjusted for comparability. Comparisons in a horizontal direction—that is, from year to year for any particular line item—are believed to be valid. Figures listed in the appropriations columns represent, in some cases, a specific congressional appropriation for the particular item concerned; in other cases, the amount an agency plans to allocate to the particular item out of a larger congressional appropriation. † Most of the reduction from the budget request represents a financing conversion for two projects to an annual appropriations basis in lieu of the full funding requested. ‡ This is not the sharp decline it seems. Unobligated funds from last year's appropriation bring the amount available for obligation in 1968 up to $50 million. § Excludes $10.8 million requested for Indian and overseas dependents' schools pending enactment of authorizing legislation. ‖ Includes some overlap with preceding figures for basic research. ¶ Excludes Appalachian-area restoration and helium fund. ** This also is not the sharp drop it seems. The additional appropriation requested was passed over without prejudice pending enactment of authorizing legislation. †† In addition to appropriations for ARS, Congress authorized a transfer of $15 million in Section 32 funds in 1968, down from $25 million in 1967.

last week by the Johnson administration. But how much worse is not clear at this writing.

The most dramatic evidence of the congressional economy mood came in the treatment accorded two agencies often regarded as sacrosanct—the National Aeronautics and Space Administration (NASA), and the Department of Defense (DOD). NASA suffered the deepest cuts of any science-oriented agency, ending up with an appropriation of $4.6 billion, more than half a billion less than President Johnson had requested and almost $400 million less than last year's appropriation (see Table, page 1287; see also *Science*, 24 November). It was the largest reduction Congress has ever made in the space program. NASA's sustaining university program was particularly hard hit, receiving less than a third of last year's appropriation.

The Defense Department, though it received essentially the same appropriation as last year for its overall research and development effort, was told to cut back its support of basic research—alarming news for those accustomed to view DOD as a convenient vehicle for slipping research funds past congressional budget cutters (it's somehow harder to vote against defense than to vote against science). The House appropriations committee told DOD its basic research program could "safely be reduced" without "endangering national security" or disrupting graduate education. Partly in response to such sentiments, DOD has cut its allocation for "research" (a budget category that includes all the department's basic research plus some applied) by more than 10 percent—from about $404 million in fiscal 1967 to about $362 million this year. DOD officials say most of the drop represents a cutback in advanced funding of contracts, particularly contracts funded through the Advanced Research Projects Agency, but there has also been some drop in the level of this year's research program and a "striking reduction" in new starts. The cutback in advanced funding means that universities will be less able to make long-term commitments to personnel.

Considering the intense economy pressures at work, the other major science-oriented agencies didn't suffer too badly at the hands of Congress. The National Institutes of Health (NIH) got less than requested—a relitively rare occurrence in recent years—but the overall NIH appropriation increased by more than $55 million and each of the eight institutes got precisely the amount requested. The only cuts Congress imposed affected two relatively new programs (regional medical programs and environmental health services) that Congress thought unready for efficient expansion. The Atomic Energy Commission (AEC) got less than requested (the cut largely reflecting a bookkeeping change) but still enjoyed a 14-percent increase over last year's appropriation. And the National Science Foundation (NSF) received a modest boost over last year, though some $31 million less than requested. NSF told Congress it plans to put greater emphasis on four fields of science this year—chemistry, social sciences, atmospheric sciences, and ocean sciences.

What does it all add up to? Final figures aren't available yet, but the congressional cuts are believed to have dropped aggregate federal support of research and development below last year's level of roughly $16.5 billion, primarily because of the huge NASA reduction. The drop occurred in the development component of R & D. A science specialist at the Budget Bureau estimates that Congress increased the research component of R & D above last year's level, and that it also boosted federal support of academic science. Basic research clearly suffered a tight year in appropriations, but the tightness apparently resulted in a slowed rate of growth rather than a traumatic decline of federal support. Of course, a slowing of expansion is bound to cause problems in institutions gearing up for new programs, and cuts in the physical sciences and in the availability of fellowships (*Science*, 3 November) may cause hardship.

Unfortunately, Congress isn't the final hurdle between federal funds and the scientist at the bench. As things stand now, most federal agencies will not be allowed to dispense the entire appropriations granted by Congress. The Johnson administration's latest budget-cutting scheme, announced last week, will require major federal agencies to reduce their obligations (commitments to spend) and expenditures below the amounts envisioned in the President's budget proposals, in accordance with a percentage formula. The plan was offered as a sweetener to coax Congress into passing the tax increase sought by President Johnson, but Charles L. Schultze, Budget Bureau director, said the cuts will be required even if Congress fails to act on a tax boost.

Some of the cuts demanded by the formula have already been made by Congress, but most agencies will have to cut back even further. NASA will be spared further goring, but the AEC is faced with "a pretty Goddamned big cut," according to one of its financial experts, who estimates that the agency will have to cut its obligations by some $86 million beyond the $114 million already cut by Congress. The Department of Health, Education, and Welfare estimates it will have to cut its obligations by $500 to $600 million beyond the $100 to $200 million already imposed by Congress. And NSF, according to the budget bureau, faces a formula cut of $53 million in obligations and $24 million in expenditures—amounts considerably larger than the cuts imposed so far by Congress. Even after all the additional cuts are made, however, aggregate federal support of research and of academic science is expected to show some increase over last year, according to informed Budget Bureau "guestimates." Unfortunately, inflation may increase even faster.

The basic thrust of the new formula is to impose an across-the-board reduction on all agencies without worrying about the question of priorities, or considering which programs are more beneficial than others. The precise programs that will be affected in various agencies are not known at this writing, for each agency is still trying to come up with a "mix" of program cuts that will produce the dollar reductions demanded by the formula. Some budget officials hope to meet the requirements primarily by deferring new construction rather than by interfering with ongoing programs.

The budget squeeze could become even tighter in the near future. Congress has indicated it wants an even bigger reduction before it will consider a tax increase, and it is also seeking assurances that spending will not soar next fiscal year if a tax increase is granted. Moreover, the advent of next fall's elections may bring the economy crusaders out in force. Perhaps ominously, the Senate Appropriations Committee asked NSF to submit a report surveying all significant private and public efforts in pure science "in view of the proliferation of basic research."

—PHILIP M. BOFFEY

War on Campus: What Happened When Dow Recruited at Harvard

Cambridge. Wednesday, October, twenty-fifth began quietly, but when it was over Harvard University had been plunged into a rare internal crisis. Inside the Mallinckrodt Chemistry Laboratory more than 200 students had crowded into a narrow corridor to prevent Frederick Leavitt, a recruiter from the Dow Chemical Company, the much-assailed manufacturer of napalm, from leaving Room M-102. The sit-in had stretched through the afternoon with no signs of ending; the students wanted Leavitt's pledge that neither he nor any other representative of Dow would ever recruit again at Harvard. Leavitt, a quiet, patient man who runs one of Dow's research laboratories, sat calmly inside the room and prepared to stay the night. Down the hallway, in what was informally christened the "war room," an assortment of university deans, administrators, and faculty members discussed what they could do. Their conclusion: nothing.

At all costs, the deans wanted to avoid involving the police, who might only inflame the situation. Police intervention would also constitute an abridgment of the university's autonomy; for years Harvard has sought, quite successfully, to remain master of its own campus. An informal understanding has existed that has kept police off the campus and let the college handle many cases of petty student crime. To call the police was to admit that Harvard could not run its own shop; and yet that might be necessary. It was obvious to Fred L. Glimp, who had been dean of the college for less than 4 months, that the sit-in could not be allowed to continue indefinitely; Leavitt's patience had limits. Glimp contemplated letting the demonstration run into the evening; he hoped that somehow it would end, or shrink, allowing the police to extricate Leavitt, with a minimum of force, late at night or early in the morning.

Glimp never called the police. Shortly after 6 p.m. the students, jammed into the hallway with cookie cartons, apple cores, and coke bottles, voted to leave. A last appeal by Glimp, buttressed effectively by speeches from some students and junior faculty members, had had its effect. Leavitt was whisked away, and almost the entire college community began a week of collective debate.

In the following days the specter of a Berkeley-style crisis loomed before many frightened and anxious administrators and faculty members. Harvard's time had finally come, they told themselves, and the students threatened to tear down the campus. Stern action had to be taken quickly, some felt. But that stern action, and the collapse of the university, never came.

The parallel with Berkeley was, in this instance at least, simply wrong. "Harvard is still more of a community than Berkeley ever was," commented one faculty member who has taught at both schools. The Dow protest did not destroy the university, but it did demonstrate the profound psychological and political impact the war has had on the college. Harvard is a self-composed and, generally, self-satisfied place. Nevertheless, this incident, for the 6 days between the event itself and the overflowing faculty meeting that approved punishments for the demonstrators, shredded the community's confident fiber.

The protest was a difficult one for the university to handle, for, though some students and faculty members thought they clearly saw the path to Truth, a large part of the community had ambivalent feelings about the entire affair. That ambivalence grew with time. This incertitude stemmed, like the demonstration itself, from Vietnam. Over the last 2½ years the college has turned overwhelmingly against the war. The antipathy is strongest and most pervasive among students, but the faculty, too, is increasingly rejecting the war. Though disenchantment is not universal, the antiwar mood is so strong that those who feel otherwise, including a number of prominent faculty members, generally stay silent.

But Harvard men also feel especially protective of civil liberties, and the sit-in—the involuntary detainment of one man for 7 hours—clearly rubbed many faculty members and students the wrong way. A dilemma was posed for many. Was civil disobedience justified by outrage over the war? If not justi-

Dow Demonstration: Students blocking a passageway at Harvard in protest against recruiting by Dow Chemical Co.

Frederick Leavitt, a recruiter from the Dow Chemical Co.

fiable, was it at least pardonable? After all, many of the nondemonstrators claimed to share the demonstrators' hatred for the war.

The debate grew deadly serious. It became a passionate, emotional issue, as if Harvard, in those 6 days, were going to settle all the moral and political problems of the war. At the *Crimson,* the college's daily newspaper, one of the most acrimonious editorial debates in years resulted in the paper's reverting to a periodic practice—running two sets of editorials, a majority and a minority. One senior faculty member prepared to resign and had to be persuaded by a colleague to wait until the college had decided on the severity of disciplinary action (in the end, he stayed). Student organizations of all beliefs and functions passed resolutions, and faculty members penned letters to their favorite deans. On a question of fundamental morality, the name of the game was stand-up-and-be-counted.

The heart of the college's problem, and the point to which much of the debate was directed, was discipline. The year before, a similar incident had occurred at Harvard when Defense Secretary Robert S. McNamara had been trapped for a few minutes by angry antiwar demonstrators who insisted that he publicly defend government policy (the only sessions scheduled for McNamara at Harvard were semiprivate affairs). After that incident, no one was punished; the Harvard administration, which likes to be tolerant, flexible, and fair, avoided action on the grounds that this type of protest, "intolerable" as it was, represented a first for the college, and the students had no way of knowing what reaction to expect. A stern verbal warning was issued, and the presumption was that a recurrence would probably result in severance—ouster, usually for a year, with the right to apply for readmission—of any demonstrators.

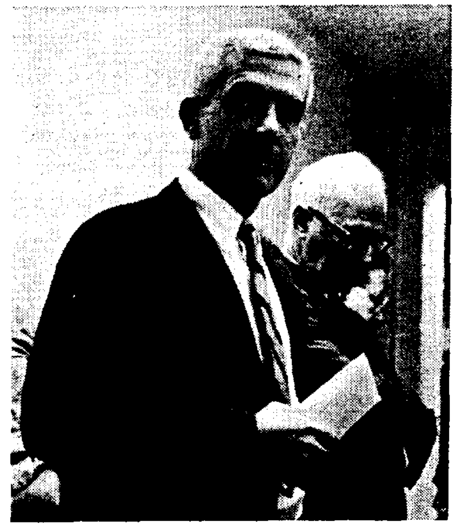
Now the question of punishment was alive again, and it reverted to the college's Administrative Board, which handles all major student disciplinary and academic problems. The Board, composed of the college's deans, a few faculty members, and senior tutors for the residential Houses (where most of the three upper classes live), faced incredibly complex situation.

First, it had to resolve substantive issues. Liberal arts colleges stand as the guardian of free speech and dissent. They abhor punishing political protest except when the protest of some has impaired the rights of others. Had that line really been crossed in the Dow demonstration, and, if so, how grave was the transgression?

Second, the Board was confronted with a baffling procedural problem. When the deans had demanded student identification cards from the demonstrators, cards came not only from those at the sit-in itself but from those in sympathy with the sit-in. More than 400 cards were ultimately turned in. Who had actually participated, and who was to be punished? Students pleaded for "collective responsibility" and portrayed their action as a fundamental moral commitment which deserved equal treatment for all. To many faculty members and administrators (as well as to some of the shrewder students who planned the move), the piles of cards represented a sophisticated tactic designed to confound and paralyze the Administrative Board. It almost did.

The Board first met the day after the demonstration, on Thursday, and its first instinct, reflected by stories in the *Crimson,* was to act tough. Some students, it was reported, would probably be severed. This prospect raised the college's internal debate to a new feverish level—especially on the part of the demonstrators' partisans, both student and faculty.

However, 5 days later, when the Administrative Board met for a third and final time and presented its recommendations for punishment to the faculty, its views had apparently moderated. No one was to be suspended; 74 demonstrators were to be placed on probation—a punishment which sounds harsh but which, for all practical pur-



During the crisis: Confronting the demonstrators, left to right, Fred L. Glimp, Dean of the College, and J. P. Elder, Dean of the Graduate School of Arts and Sciences.

poses, amounted to a very sharp warning. (Some of the traditional "teeth" of the penalty were deliberately drawn; no one placed on probation was to have his scholarship reviewed, nor was anyone already on probation to face automatic severance.) What happened in those 5 days demonstrated why Harvard is different from Berkeley.

The Administrative Board's shift was real enough, but not so sharp as it seemed. Some students suspected that the Board's change of heart represented a shrewd strategy: first act inflexible and frighten the students; then soften up and win their silent and grudging gratitude. Events probably tended to have that effect, but the script was not written in advance.

The Board was never as vindicative as it sounded. Most of the Thursday meeting was spent bringing order out of confusion. Specifically, the Board, on the basis of visual identification, decided to divide the stacks of identification cards into three groups—individuals who had actually been seen blocking the door to the room where Leavitt was trapped, those who had been seen at, but not taking part in, the demonstration, and those who had simply handed in their cards. There was no binding discussion of punishment. On the Board there were those who believed that severance was inevitable, if not desirable, and those who felt, even this early, that severance was too stiff a penalty. The *Crimson's* readers received an impression of greater rigidity for two reasons. First, Dean Glimp, who chairs the Board, felt initially that severance was inevitable, and the *Crimson* reporters naturally lent weight to the dean's opinion. Second, the separation of the identification cards into three groups seemed to correspond naturally with the three forms of punishment (severance, probation, and a simple admonition).

It was a tense faculty which approved the Board's recommendations for probation the next week. The motion passed, on a hand vote, by a 4-to-1 or 5-to-1 margin, and the most relieved were those who had pleaded for leniency and expected harshness. The Board had, in fact, made an eminently practical and thoroughly political decision. It delighted few, but satisfied almost everyone.

In moderation, the college actually got what it demanded. No one really wanted to see the issue brought to a sharp head at the risk of shattering the university. In general, Harvard students and faculty alike enjoy being in Cambridge; they are snobbish and protective about their university; most of them—whatever their dissatisfactions, and they have many—want to stay at Harvard. Students and faculty, parochial as they are, had a common interest in hoping the demonstration would not snowball into something bigger. One of the most radical members of the faculty, Barrington Moore, Jr., emphasized this point in a retrospective article:

"As students and teachers we have no objective interest in kicking down the far from sturdy walls that still do protect us. For all their faults and inadequacies the universities, and especially perhaps Harvard, do constitute a moat behind which it is still possible to examine and indict the destructive trends in our society."

The Administrative Board's recommendations were soothing, not so much because the Board calmly calculated what the community would accept—such problems were discussed sparingly, if at all, in the Boards' meetings—but because so many people were so aroused that they made their thoughts known to anyone who would listen. All the pressures ultimately came to bear on the Board.

To recommend no punishment for the demonstrators, or a simple admonition for all, as some faculty members wanted, would have been to disregard the views of a majority of the faculty (including the University president), who thought the sit-in should clearly be branded as bad. Many Board members actually felt that the recommendations would have to be defended against charges of leniency.

NEWS IN BRIEF

• **COOPERATIVE POPULATION STUDY**: A joint study on population control has been started by the population committees of the National Academy of Sciences and the Royal Society of London. The study is being supported in the United States by a $45,000 grant from the National Institute of Child Health and Human Development and by a $10,000 grant from the Population Council.

• **BOOKS FOR ASIA:** College-level books for use in Asian academic institutions are being sought by the Asia Foundation. Physical sciences books, published since 1955, and social sciences and humanities books, carrying a 1950 or later publication date, are being accepted. Literary classics and anthologies of any age are also sought. The book donations, which are tax deductible, should be sent to Books for Asian Students, 451 Sixth St., San Francisco, Calif. 94103.

• **NSF CHEMISTRY SECTION:** The National Science Foundation has announced the reorganization of its Chemistry Section to "more accurately reflect current research interests and activities of its component programs." M. Kent Wilson, who previously headed the Chemistry Section, continues in that position.

• **LATIN AMERICAN PROGRAM**: Plans for a multinational program for science and technology in Latin America are progressing rapidly, James R. Killian, Jr., has reported to President Johnson. Killian, who is chairman of the MIT Corporation, is serving with a group of experts to develop science and technology in Latin America. The group was formed at the direction of the presidents of the American states when they met at Punta del Este in April. Among the items under consideration are the establishment of multinational centers for science and technology and the strengthening of existing centers. Bernard Houssay, a Nobel laureate from Argentina, is chairman of the group.

• **FUND DRIVES:** Three universities have announced fund drives with combined goals totaling $269.1 million. Funds from each of the drives will be partially used for new construction and endowed professorships. The Massachusetts Institute of Technology is seeking $135 million. The California Institute of Technology is attempting to raise $85.4 million, and Harvard is looking for $48.7 million. Harvard's drive is "aimed especially at putting new zest in the undergraduate instruction in science" and will provide for the construction of new science facilities and endowed professorships in astronomy, biology, engineering and applied physics, mathematics, and physics.

• **SOVIET'S UFO STUDY**: The Soviet government, reversing its previous policy of largely ignoring reports of unidentified flying objects, has created a commission to study UFO reports. Air Force General Anatoly Stolyerov was named to head the commission.

• **PHARMACEUTICAL RESEARCH**: The Pharmaceutical Manufacturers Association has published data indicating that the industry spent $416.1 million for research and development in 1966. According to the association, 17.3 percent of the expenditure was for basic research.

• **OCEANOGRAPHY**: The Commission on Marine Science, Engineering, and Resources—a temporary body established in January primarily to develop an organizational plan for the government's widely scattered oceanographic enterprise—will give interested parties a chance to react to its proposals before reporting to the President. According to Julius A. Stratton, chairman of the new body, the commission seeks to have its life extended by 6 months to allow more time for informal discussion of its proposals with government agencies, industry, and academic centers. Congress has been asked to permit the commission to report in January 1969 instead of next July; routine approval of this request is expected. Stratton says that by mid-year the commission's tentative proposals should be in hand. A not altogether incidental advantage of the 6-month postponement is that the report will not go to the White House in the midst of a presidential election campaign. Speculation now centers on whether the commission will recommend a "wet NASA" or a looser form of organization for the government's oceanographic activities.

Severe penalties, on the other hand, would have alienated a significant portion of the faculty who sympathized with the demonstration. In a body like the Harvard faculty which avoids consistently divisive controversy and normally operates on consensus, such a division would have been remarkable; it was not a step to be taken lightly.

Nor were the sympathetic faculty members simply junior men who were both angrier and less distinguished than their older colleagues. Eight senior professors had visited Glimp two days after the demonstration. In addition, the morning of the faculty meeting, 20 tenured members of the faculty signed an open advertisement in the *Crimson* declaring their sympathy for the demonstrators. These men were taking the Dow demonstration very seriously—so seriously, in fact, that a number of them actually caucused before the faculty meeting, a rare acknowledgment of the political process at Harvard.

Many faculty members identified with neither pole of opinion ("Kick the bums out," or "Give the heroes medals") found ample reason to be troubled. Instinctively repelled by the demonstration itself, they could, because of their own dislike for the war or their own regard for faculty and students who had allied themselves with the demonstrators, support some sort of leniency. Furthermore, the draft also worked for leniency. Students, if dismissed, would soon be called up by Selective Service, and how could any faculty members who claimed to hate the war send Harvard men to the army or jail in good conscience?

Student sentiment was equally muddled. The issue was not as simple as supporting or damning the Dow sit-in itself. The war colored all, and hate of it united many students who were indifferent to the specific act of protest. At the demonstration, some students handed in their identification cards out of simple disgust for the war; others surrendered the cards to protect the protesters. The war, for growing numbers of them, was something that could not be sidestepped. The power that moved students was described, perhaps exaggerated, by *Crimson* writer James Glassman as he discussed the decline of the Harvard "cool-liberal" political ethic:

> Harvard cool-liberalism means the good old basic beliefs in equality and civil rights . . . [The] lack of passion keeps you clean. Student politics is farcical. It is left to former Midwestern student council presidents. There are causes and causes. Issues come and go. You cluck your tongue or nod your head. Eisenhower was dull and stupid; Kennedy had style, you know; the Cuban invasion was bad. . . . And so on. Many of us don't sign petitions because, well, what of our political careers and all?
>
> But passion, which is a dirty word from the Freshman Mixer to the Class Marshall Elections, has reared its dread head. We are being forced to be passionate or, if we choose not, to be anti-intellectual or perhaps immoral or perhaps wrong.

This is not the mood of all students; it is probably not an enduring mood for most. But it is a mood that grips many students for the moment; as the war grinds on, the guilt of having been once "for" it, or of having done nothing to stop or protest it, will swell in strength. At Harvard, this instinct was strong enough to give the demonstrators a wide base of student support, even from many students who thought the sit-in, of and by itself, undesirable.

Two considerations reputedly convinced many members of the Administrative Board to opt for probation, not severance. First, the students, by and large, seemed to realize that the demonstration was not appropriate; thus, what the Board had to do was to make its action strong enough to be an effective warning yet not seek vengeance on the students. Second, the warnings given after the McNamara incident were said to be sufficiently vague to warrant the less severe action.

Were these conclusions actually true, or were they simply sophisticated rationalizations on which the Board could base its actions? That depends on who is doing the talking; in truth, there was probably a bit of each. Classifying student opinion is as difficult as classifying any other body of opinion. Only one poll was taken during the week-long episode; it showed that, in one of Harvard's eight residential Houses, 10 percent favored severance for those who had obstructed Leavitt's departure; 10 percent wanted no action at all; 50 percent supported probation or admonition for all those who had blocked the doorway; and about 25 percent favored admonition for anyone who had turned in his identification card.

With feelings running as they were, severance could, in fact, have been incendiary. The campus chapter of Students for a Democratic Society, whose members had been instrumental in starting the Dow sit-in (though the chapter had slipped into the background in the subsequent uproar) would probably not have remained quiet. But many others were also agitated. Nine hundred students had signed a petition reaffirming university policy on free speech and recruiting but asking for leniency. A mass meeting of more than 800 students, held the night before the faculty meeting, seemed to make the same point. The possibility that stiff penalties would have provoked more demonstrations and an uncontrollable polarization on campus could not be dismissed. Thus, perhaps the most interesting result to emerge from the Dow episode was Harvard's unconscious acknowledgment, in its official actions, that numbers alone —simple majorities—are not very useful guides for making decisions when a minority is sufficiently aroused.

The Administrative Board did not escape the Dow incident unscathed. When it rejected the plea for "collective responsibility," the Board had to select those students who, it was convinced, were actively involved in the sit-in. In so doing, it opened itself to charges of arbitrariness and capriciousness; these problems generated numerous complaints and some good newspaper copy. But, as one tutor remarked, "People were surprised by the number of people put on 'pro,' but no one cared, because no one got kicked out. Three hundred people could have been put on 'pro.'"

After the faculty meeting, talk of the Dow incident died of exhaustion; the emotions generated by the controversy could not be sustained. But the event had its sequel. At the faculty meeting, Stanley Hoffmann, professor of government, proposed the creation of a student-faculty committee, the first in the college's history, to study issues of the university's relationship with the war. The administration's reaction to the proposal seems to reflect its uneasiness over the Dow incident and its eagerness to satisfy faculty and student critics. Without waiting for a full faculty vote, Franklin L. Ford, dean of the faculty, has acted to get the committee going and, in fact, has given it a student majority. No one really knows what the committee will do. It may become bogged down in petty matters of procedure, or, alternatively, at least look into a number of areas involving the university and the war. These include:

• *Recruiting.* By lending its facilities to companies and government agencies that aid the war effort, the university, it is charged, implicitly endorses the war. Should the university cease to permit such recruiting on its own property? Most students and faculty recognize a distinction between recruiting, which they regard as a service, and free speech, which they regard as a right. But there seems to be a developing consensus that, if some recruiting is to be ended, all recruiting (excepting perhaps by educational institutions) must be ended; to give administrators arbitrary power to distinguish between different government agencies and firms would be discriminatory and could lead to continuing inequities.

• *Research.* Harvard, unlike many universities, does not permit classified research on university time, but a faculty member is free to use 1 day a week for any outside consulting he desires. Nevertheless, there are charges that the university is "complicit" in the war because of some of its research commitments. No one really knows the facts about the broad scope of research conducted at the university, and some faculty members suspect that there may be ways around the university's absolutist rule. This area of study is now the most ambiguous, but could be extraordinarily important.

• *Free speech and forms of protest.* The issues raised by the McNamara and Dow incidents may be reviewed again. There is a school of thought that believes Harvard should lay down definite guidelines about the kinds of demonstrations that are unacceptable and the punishments they will carry. The college administration has avoided this

Waterman, First NSF Head, Dies at 75

Alan T. Waterman, first director of the National Science Foundation and former president of the AAAS, died on 30 November at the age of 75, following a brief illness. Waterman headed NSF from its founding in 1951 until 1963. In the last year of his service, he was past the government's compulsory retirement age, but continued to serve under a special order from President Kennedy.

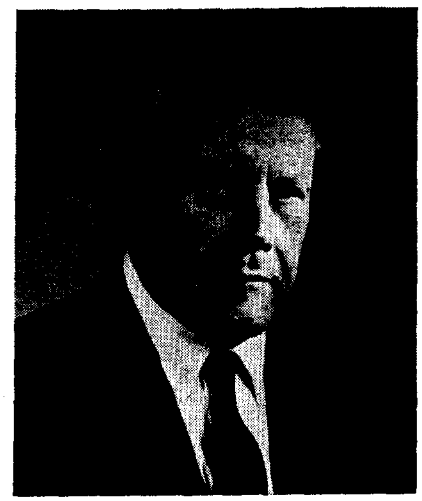
Waterman completed both his graduate and undergraduate work at Princeton. After receiving his Ph.D. in 1916 he became an instructor in physics at the University of Cincinnati. During World War I, he spent 2 years with the Science and Research Division of the Army Signal Corps. He then became an assistant professor and later an associate professor of physics at Yale.

During World War II he served with the Office of Scientific Research and Development, holding several positions, including chief of the Office of Field Service. In 1946, Waterman became deputy chief and chief scientist of the then newly established Office of Naval Research. He went directly from ONR to NSF.

Since his retirement he had been active in various advisory and administrative activities, serving on numerous boards and committees, including the Board of Trustees, Atoms for Peace Awards; Advisory Board, Center for Strategic Studies, Georgetown University; Liaison Committee on Science and Technology, U.S. Library of Congress; Special Consultant to the President, National Academy of Sciences, and Chairman, Committee on Scholarly Communication with Mainland China; Advisory Committee, Pacific Science Center, and Board of Trustees, University Corporation for Atmospheric Research.

Waterman was a member of many scholarly organizations, and recipient of numerous awards including the Presidential Medal for Merit, for his work with OSRD, and the Presidential Medal of Freedom for his leadership in government support of basic research. He also held the Captain Robert Dexter Conrad Award, from ONR, and the Public Welfare Medal from NAS. Recently he received the Karl Compton Award from the American Institute of Physics.

On the death of Waterman, his successor at NSF, Leland J. Haworth, issued a statement, which said in part: ". . . When Alan Waterman took the helm of this fledgling agency in 1951, few in Government recognized the importance of basic research in the total spectrum of the Nation's scientific and technological enterprise. Alan Waterman was one of those few; his work at the Office of Naval Research had already established that agency's leadership in providing financial support for basic American science. When he came to the Foundation he began to build another organization through whose efforts science could develop strength commensurate with its promise and with the Nation's needs.



"Following the precepts set forth in the famous report by Vannevar Bush, 'Science, the Endless Frontier,' as embodied in the National Science Foundation Act of 1950, Dr. Waterman, in concert with the National Science Board, established the basic philosophy still used in the Foundation, whereby scientists themselves largely determine the direction and progress of basic research. The Foundation early established the pattern of giving strong support to research at the Nation's colleges and universities where much of the best basic research and all of the training of future scientists, engineers, and physicians is carried out. To the widely endorsed concept of providing strong support to advanced students already committed to scientific careers, the Foundation, under his leadership, added the next logical step of assisting improvement of scientific education on the earlier rungs of the educational ladder. Thus the Nation is also strengthened through a better informed citizenry, with an ever-increasing depth of understanding of what science is, and what part it plays in the lives of everyone. . . ."

—G.M.P.

strategy, apparently on the theory that protest activities defy effective definition and that, by spelling out punishment, it might paint itself into a corner. The deans are relying on the power of precedent.

An informal Gospel has grown up about the Dow demonstration, and the quick formation of the student faculty committee is part of it. Book One of the Gospel says that the incident, despite its inconveniences, was "healthy" for the university—that it laid bare many of the students' deep frustrations and opened the way for a better understanding of the war's impact on the university. Book Two says that the reason Harvard was so successful in resolving the problem without splintering the community was the smallness of its full-time professional administration and the easiness of faculty-student dialogue. Book Three contends that, even in a disorderly demonstration, Harvard men acted with restraint: after all, they did let Leavitt go, they always permitted the deans free access to Leavitt's room, and never once during the protest was anyone, regardless of viewpoint, shouted down by the demonstrators.

There is more than a skeleton of truth to each of these claims. It is also true that they have given rise to some feeling of self-satisfaction and complacency: Fortune has tested her, and Harvard, as always, has survived. As long as the war continues, that feeling will probably be misplaced. Most Harvard students have come to oppose the war for fundamentally different reasons: moral ("Why are we burning babies in Vietnam?"); political (We're drastically overextended, trying to achieve impossible goals at the cost of destroying America drastically"); and personal ("General Hershey, why don't you leave me alone?").

These differences deny the antiwar movement a certain coherence, even at a place like Harvard. Those faculty members and students who first opposed the war on essentially moral grounds have been—and continue to be—the most vocal, the most angry critics of the conflict. But as the frustration of fruitless protest builds, as the war moves unfalteringly forward, and as the threat of the draft lurks closer for many, the reasons for opposing the war blur: moral arguments are made by those whose first opposition was political. More and more students borrow the "radical" perspective, because the "radicals" have been proved consistently "right" by events. The draft-resistant movement, small to begin with, is still small, but getting larger. Students' respect for established authority diminishes because the established means and institutions seem totally unresponsive to their anger. They come to believe that, as Barrington Moore, Jr., a lecturer on sociology, noted: "No system of law and order has been politically neutral in practice. At the present moment in the United States, law and order protect those who conduct, support, and profit from a war that more and more of us regard as atrociously cruel and strategically stupid."

For students, this apparent rigidity is especially frustrating, because their political time horizon is measured in days and months, not years and decades.

This does not mean that a whole generation of Harvard students is being irreparably "alienated." The Dow demonstration posed the problem of putting opposition to Vietnam policy above allegiance to the established institutions and procedures which created that policy; an overwhelming number of students still believe that Lyndon Johnson's government is legitimate, even if they think it is stupid, wicked, and wrong.

The balance is tipping, however, and no doubt will continue to tip. The irony is that, when more and and more people at Harvard are coming to view the war with greater and greater horror, protest against the war is focusing on, or at, the university. This is a measure of the accelerating anger of many students, and the seeming ineffectiveness of outside demonstration. The weekend before the Harvard Dow protest, many Harvard students had journeyed to Washington for the march against the Pentagon. It was, for some, a profoundly disillusioning, frightening experience; it contributed to the anger and frustration that produced the Dow sit-in 4 days later.

Some students and faculty believe the antiwar outrage has given rise to a romantic vision of politics and reality—a fuzzy fantasy that leads to the attacking of the university, however indirectly, for the war. Even some of the earliest critics of American involvement have raised this point. One apparent reaction—to the frustration and the sometime student feeling that the university is side-stepping the war issue—has been the formation of several informal student-faculty ventures to channel their protest together.

The history of the antiwar protest, at Harvard at least, is that it is unpredictable. The frenzy of the Dow demonstration and its aftermath have both frightened many students—very few really want to get kicked out—and relieved the tension. This disappoints some radicals who insist the war is so bad that one cannot cease to be demonstrably angry. But the war continues. Each incoming Harvard class enters with a more developed antiwar consciousness than its predecessor. Someday the unpredictability of passion may return to Harvard, and, if it does, the next "intolerable" demonstration may not have a "healthy" ending.

—ROBERT J. SAMUELSON

Un-American Activities: Court Rule Aids Stamler in Contempt Case

Two and a half years after Jeremiah Stamler, a distinguished medical researcher in Chicago, was subpoenaed by the House Un-American Activities Committee (HUAC), a three-man U.S. District Court has ruled, as the result of action initiated by Stamler and two others, that HUAC must defend its constitutionality. The significance of the action, Stamler's legal counsel noted, is that "the validity of the Committee's enabling act and procedures will be tried."

Stamler was one of 16 persons subpoenaed by HUAC in May 1965 to testify during its hearings on Communist activities in the Chicago area (*Science*, 23 July 1965). The District Court ruling follows two civil suits filed against the committee and a criminal indictment charging Stamler and two other defendants with contempt of Congress.

What is significant in the Stamler case is that he, an employee of the city of Chicago, chose, along with Mrs.

Yolanda Hall and Milton M. Cohen, to test HUAC's constitutional grounds rather than answer the committee's questions. This refusal to submit to questioning led to the contempt of Congress charges.

Stamler, who is 48, is director of the Heart Disease Control Program and the Division of Adult Health and Aging for the city of Chicago. After the indictment he was placed on inactive status by the Chicago Board of Health pending the outcome of the case. Stamler is also the executive director of the Chicago Health Research Foundation, the Board of Health's research arm, an associate professor in the department of medicine at Northwestern University Medical School, and Western Hemisphere editor of the *Journal of Atherosclerosis Research*. He has published more than 150 articles on diseases of the heart and blood vessels and has written several books since 1949, the year he was licensed to practice medicine.

In May 1965, on the day he was named to receive the Albert Lasker Award in Medical Journalism for his coauthorship of a series of articles on the prevention of heart disease, Stamler and Mrs. Hall, a research nutritionist associated with him at the research foundation, were subpoenaed to appear before the HUAC hearings. Along with Cohen, a Chicago social worker, they filed a civil suit against HUAC on 24 May 1965, the day before the hearings were to open. The suit, which attempted to enjoin the hearings and to have the committee's enabling act declared unconstitutional, was dismissed as premature.

Stamler, Mrs. Hall, and Cohen then appeared during the HUAC hearings, along with 13 other witnesses who had been called. But unlike the 13, who cited the Fifth Amendment as grounds for refusing to testify. Stamler, Mrs. Hall, and Cohen refused to testify at all, except for giving their names and addresses. As a consequence, the three were cited for contempt of Congress in October 1966. HUAC never revealed why they had been called. However, their attorney contends that the committee was attempting to deter Mrs. Hall from any involvement in civil rights activities by harassing both her and Stamler.

For 9 months following the congressional action the government did nothing to secure criminal indictments against the three. Then, on 7 July 1967, the government announced its intention of seeking indictments. Albert E. Jenner, Jr., a well-known Chicago attorney who was a senior counsel to the Warren Commission, heads the legal team working on Stamler's, Mrs. Hall's, and Cohen's behalf. Jenner sought an injunction to halt the government action, but the request was denied, and before review could be sought, the government presented the cases to a grand jury and obtained criminal indictments.

As a result of the indictments, the Chicago Board of Health, which had given Stamler a vote of confidence following the HUAC hearings, placed him on inactive status, without salary, pending the outcome of the contempt proceedings. Eric Oldberg, president of the Chicago Board of Health, told *Science* in a telephone interview that Stamler was placed on "inactive" status rather than suspended—as Chicago rules demand when city employees are under indictment on criminal charges—because Oldberg felt there was less stigma attached to being made inactive. Although Stamler is not receiving his $21,800 annual salary from the Board of Health, he does continue to receive his salary from the privately operated Chicago Health Research Foundation, of which Oldberg is president. If Stamler is eventually cleared of the contempt charge, he will receive his back pay from the Chicago Board of Health.

Second Suit Filed

Following the HUAC hearings in Chicago, Jenner filed a second civil suit, on 6 December 1965, against the committee. That suit updated the first civil action and described in detail what had taken place before the subcommittee. The second suit requested a judgment which would have declared that the hearings were invalid, that the subpoenas served on Stamler, Mrs. Hall, and Cohen were invalid, and that the committee's enabling act was unconstitutional. Like the first suit, the second was dismissed on the basis that it involved certain "threshold" questions. Jenner immediately appealed the decision and consolidated the appeal action with the appeal for the first suit.

What opened the door for the latest judicial decision, challenging the committee to prove its constitutionality, was a ruling on 10 November 1966 by the U.S. Court of Appeals for the Seventh Circuit, which overturned the prior judgments by a lower court that had dismissed the first and second civil suits filed by Stamler, Mrs. Hall, and Cohen.

On 9 November 1967, just one day short of a year after the Court of Appeals paved the way for the suits against HUAC to be heard, the three-judge U.S. District Court for the Northern District of Illinois unanimously denied a motion by HUAC to dismiss the suit against it. The court ordered HUAC's members to file an answer to the charges relating to the committee's constitutionality by 8 January 1968. The court also, with one judge dissenting, ruled that the Attorney General of the United States and the U.S. attorney for the Northern District of Illinois be added as defendants to the suit, along with the members of HUAC.

Jenner, in a letter written to heart surgeon Paul Dudley White, who is chairman of Stamler's Legal Aid Fund,* noted on 22 November that the latest "rulings are a milestone in this litigation. The House of Representatives Committee on Un-American Activities and the members are subject to being called to testify at pre-trial depositions."

To date, the costs in the various suits brought by Stamler, Mrs. Hall, and Cohen, and those in preparation for their defense in the suits brought against them, have run about $100,000 —an amount nearly equal to that raised by more than 2000 sponsors of Stamler's legal aid fund.

The criminal indictments against Stamler and his fellow defendants have been consolidated, but no trial date has been set. On 12 January, a status report will be issued by the court, 4 days later than HUAC is supposed to answer the charges brought against it in court. Clearly, the outcome of the battle between Stamler and HUAC will rest largely on the final action in the civil suit. Jenner stated in his letter to White that he hopes "eventually to obtain a general order of continuance of the criminal cases pending outcome of the civil case." If the civil case, in which HUAC's constitutional basis is challenged, is decided in favor of Stamler, Mrs. Hall, and Cohen, there would appear to be little on which the contempt of Congress charges could be based.—

—KATHLEEN SPERRY

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Book Reviews

Man as Sensor

Sensory Inhibition. GEORG VON BÉKÉSY. Princeton University Press, Princeton, N.J., 1967. 277 pp., illus. $8.50.

This book is based upon the Herbert S. Langfeld Lectures delivered by von Békésy at Princeton University in the fall of 1965. Von Békésy's report of his own extensive experiments in the processes of sensory inhibition represents an important substantive and methodological contribution. On the substantive side, the formulation of the idea of "funneling" as a general principle underlying the inhibitory interactions that filter information from sensory receptors clarifies the relationships between phenomena of perceptual resolution, sensitivity, and integration. On the methodological side, it is appropriate that, in a period increasingly dominated by electrophysiological approaches to sensory research, the advantages and unique achievements of psychological experiments be explicitly stated.

Von Békésy's concern with inhibition goes back to 1928 and his study of the mechanical properties of the basilar membrane. Depending upon the frequency of vibration, different sections of the basilar membrane vibrate at maximum amplitude, but the maximum is relatively flat. In order to explain the precision of pitch discrimination, von Békésy suggested that the lateral fibers of the basilar membrane sharpen resolution by suppressing the response of all the nerves but those stimulated near the maxima. In 1930, he proposed that inhibition is also a factor in the perception of the direction of a sound. The inhibition that occurs in the basilar membrane and in directional hearing, however, differs in nature from the inhibition of motor responses, in that it is accompanied also by summation. Though a large binaural time difference localizes a sound completely in one ear, the loudness that is perceived is greater when both ears are stimulated than when only one ear is stimulated. Von Békésy conceives of this simultaneous action of inhibition and summation in sensory processes as a funneling of laterally spreading stimulation into a localized neural pathway. Funneling by filtering and amplifying the neural response serves the important function of increasing the signal-to-noise ratio.

Von Békésy's view of funneling is far-ranging and varied. He shows it to be a general characteristic of the nervous system that may occur at many different levels. Funneling is a function of the spatial and temporal distribution of stimuli, the magnitude, frequency, and abruptness of a stimulus, and the density of neural interconnections. The experiments he reports show that it affects sensitivity, resolution, and the integration of spatial and temporal patterns of stimulation. A large amount of funneling produces a low absolute threshold, a large difference threshold, a lower rate of increase in sensation magnitude with increase of stimulus intensity, and precise apparent localization. Pursued in depth, the processes of funneling raise many fascinating and fundamental questions.

A basic type of funneling action is that responsible for Mach bands. In Mach bands, a graded distribution of light is transformed into a much sharper distribution of sensation. Von Békésy demonstrates that Mach bands are not restricted to the eye but occur on the skin for both direct pressure and vibration. The basic effects of excitation and inhibition that produce Mach bands are derived from observations on the sensory impressions produced by two points of stimulation on the skin as their distance is increased. The summation of adjacent stimuli and the inhibition of more distant stimuli lead von Békésy to propose that every stimulus produces an area of sensation surrounded by an area of inhibition. This pattern of activity is basic to all sensory systems and constitutes a neural unit. The concept of a neural unit furnishes a unifying explanation for the phenomena of two-point stimulation and Mach bands. The properties of a geometric model of Mach bands on the skin and in the eye are examined in some detail. Von Békésy shows that if Mach bands are to occur the inhibitory area has to be larger than the sensory area, and that an adequate description of observed Mach bands is obtained if the size of the inhibitory area and the magnitude of inhibition are assumed to increase with the intensity of the stimulus. He also demonstrates that the proposed model is consistent with the occurrence of inhibition at one level or at successive levels of the nervous system, and that the dimensions of the neural unit determined for the skin and for the eye account for the differences between Mach bands on the skin and in the eye.

The funneling effects found in directional hearing as a function of the inequality of the magnitude or time of arrival of two sounds also has its counterparts in other sense organs. A difference of 1 millisecond is sufficient to localize a sensation of vibrations, taste, or smell as coming from the point from which stimulation arrives first. Moreover, the localization of vibration on the body may be shifted by introducing delays in activating two vibrators analogous to that which occurs in the dichotic localization of a sound, though the cutaneous receptors, unlike the auditory receptors, possess "local signs" that indicate spatial position. Even when two vibrators are placed in a vertical position on the same side of the body, it is possible to localize the sensation as coming from a point from which stimulation arrives first. Thus localization is not tied to interactions between the hemispheres. Only in experiments on warmth and pain has localization not appeared in time intervals as short as 1 millisecond. Von Békésy attributes this failure to his procedure, which produced a slow onset time for both these sensations. He shows auditory and cutaneous localization to be best when the onset of a stimulus is abrupt.

Speed of Transmission

Von Békésy's study of funneling expands into related topics. Since we do not perceive a large area over which traveling waves move when the body is stimulated by a vibrator, the funneling process in localization must be rapid and in the millisecond range. Change in localization as a result of delay of stimulation provides a means of measuring the speed of nerve conduction. Helmholtz used a reaction-time experiment to measure the speed of nerve transmission and found it to be between 50 and 60 meters per second. When localization is used to estimate the speed of conduction, the estimates are much greater. Von Békésy estimates the speed of transmission for vibrations on the skin to be 208 meters per second. He suggests that there are two speeds of neural conduction—a fast process for the inhibitory interactions that produce localization, and a slower process for the growth of a sensation. Whereas localization is determined within a few milliseconds after the onset of a stimulus, the time necessary for the growth of a sensation may take from 20 milliseconds in hearing to more than 1000 milliseconds in taste, smell, and vibration. Von Békésy found that the speed of neural transmission is greatly affected by temperature and pain. He reports that an electric shock applied 10 seconds before an observation will cause a significant drop in the speed of nerve transmission. The lower speeds reported from animal studies may therefore be due to the effects of anesthesia, temperature, and pain which disturb the nervous system.

Localization is a powerful method for probing neural activity. Cyclic changes in localization when the tongue is stimulated indicate a periodicity in taste sensations. Localization phenomena also divide the four basic taste sensations into two groups: sour-salt and sweet-bitter. Simultaneous stimulation of the sides of the tongue with bitter and sweet or sour and salt produces a single sensation in the middle of the tongue which can be moved from side to side by suitably timing the stimulations. A single sensation is not produced, however, for simultaneous stimulation with bitter and sour or salt and sweet. Thus there appears to be a closer relation between bitter and sweet and between salt and sour than between other pairs. An unusual type of neural funneling is shown when vibrators with frequencies of 20, 40, 80, 160, and 320 cycles per second are placed on the arm. Only the middle vibration of 80 cycles per second is felt. The presence of all the vibrators, however, increases the magnitude of the sensation through summation. This indicates that even a flat maximum may set into action inhibitory effects that produce a sharp localization.

Von Békésy's contrast of the use of psychological and electrophysiological methods to investigate sensory functions highlights the strengths and weaknesses of each approach. The limitations besetting each method make it important that sensory functions be studied by both electrophysiological and psychological experiments. Von Békésy suggests, for example, that localization of a stimulus is determined by the onset of nerve firing, the later firing serving to indicate the magnitude and quality of a sensation. The evidence here is psychological. A 2000-cycle-per-second tone can be determined quite well from only two cycles of vibration; similarly, localization of a vibratory pattern on the skin of the arm will occur when only two complete cycles are presented. This demonstrates the difficulty in using only electrophysiological methods to study sensory processes. Electrophysiologically, there is at present no means for separating the initial burst from succeeding spikes in neural transmission and for correlating initial bursts with the phenomenal property of localization and succeeding spikes with the properties of magnitude and quality. A central problem in the study of sensory processes is the relationship between neural responses and subjective attributes. Von Békésy's discussion emphasizes that any hypothesis about the neurophysiological correlates of sensory attributes must remain tentative in the absence of corroborating psychological experiments. Though not mentioned in the book, a most interesting divergence between electrophysiological and psychological studies concerns the question of coding taste. Electrophysiological measures indicate that there are no receptors that are specifically sensitive to taste qualities; rather, taste is determined by the pattern of neural activity. In contrast, von Békésy's psychological studies indicate that there are single receptors which are sensitive to specific tastes such as salt, sour, bitter, and sweet. It is possible that electrophysiological recordings from nerve fibers do not fully reflect the funneling action that occurs at higher levels of the nervous system, or that the taste system in man differs from that of animals. Whatever the final resolution of this issue, it reveals clearly that electrophysiological recordings must be shown to be consistent with psychological experiments before electrophysiological measures of neural responses can be interpreted unambiguously.

Experimental Methods

Von Békésy discusses the difficulties of using psychological observations in the analysis of sensory functions. The foremost requirement is that methods of stimulation produce a well-defined and constant effect. The book amply attests to the difficulty of this requirement and to von Békésy's skill in arranging experimental procedures that meet it. Von Békésy shows that psychology can be as precise in its methods as electrophysiology. Precise experimental control is not sufficient, however. The sensory effects produced by even a simple and precisely defined stimulus are often numerous, and the subject must be trained to report only on the particular sensation one is concerned with and to inhibit other sensations. A careful analytic description of the possible percepts may even be necessary. Perceptual experiments for the purposes of sensory analysis must be guided by an introspective attitude that reduces cognitive and motivational factors to a minimum.

Funneling and inhibition can also occur at a cortical level. A form of cortical inhibition is involved in the fact that we appear to observe discontinuously, taking in sensory information in temporal quanta. Through training one can also learn to inhibit stimulation. For example, a singer apparently can be trained not to hear the bone-conducted sounds coming from his throat and to hear his voice only through the air-conducted sounds. A complex case of funneling occurs in the projection of sensations outside the body. Von Békésy reports that when there is a time interval in stimulating the two knees with vibrators there is a jumping of sensation from one side to the other depending upon which knee is stimulated first. After several weeks of training, however, a subject can experience a continuous motion of the vibratory sensation from one knee to the other as a function of the time interval. Now when the knees are stimulated simultaneously, the vibrations are localized in the free space between them. Moreover, a displacement of the sensation in this free space will occur with suitable changes in the timing of stimulation. The projection of sensations into external space appears to be closely related to cortical funneling in ways that are not at all understood.

Von Békésy does not adopt a single viewpoint or comprehensive theoretical position toward funneling and inhibition processes. Rather, he shows the advantages of a many-sided investigation of these phenomena. The experiments presented succeed in demonstrating funneling and inhibition as processes common to different sensory organs and to different levels of the nervous system. The research reported thus discloses the commonality among diverse phenomena. The pulling together of different phenomena in a way that reveals similarities will provide stimulating insights not only to sensory physiologists and psychologists but also to those interested in more complex perceptual and decision processes. Von Békésy's research clearly fulfills the quotation from Goethe inscribed at the beginning of the book—*Willst du ins Unendliche schreiten geh nur im Endlichen nach allen Seiten.*

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Newton as an Elder Statesman

The Correspondence of Isaac Newton. Vol. 4, 1694–1709. J. F. SCOTT, Ed. Published for the Royal Society by Cambridge University Press, New York, 1967. 611 pp., illus. $38.50.

With the publication of this fourth volume the monumental Royal Society edition of the correspondence of Newton has now turned the corner toward completion of its seven volumes. It is very fortunate that J. F. Scott was available and willing to shoulder the heavy burden of continuing the work which had been carried so far by the late H. W. Turnbull.

The present effort covers the years 1694–1709, and since Newton's earliest letters were from 1661 the four volumes represent about three-quarters of his writing years (he died in 1709), leaving the next three volumes to contain the last quarter of years, the undated material, and the collected indexes and scholarly machinery. This fourth volume, though only slightly larger in pages than its predecessors, carries almost twice as many individual items. As a sign of the times, in the lapse of five years or so during the change of editors, the price of the volumes has jumped to half as much again; but then no standard library or specialist researcher on Newton and his period can afford to be without constant access to this fundamental work of the highest caliber.

The Newton that is found in the pages of this volume is already the elder statesman of science, reaping the just rewards of the *Principia* and beginning, seven years after its publication, to toy with the idea of extending it in a second edition. To continue his work with the fundamental lunar theory he had need of the observations of Flamsteed; and so developed one of the most famous and unpleasant altercations between scientists of great worth but incorrigibly prickly character. Further in the matter of rewards, Newton was appointed to his office at the Royal Mint, an office which was intended as a sinecure, but taken so conscientiously and seriously that one must credit quite a lot of the later economic strength and security of England to the efficient reforms and administration of Newton; perhaps one might suggest that the next Nobel prizewinner should be drafted to a similar "sinecure" in the office of Postmaster General. From the same period comes Newton's absolutely uneventful term as a Whig University Member of Parliament, and his being knighted, though exactly why he got these two honors still remains a rather dark mystery.

As usual with the Newton material—and we can expect nothing different from the remaining volumes—there is hardly a trace of the human being existing within this scientist shell. Even the tirade at Flamsteed, though violently angry, nevertheless maintains a certain impersonality. Just a touch of the triumphant mathematician may be seen in number 561, where he copies at length the challenge to solve the problems of the brachistochrone as just proposed by Bernouilli, then adds, "Thus far Bernouilli. The solutions of the problems are as follows. . . ." Perhaps most important is the interesting matter of number 695 and number 697, where Newton writes to Sloane to arrange for Francis Hauksbee, well-known inventor of electrical machines and of a fine new air pump, to bring his pump and demonstrate the phenomena of vacuum. What is interesting is that Newton suggests that Hauksbee come to his house where he can "get some philosophical persons to see his Expts who will otherwise be difficultly got together." It must be supposed from this that there is some possibility that a group of the Royal Society amateurs may have actually met at Newton's house; it gives an image far from that of the completely antisocial recluse.

Of more direct scientific interest in this volume, apart from the already mentioned and very extensive contributions to lunar theory, there is a fine dissertation on the quantifying of degrees of heat in the temperature scale, with astute experimental observations on melting points and other fixed marks in the range. To speak, however, of the matter of scientific content rather than the historical information of the letters must bring up another publication that has just started to come forth from the Cambridge University Press in their same superlatively competent style. The new series is that of *The Mathematical Papers of Isaac Newton*, of which the first of a projected set of eight volumes has just come out, edited by D. T. Whiteside [reviewed in *Science*, 13 Oct. 1967]. Now that we have both sets of Cambridge University Press volumes begun and a full variorum edition of the *Principia* long promised and on its way, we may take this passing of the halfway point of the *Correspondence* as a signal that Newton studies have now become very much an excitingly successful and full-time occupation for very competent people.

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Whither Queues?

Queuing Theory: Recent Developments and Applications. Proceedings of a NATO Science Committee conference, Lisbon, Sept.–Oct. 1965. R. CRUON, Ed. Elsevier, New York, 1967. 240 pp., illus. $13.50.

"Queuing theory" is a term of recent vintage (the 1940's) for mathematical studies of situations producing congestion and hence delays or waiting lines (queues). The typical mathematical model is that of a service system in which a stream of demands for service appears before a service center with one, or many, servers, and either the time epochs at which demands are made or the service time required, or both, have a probabilistic (stochastic) character. With the appearance of a flood of recent books, the study of this model in all its many guises, elaborations, and variations may be regarded as in a sense completed. What now happens to queuing theory, and to operations research (in which it has played an important role)? One of the most interesting aspects of the book under review is the light it casts on this question.

In his introductory lecture, Philip Morse (U.S.) suggests a promising line of growth by effectively invoking the Jacobi injunction: always invert. In present uses of the theory, the input and structure of the system are usually taken as given, in some convenient probability form, whether or not measurements or observations are available to establish their relevance. In the inverse uses, the characters of the input and structure would be inferred from the output. Of course, an extensive mathematical development, probably more difficult to carry out than the existing theory, is necessary.

In the third session of the conference, J. F. C. Kingman (U.K.) in an invited paper examines the heavy-traffic condition (that is, a condition close to the limit of stability of the system) with a view to finding an approximation of the performance of the system (the distribution of delays) which holds under more relaxed assumptions than the usual independence ones. For a single server and order-of-arrival service, he finds a remarkably simple approximation. For many servers and for other orders of service, there is an open field for hardy investigators. Finally, in the closing session, T. L. Saaty (U.S.) offers many nonmathematical remarks under the title "Ordering disorderly queues." The matters he mentions range from improving the condition of waiting rooms (more comfort) to improving the behavior of waiting people (more courtesy). In supermarkets, the multiple checkout lines seem to him less efficient and less equitable than a single line with first-come, first-served service to the idle checkers. Curiously, he does not consider the question of whether there may not be a critical queue size beyond which order is impossible, that is, beyond which the waiting line becomes a mob. It has been known for some time that telephone operators handling long-distance calls by ticket inevitably pass from order-of-arrival service to random service as the number waiting increases, and such transition in any service control may be expected to alter waiting behavior.

Aside from these glimpses into the future, the technical reader will be pleased to find a résumé, though a somewhat disjointed one, by R. Syski (U.S.) of the work of a pioneer in the theory, Felix Pollaczek, who at last receives the appreciation he deserves. The individual papers, which cannot be given detailed notice here, illustrate the variety of interesting uses of the theory.

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Antimicrobial Agents

Biosynthesis of Antibiotics. Vol. 1. J. F. SNELL, Ed. Academic Press, New York, 1966. 246 pp., illus. $10.

It is historically fitting in a volume devoted to the review of our knowledge of the biosynthesis of antibiotics that the first group of antibiotics to be discussed in depth is the penicillins and cephalosporins. In an excellent contribution, A. L. Demain reminds us that penicillin "still remains the most active and one of the least toxic" antibiotics. Advances in the biochemistry of fermentation and production methods are especially impressive when one reads that in the early stages of the development of penicillin it took over a year to accumulate enough for clinical trials. Today's cultures produce 5 milligrams per milliliter. Evidence for the biosynthetic origins of the β-lactam-thiazolidine ring nucleus common to all penicillins is reviewed. It is particularly useful to have the associated pathways of sulfur and carbon synthesis in cysteine and other pathways related to penicillin biosynthesis presented in parallel. A review of the "new penicillins," penicillinases, and the biosynthesis of cephalosporin C and its derivatives and mention of the use of particulate fractions bypassing permeability difficulties all make this chapter well worthwhile.

A concise and lucid chapter on the status of the biosynthesis of the tetracycline antibiotics is presented by R. H. Turley and J. F. Snell. The use of mutants in working out the probable steps of formation of 7-chlortetracycline from 6-methylpretetramide is of interest; it is evident that other mutant-selection techniques will be needed before the steps from acetate or malonate to naphthacenic intermediates can be worked out.

It is surprising that although the chemistry and the major sources of carbon atoms in the streptomycin molecule have been known for years, there is still no knowledge of the manner in which the individual units are linked together by *Streptomyces*. However, a clearer idea of the immediate precursors of the streptidine moiety and streptose has emerged from recent studies. J. D. Bu'lock reviews the biochemistry of the polyacetylenes, an interesting group of fungal compounds which have not reached the chemotherapeutic eminence of other antibiotics. The macrolides represent the final group of fascinating antibiotics covered in this book, and although they are relative "newcomers," considerable progress in the understanding of their chemistry and biogenesis is evident from the data given in the chapter by J. W. Corcoran and M. Chick.

The chapter on the "Preparation of radioactive antibiotics" is a useful source of material, although it would have been better placed at the end of the volume so that the reader would have first been informed about the biosynthetic pathways. The volume is well supplied with references and will provide many with a very useful condensation of current knowledge in this field.

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Organic Compounds

Carbohydrate Chemistry. EUGENE A. DAVIDSON. Holt, Rinehart, and Winston, New York, 1967. 447 pp., illus. $11.95.

The author indicates that a major stimulus for this work has been the need for a book on carbohydrate chemistry in which the principles of modern physical organic chemistry are applied to the properties and chemical reactions of the carbohydrates.

The principles of optical activity and of the spectroscopic methods of nuclear magnetic resonance, infrared, and optical rotatory dispersion, with some applications to carbohydrates, are well presented. The discussions of NMR and infrared are not illustrated with reproductions of spectra and their interpretation; the *tau* values and the infrared absorption bands for some important substituents are listed in tables, however. Aspects of the biochemistry of carbohydrates, including photosynthesis, glycolysis, the trichloracetic acid cycle, and several enzymic reactions of particular importance are discussed and well integrated, and polysaccharides are discussed effectively. Other attractive features of the book include abridged rules for carbohydrate nomenclature, useful general and specific references, and numerous summaries of important topics.

Along with these many strong points, there are a number of aspects which seriously detract from the book's usefulness. The theoretical discussions of optical rotatory power and NMR are inadequate for the advanced reader and too involved for the beginning student. The structure of D-glucose is developed fully. Although the structures of the monosaccharides may be gleaned through the illustrative examples, the author nowhere compares the structures of the pentoses, hexoses, or hexuloses. Many of the figures appear to have been drawn carelessly—Fig. 6.31 presents a conformationally inaccurate representation of 1,6-anhydro formation, for example—and few of the figures and tables are conveniently placed with respect to the applicable portions of the text. Although the author is aware of good carbohydrate nomenclature, a great many of the names used are inaccurate. Finally, the index is inadequate.

This book is basically a good book in carbohydrate chemistry, but its usefulness is somewhat decreased by the many errors, most of which are not of concept but of execution.

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Mammalian Behavior

Play, Exploration and Territory in Mammals. Proceedings of a symposium, London, Nov. 1965. P. A. JEWELL and CAROLINE LOIZOS, Eds. Published for the Zoological Society of London by Academic Press, New York, 1966. 294 pp., illus. $11.50.

Recent reports of many field studies of nonhuman primates have led to renewed efforts to examine systematically the naturalistic behavior of a wide range of other mammals. The proceedings of this symposium importantly advance these efforts. The contributors describe play in mammals; play, exploration, and territory in wild lions; aggressive play in polecats; exploration and fear in rats; exploration and play in children; home range in mammals; movements in small mammals; territory in carnivores; scent marking in Canidae; grouping and range in feral Soay sheep; dispersal of red deer; home range and agonistic behavior in the gray squirrel; group structure and movement of gelada baboons; and spatial organization of nutria. Most of the observations reported were made in the natural habitats of the animals, but some observations of behavior in captivity are included.

The symposium describes many other kinds of related behavior in addition to those suggested by the title; extensive observations of nutrition and feedings, aggressive and reproductive behavior, marking and signaling, population organization, and selective adaptations are reported. There are significant contributions to the subjects of population organization and control and the composition and structure of families, colonies, and groups of animals. Aggressive and defensive behavior and their associated functions are described for many of the species.

Each paper adds new observations to the general literature on free-ranging mammalian behavior. New problems are defined, and a few new methods and techniques are briefly described. For example, lemmings do not plunge blindly into lakes, but they, and nutria too, cross lakes when silhouettes of the opposite shore can be seen. Telemetry, radio transmission, and radioisotopic tracers are described as standard techniques for both tracing and recording the movements of small mammals.

The collected papers for the symposium do not develop a coherent theme. The contributions are somewhat irregular in scope and quality of treatment of the wide variety of subjects. Although new and extended information and new variations of patterns of movements of animals *in-space-over-time* are described, old definitions of "home range" are repeated too often. The relative exclusivity of mammalian home ranges and the existence of more than one focus of activity in definable ranges should be generally accepted. In contrast, the attention given to community and group ranges, life ranges, the effects of varied ecological contexts, and the evolutionary significance of behavior represents an important contribution of the book. Learning and conditioning mechanisms as possible explanatory concepts for territoriality are seriously neglected. The issue of defensive behavior as a criterion of territoriality continues in this symposium to receive too much attention relative to its importance in animal economy.

Play, exploration, and territoriality are kinds of behavior that are basic and general, but neglected, subjects of study. This well-designed book, with good abstracts and summaries for each chapter, emphasizes the importance of these activities, advances analysis and understanding of them, and once again calls attention to their biological significance.

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Organisms in Environments

Pollution and Marine Ecology. Proceedings of a conference, Galveston, Texas, March 1966. THEODORE A. OLSON and FREDRICK J. BURGESS, Eds. Interscience (Wiley), New York, 1967. 382 pp., illus. $12.

Other than the suggestion, by the author of the welcoming remarks, that support of pollution studies may be one of the largest categories of federal expenditure in the future, the problem presented by the increase in our capacity to influence our environment adversely was not examined in this conference. The implication of the proceedings, with several papers that are essentially basic ecology, is that studies of whole plants and animals in their settings are indeed returning to favor and that studies of unpolluted or natural conditions are desirable. Thus we find in this book the only recent essays on intertidal ecology on the Oregon coast and on subtidal ecology at Anacapa Island, and a 50-page summary by H. T. Odum of biological circuits and marine systems in Texas, together with the usual sorts of papers about indicators, trace substances, "parameters of pollution," and so on. The book is not a complete treatment for ecologists or pollution engineers, but it will be essential for both.

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Reports

Freshwater Peat on the Continental Shelf

Abstract. *Freshwater peats from the continental shelf off northeastern United States contain the same general pollen sequence as peats from ponds that are above sea level and that are of comparable radiocarbon ages. These peats indicate that during glacial times of low sea level terrestrial vegetation covered the region that is now the continental shelf in an unbroken extension from the adjacent land areas to the north and west.*

Evidence of sea levels lower than the present level has long been provided by submerged intertidal or shallow-water topography, sediments, fauna, and flora. So many examples of these features are known throughout the world in the narrow depth range of the continental shelves that they must denote eustatic changes of sea level recent enough to have been associated with Pleistocene glaciation.

One of the most interesting sediments on the continental shelf and one that is related to the low sea levels is deeply submerged peat, especially that of freshwater bogs. These deep deposits are much older than the well-known peat and tree stumps that are common just beyond the shoreline. The longest-known examples are off Europe. One is Dogger Bank in the English Channel (*1*), where a sample from 39 m has been dated, by the radiocarbon method, as 9300 years old (*2*); another is in the Baltic Sea (*3*), where a deposit at 35 to 37 m dates from 7375 years (*4*). Cores of the sea floor in the Gulf of Mexico off Texas include a transgressive salt-marsh and freshwater peat whose seaward limit at about 25 m has been dated by radiocarbon at 10,200 years (*5*). Dates for many freshwater peats encountered in borings of the Mississippi Delta have been reported (*6*). Bridge borings off western Australia penetrated freshwater peat, at 21 m, having an age of 9850 years (*7*). Other bridge borings off British Guiana reached freshwater peat, which had an age of 8590 years, at 20 m (*8*). Freshwater peat cored in Malacca Strait, off Malaya, at a depth of 27 m has been dated at 10,000 years (*9*); similar peats containing the bivalve *Cyclina* have been dredged from 50 to 80 m in Naruto Strait, an entrance to the Inland Sea of Japan, and others containing large palm trees have been observed in Toyama Bay, Japan (*10*). Submerged soils rich in organic debris, and about 12,000 years old, have also been cored off Nigeria (*11*) and elsewhere. Hence, freshwater, as well as salt-marsh, peats are widely distributed on the continental shelves of the world.

In 1964 a large mass of peat was recovered by Captain Norman Lepire

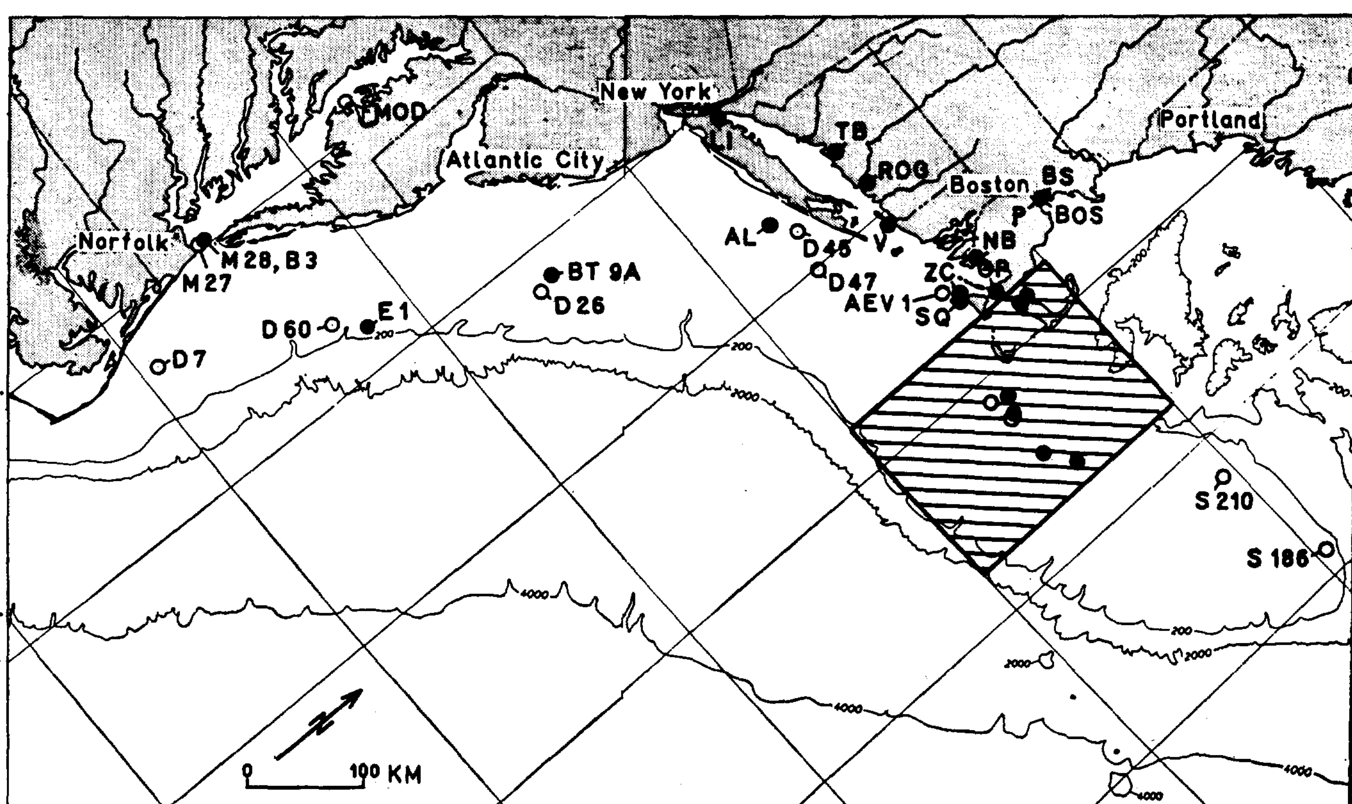


Fig. 1. Positions of peat samples (closed circles) and of near-intertidal oyster shells (open circles) on the continental shelf and in coastal areas from New England south to Cape Hatteras. Sources of data are listed in Table 1; contours are in meters. Cross-hatching denotes the area of the more detailed Fig. 2.

Table 1. Base data for peat and shells. MLW, mean low water; n.d., no data.

	Location	Material	North Lat.	West Long.	Depth (m) Below sea level (MLW)	Depth (m) Below sediment surface	Source	Weight (g)	Sampler	Age (yr)	Lab. No.	Ref.
					Peat							
G 2198	*Gosnold* 2198	Wood	40°59′	69°01′	−82	0	W.H.O.I.–U.S.G.S.	10	Rock dredge	1,320 ± 250	W-2001	
E 1	*Explorer* 1	Matrix	37°38′	74°30′	−64 to −68	0	Tim Furtado	300	Scallop dredge	13,500 ± 350	W-2014	
RL 1	*Ruth Lea* 1	Wood	41°09′	68°43′					Scallop dredge	n.d.		
		Matrix	41°09′	68°43′	−59	0	Capt. Norman Lepire	100,000		11,000 ± 350	W-1491	(*12*)
BT 9A	Bell Telephone 9A	Debris	39°00′	73°42′	−43	0.4	Robert Allen	10	Corer	n.d.		
RL 2	*Ruth Lea* 2	Wood	41°06′	69°42′					Scallop dredge	10,630 ± 300	W-1736	
		Matrix	41°06′	69°42′	−40	0	Capt. Norman Lepire	500		11,090 ± 300	W-1737	
LI	Long Island	Matrix	40°48′	73°50′	−34	?	Columbia University	?	Boring	11,950 ± 200	L-606A	(*27*)
V	A. E. Verrill 1874	Matrix	41°18′	71°52′	−33	0	Yale University	5	Biology dredge	n.d.		
AL	*Albatross IV* 63-7 (157)	Matrix	40°43′	72°40′	−28	0	Bur. Comm. Fisheries	10	Otter trawl	n.d.		
M 28	Chesapeake Bay	Matrix	36°59′	76°06′	−27	10.7	Bridge tests	?	Boring	15,280 ± 200	ML-91	(*28*)
B 3	Chesapeake Bay	Matrix	36°59′	76°06′	−26	6.1	Bridge tests	?	Boring	11,590 ± 150	ML-89	(*28*)
RL 3	*Ruth Lea* 3	Matrix	41°02′	69°30′	−20 to −27	0	Capt. Norman Lepire	1000	Scallop dredge	8,620 ± 300	W-1735	
OP 2	Oyster Pond 2	Debris	41°33′	70°38′	−18	13	E. S. Deevey	?	Boring	11,750 ± 300	Y-1459	(*29*)
ROG	Rogers Lake, Conn.	Debris	41°21′	72°18′	−10	15	J. P. Schafer	?	Boring	14,240 ± 240	Y-950/1	(*30*)
NB	New Bedford, Mass.	Matrix	41°38′	70°55′	−8	0	E. S. Barghoorn	?	Boring	4,150 ± 130	O-1127	(*15*)
BS	Boylston Street fish weir	Matrix	42°21′	71°05′	−8	4	E. S. Barghoorn	?	Excavation	4,450 ± 130	O-475	(*31*)
BARN	Barnstable core 23	Matrix	41°43′	70°22′	−8	8.3	P. Butler	?	Boring	5,480 ± 120	W-676	(*32*)
OP 1	Oyster Pond 1	Debris	41°33′	70°38′	−5	2.3	E. S. Deevey	?	Boring	3,420 ± 120	Y-1663	(*29*)
P	Boston (Prudential Bldg.)	Matrix	42°20′	71°06′	−5	2	C. A. Kaye	?	Excavation	3,850 ± 130	O-1124	(*33*)
CEN	Centerville, Mass.	Matrix	41°38′	70°21′	−4	4	A. C. Redfield	?	Boring	5,500 ± 300	W-586	(*15*)
BOS	Boston Commons garage	Wood	42°21′	71°04′	−2	8	C. A. Kaye	?	Excavation	12,170 ± 300	W-991	(*33*)
ZC	Zacks Cliff	Debris	41°20′	70°50′	+4	8	C. A. Kaye	?	Sea cliff	15,300 ± 800	W-1187	(*18*)
TB	Totoket Bog, Conn.	Debris	41°20′	72°49′	+6	8	E. S. Deevey	?	Boring	15,090 ± 160	Y-446A	(*34*)
SQ	Squibnocket Cliff	Matrix	41°18′	70°47′	+9	3	C. A. Kaye	10,000+	Sea cliff	12,700 ± 300	W-710	(*18*)
					Crassostrea virginica (Gmelin)							
D 60	*Delaware* 60-7		37°24′	74°39′	−64	0	Bur. Comm. Fisheries		Scallop dredge	9,600 ± 600	L-948	
D 26	*Delaware* 26		38°49′	73°39′	−55	0	Bur. Comm. Fisheries		Scallop dredge	9,780 ± 400	W-1403	(*22*)
S 186	S 186		42°05′	67°15′	−53	0	Canadian Fisheries Board		Scallop dredge	10,600 ± 130	S-186	(*23*)
D 47	*Delaware* 47		40°40′	71°59′	−51	0	Bur. Comm. Fisheries		Scallop dredge	10,850 ± 500	W-1401	(*22*)
AEV 1	*A. E. Verrill* 1		41°18′	71°00′	−34	0	Marine Biological Lab.		Biological dredge	9,300 ± 250	W-2013	
IN 1	*Invader* 1		40°59′	69°44′	−45	0	Capt. Norman Lepire		Otter trawl	7,310 ± 300	W-1981	
D 45	*Delaware* 45		40°43′	72°25′	−37	0	Bur. Comm. Fisheries		Scallop dredge	9,920 ± 400	W-1400	(*22*)
S210	S210		41°55′	67°35′	−46	0	Canadian Fisheries Board		Scallop dredge	10,300 ± 150	S-210	
D 7	*Delaware* 7-1		36°09′	75°20′	−33	0	Bur. Comm. Fisheries		Scallop dredge	8,130 ± 400	W-1402	(*22*)
M 27	Chesapeake Bay		36°59′	76°06′	−21	?	Bridge tests		Boring	8,135 ± 160	ML-196	(*28*)
MOD	Chesapeake Bay		38°33′	76°13′	−2	0	Harvard University		Hand	Modern	W-1399	(*22*)
					Crepidula fornicata (L)							
TT 3	Texas Tower 3		41°01′	69°30′	−47	29	J. M. Zeigler		Boring	11,465 ± 400	I-852	(*13*)(*35*)

aboard his scalloper *Ruth Lea* from 59 m on Georges Bank. The material contained both a salt-marsh component (*Spartina*) and a freshwater one (twigs and pollen of spruce, fir, and pine; and frustules of freshwater diatoms) (*12*). Subsequently, additional samples of freshwater peat were obtained in trawlings by Captain Lepire, and others were found in samples of bottom sediments collected for biological and geological studies by ships of the U.S. Bureau of Commercial Fisheries and of the Woods Hole Oceanographic Institution–U.S. Geological Survey program. One peat was supplied by T. J. M. Schopf (Marine Biological Laboratory at Woods Hole, Mass.) from a dredging made by A. E. Verrill in 1874. Other samples were found within cores from the sea floor taken for engineering studies and for investigations of pollen succession. These peats from the sea floor are supplemented and compared with others obtained in borings made on land or in freshwater ponds during studies of postglacial history (Table 1). The many samples materially extend the information that was previously available on the distribution, nature, and age of freshwater peat.

The distribution pattern of the peats (Table 1; Figs. 1 and 2) shows a high degree of correlation with areas that were glaciated. This is reasonable in view of the ability of glaciers to form depressions by both erosion and deposition. Especially striking is the presence of four samples bordering Great South Channel (Fig. 2). The fabric and composition of till on nearby Cape Cod indicate that a tongue of the Wisconsin glacier moved through this channel (*13*). Some of the samples, however, are from unglaciated regions, and presumably they are representative of deposits on poorly drained topography bordering estuaries and lagoons.

Many of the samples of peat from the sea floor are small, but those collected aboard the *Ruth Lea* had estimated weights (on an air-dry basis) as great as 100 kg (Table 1). The samples were irregular in shape, but they broke easily into flat slabs because of their bedded structure. Usually one surface, considered the top one, is more or less riddled with the holes of boring organisms, chiefly the pelecypod *Zirfaea crispata* L. [Fig. 3 and (*12*, Fig. 2)]. The presence of borings on only one side of a slab, the fragile nature of the peat, the large size of some pieces (to 60 cm), and the fact that at least sample RL 1 is from a peat-covered area reported to be at least 1 km^2 in extent, indicate that many of the samples are from outcrops of the sea floor. Other samples are small (10 g or less), perhaps because of washing during the dredging operation. Although some small samples may not represent *in situ* deposits, they are generally from so near the sites of larger samples that only a short distance of transport is suggested. Sample BT 9A consists of only 2 cm of thinly interbedded organic debris and detrital sand; thus some transportation occurred prior to deposition at the coring site.

Most of the samples consist only of fine-grained fibrous organic material packed into thinly bedded masses containing few or no visible inorganic grains. For convenience here, this type of peat is given the general term matrix, whereas the obviously reworked organic fragments occurring in dominantly inorganic sediment are called debris. Samples RL 1 and RL 2 (Fig. 3B) contain pieces of wood as long as 30 cm, which are partly to completely surrounded by matrix; sample G 2198 is a piece of wood that at the time of recovery was thought to have come from a deeply submerged peat deposit.

Twenty-three freshwater peat samples are listed in Table 1. Analyses of pollen content, all in the form of pollen diagrams, are reported in the literature for eleven of these samples. Table 2 lists our readings of the more diagnostic pollens from these diagrams. In addition, we made new counts for seven samples and listed them in Table

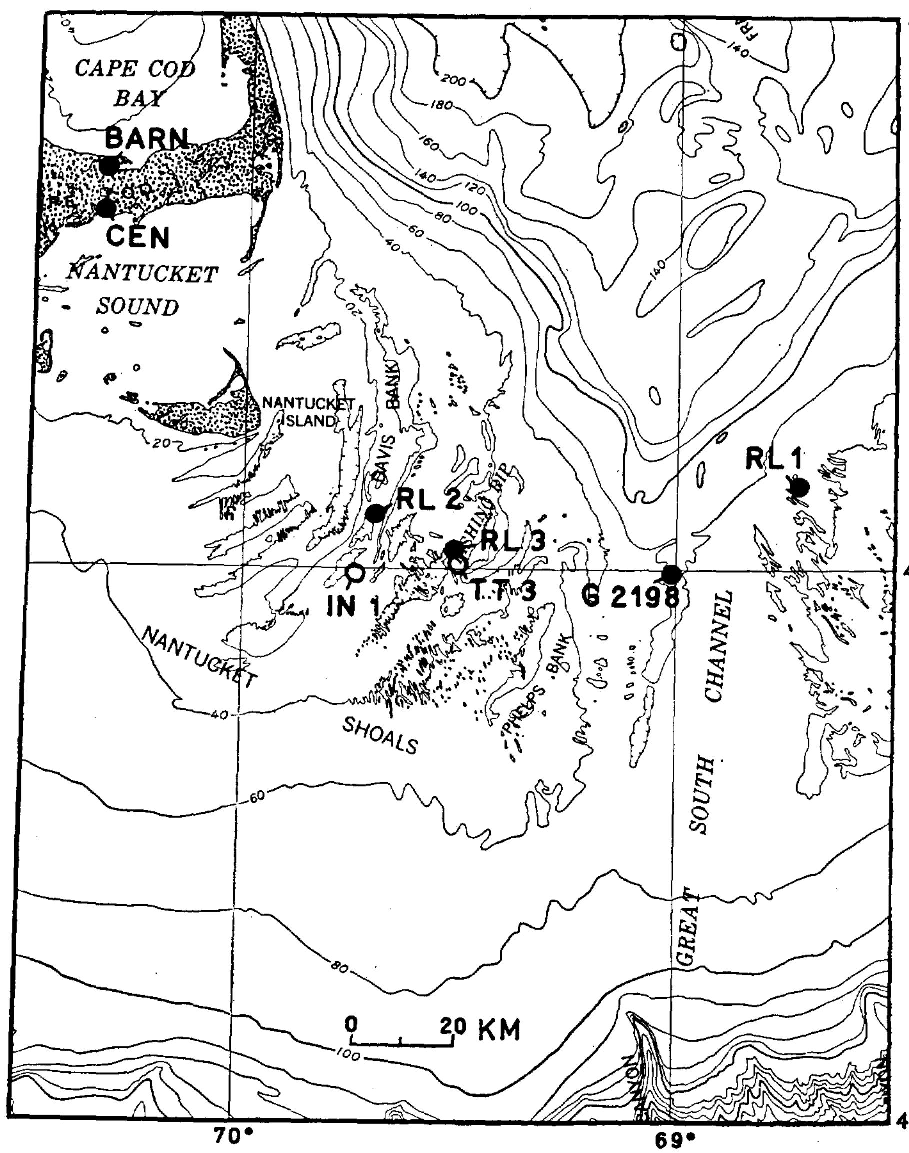
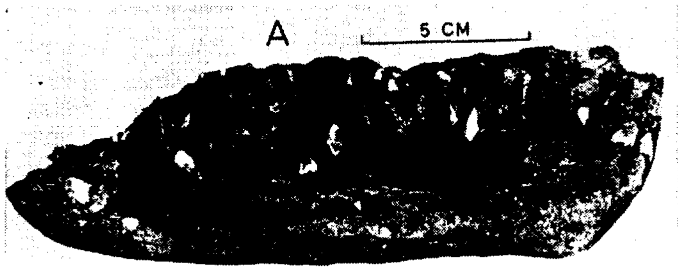


Fig. 2. Positions of peat samples (closed circles) and of oyster shells and Texas Tower No. 3 (open circles) superimposed upon the topography of the sea floor off Cape Cod (see crosshatched area of Fig. 1). Contour interval is 20 m to a depth of 200 m; contour interval at greater depths is 200 m [from Uchupi (*41*)].



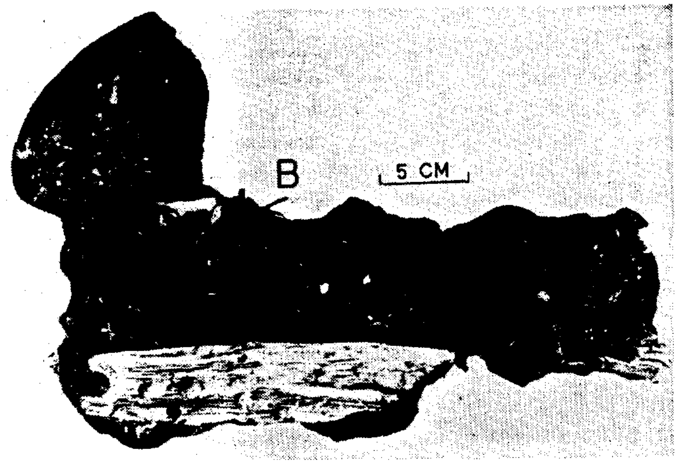


Fig. 3. Photographs of peat fragments from two large samples. (A) Fibrous peat from sample RL 3 that shows holes bored by pelecypods into the top surface, indicating that the peat was broken from a larger mass that had remained in an undisturbed position on the sea floor for a long period of time. (B) Peat from sample RL 2 showing abundant pieces of wood enclosed in a fibrous matrix.

2 along with notations of the kind of wood that was present. The pollen counts provided the basis for assignment of the samples to pollen zones A, B, and C, respectively. Several samples also contained pollen of *Nymphaea* (water lily), Cyperaceae (sedges), *Sagittaria* (arrowhead), or abundant fern spores, or all of these, which provides additional evidence of their freshwater origin.

Efforts to construct standard pollen sequences of general stratigraphic and chronologic application to late glacial and postglacial climatic and vegetational history of New England have resulted in the generalized scheme given in Fig. 4. The major palynological divisions, designated zone A (spruce dominance), zone B (pine dominance), and zone C (oak–mixed hardwood dominance), have repeatedly been verified from intensive study of both coastal and inland postglacial sediments from the northeastern United States. Although analyses of specific palynological sequences may differ in detail, climatic control of the basic vegetational succession can be demonstrated in the samples studied in this investigation (Table 2). It should be noted, however, that latitude influences the chronology of this sequence of forest transition. For example, the transition from zone A of spruce dominance to zone B of pine dominance clearly took place at an earlier date in the southern parts of the New England coastal plain than in the more northern and upland sites. The generalizations regarding the latitudinal variations of the major forest transitions are verified by the two pollen spectar B 3 and M 28 from near the mouth of Chesapeake Bay, and of E 1 (Table 2) that is far out on the shelf at about the same latitude. The age of the first two samples, in terms of New England forest history, would indicate occurrence in zone A; instead, they are in zone B, in which pine rather than spruce is dominant. The third sample has pollen ratios that differ from those of New England for the same date, but they still indicate zone A. Apart from these three samples, the pollen zones and the radiocarbon dates of peat samples from the more northeasterly areas agree closely (Fig. 5). Accordingly, two samples (*V* and *AL*) that were too small for radiocarbon dating can be approximately dated by their pollen content.

Support for the freshwater origin of several samples of matrix and wood is provided by measurements of stable carbon isotopes. As shown in Table 3, the δC^{13} measurements are between −23.5 and −27.8 per mil, in contrast to measurements of between −11.6 and −15.5 per mil for six samples of salt-marsh peat from Barnstable salt marsh at approximately the same position as *BARN* (Table 1 and Fig. 2). Each of the sets of measurements is well within the range that characterizes freshwater organic matter and marine organic materials, respectively (*14*). We were surprised that the value for salt-marsh peat was so clearly typical of marine plants, in view of the fact that the peat surface is exposed to the air a large part of the time. This point was further investigated by determining the δC^{13} for a composite sample of the

Table 2. Identified pollen and wood in peat samples. P, present; D, dominant; n.s., not significant.

Sample No.	Pollen percentages						Wood	Pollen zone	References
	Fir	Spruce	Pine	Oak	Water lily and/or sedge	Others			
OP 1	0	0	22	40	n.s.	38		C	(*36*), Fig. 7, 2.0–2.7 m
BS	0	<5	18–50	2–28	20–58	?		C	(*37*), Fig. 8, Lower Peat
BARN	0	0	30	47	0	23		C	(*32*), Fig. 1, 327 inches
RL 3	0	0	17	20	5	58		C	
B 3	2	15	60	7	6	10		B	(*28*)
M 28	1	26	60	2	6	10		B	(*28*)
AL	0	12	73	2	2	9		A-B	
V	0	36	13	3	10	38		A	
RL 1	P	83	9	0	0	8	Juniper Spruce	A	
BT 9A			P			D‡			See also (*38*), Fig. 1, 43–49 cm
RL 2	3	21	16	4	0	56§	Juniper	A	
OP 2	7	15	15	11	n.s.	52‖		A	(*36*), Fig. 7, 13.1–13.5 m
E 1	2	12	8	4	11	63¶		A	
BOS							Birch	A?	(*33*)
SQ	2	<5	4	1	50	>38¶		A	(*39*), Plate 1
TB								A	(*40*)
ROG	0	5	22	2	35	36		A	(*30*), Fig. 3A, 14.5 m
G 2198							Conifer		

* Not stated in publication. † Pure sphagnum peat, a freshwater indicator. ‡ Mostly worn and redeposited fern spores. § Abundant Ericacea. ‖ Mostly birch. ¶ Includes fern spores, sphagnum spores, *Lycopodium*, and arrowhead.

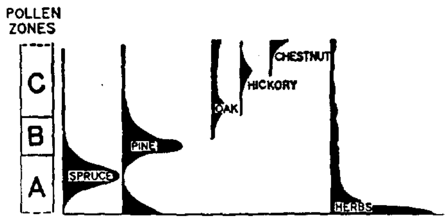


Fig. 4. A generalized standard pollen zonation for northeastern coastal United States for postglacial time [after Leopold (*40*)].

Table 3. The δC^{13} for peat samples. Analyses were made in duplicate by J. M. Hunt, Woods Hole Oceanographic Institution, relative to Chicago standard Cretaceous belemnite (PDB).

Sample No.	Depth (m)	Type of material	δC^{13} (‰)
G 2198	−82	Wood	−26.9
E 1	−64 to −66	Matrix	−27.6
RL 1	−59	Wood	−23.5
		Matrix	−26.2
BT 9A	−43	Debris	−25.8
RL 2	−40	Wood	−27.1
		Matrix	−26.8
V	−33	Matrix	−26.0
AL	−28	Matrix	−26.1
RL 3	−20 to −27	Matrix	−26.0
Barnstable salt marsh			
Six samples	−1.5 to +1.5	Matrix	−11.6 to −15.5
Spartina patens			
		Blades	−11.7
		Rhizomes	−12.7

blades of ten specimens of *Spartina patens* from Barnstable salt marsh and for another composite sample of their rhizomes (rootlike parts). *Spartina patens* is a high-marsh plant, submerged only at high tide. The values of δC^{13} for blades and rhizomes are similar and within the range obtained for the salt-marsh peat. Thus δC^{13} appears to be a useful tool for distinguishing between salt-marsh and freshwater peats.

During the past decade about 400 radiocarbon dates of calcareous and carbonaceous materials from known depths below sea level have permitted the construction of generalized curves of sea level versus time. Radiocarbon dates, based mostly upon borehole samples from salt marshes, show that sea level rose slowly to its present position from about −3 m approximately 4000 years ago (*15, 16*). Prior to that date the rise was much faster. Dates of shells, coral, and other materials extend this faster rate back to about 15,000 years ago (*17*). Earlier dates from the sea floor are rare, but they are supplemented by dates of the glacial maximum on land (*18, 19*), dates and isotopic temperatures of deep-sea sediments (*20*), and estimates of ice volumes (*21*). These sources suggest that sea level was as low as −123 m about 19,000 years ago; before this, the levels were higher.

Data on low sea levels of postglacial time are provided on the Atlantic continental shelf of the United States and Canada by radiocarbon dates on shells of the commercial oyster, *Crassostrea virginica* (Gmelin) that generally lives in a restricted zone between high tide and a depth of several meters in estuaries and lagoons. The depth-date measurements for the oysters (*22, 23*) and for a salt-marsh component of the peat in sample RL 1 are somewhat erratic, perhaps because the oysters were not completely restricted to shallow water or because currents moved some shells seaward. A rather wide variation was also present in the data used by Shepard (*17*), whose best-fit curve is shallower than our oyster-shell and peat data. We believe that our data indicate a postglacial subsidence of the continental shelf off northeastern United States relative to most other shelves of the world. In Fig. 6 the points plotted for the freshwater peats are shallower than the sea level of the same general age, as one would expect.

In order to avoid the complexities of Fig. 6, a simplified version (Fig. 7) is useful; this version is based upon the past sea levels shown in Fig. 6 for the shelf off northeastern United States. The zone a few meters below or above this line (illustrated by vertical marks on the sea-level line of Fig. 7) serves to limit the age and present depth of salt-marsh peats and of most remains of oyster shells. This zone defines the shore or lagoonal environment. The region below this zone and the one extending beyond the lower depth limit of the figure represents the ocean environment. The region above the zone and that extending beyond the upper limit of the figure is the subaerial or the freshwater pond environment. The area to the right on the diagram shows glacial ice occupying part of the shelf off New England; in other regions the pond environment extends to the right through this area of the graph until limited by high sea levels 25,000 to 30,000 years ago (*24*). In other words, Fig. 7 is a boundary diagram which shows that the dates and depths for future recoveries of marine shells should lie within the area marked *OCEAN* and

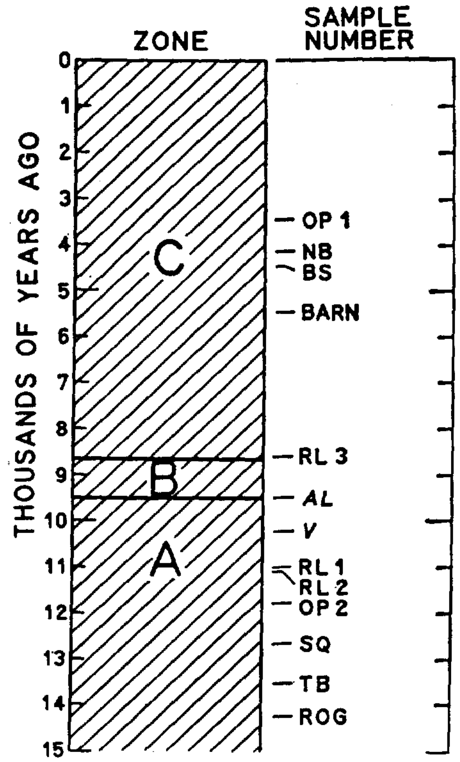


Fig. 5. Positions of the sea-floor and coastal peats of Table 1 with respect to the pollen zones of Fig. 4. Age limits for the pollen zones are those of Davis (*42*). Most peat samples are plotted according to both radiocarbon ages and pollen percentages, but *V* and *AL* are plotted only by their pollen percentages because both samples were too small for accurate radiocarbon measurements.

that the dates and depths for future recoveries of freshwater peats should lie within the area marked *PONDS*.

The presence of freshwater peats on the continental shelf reinforces the belief that during glacial stages of low sea levels the shelves became seaward extensions of the previous (and present) land areas. Coastal plains were enormously widened. The belt of new land soon became covered by vegetation similar to that of the adjacent old land, so that the former shore zones were almost obliterated. Land animals, including elephants, moose, musk ox (*25*), and probably man (*26*), soon followed. Their new habitation was temporary, however, for when the sea advanced several thousand years later, it flooded the land vegetation, leaving only some peat deposits as evidence of former forests and grasslands. Similarly, the advancing sea either drove ahead of it the animal inhabitants or submerged their remains, as, even now, it continues to displace them with its present advance of a few millimeters per year.

Detailed quantitation and integration of chronological and palynological data have not been available for assigning precise values to the latitudinal retreat of the boreal forest during the period of climatic amelioration that began about 11,000 years ago. Evidence needed for such a quantitative approach may be present in the freshwater autochthonous peats that are submerged off the southeastern coast of New England as the result of the postglacial worldwide rise in sea level. The exposed broad coastal plain of low relief provided abundant shallow sedimentary basins in which the gradual transition of forest types may have been recorded. Many of the offshore swamps and bogs should have been relatively free of the local edaphic and physiographic variables that complicate many upland sites of organic deposition, such as the pollen rain from the windward montane forests of the Appalachian Highlands. Accordingly, further work on the offshore peat deposits may be highly rewarding for studies of paleoclimatology.

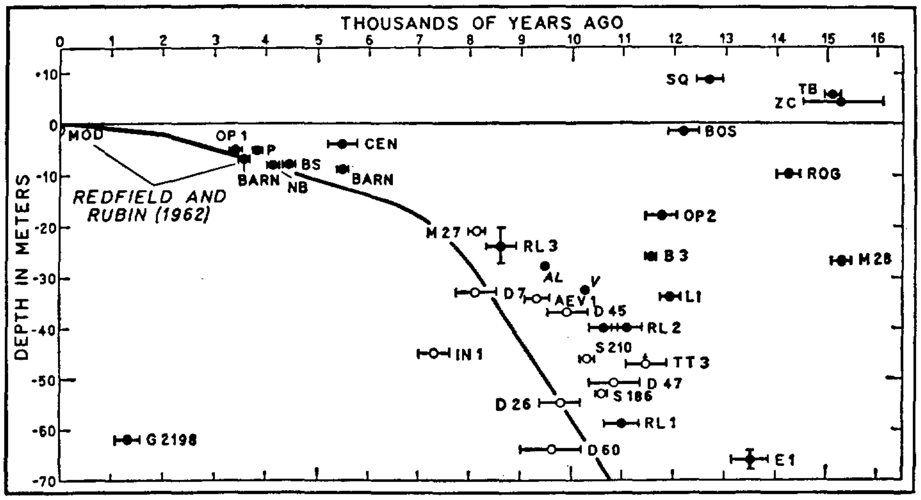


Fig. 6. Depths of radiocarbon-dated samples of peat (closed circles) and shells (open circles) whose positions are given by Table 1 and in Figs. 1 and 2. Dates for *V* and *AL* are based only upon their pollen contents. The curved line shows the position of sea level 4000 to 11,000 years ago according to the ages and present depths of oyster shells and of the salt-marsh peat within sample RL 1. At the left, the wide straight lines indicate the position of sea level during the past 3800 years according to radiocarbon dates of Barnstable salt marsh (*15*).

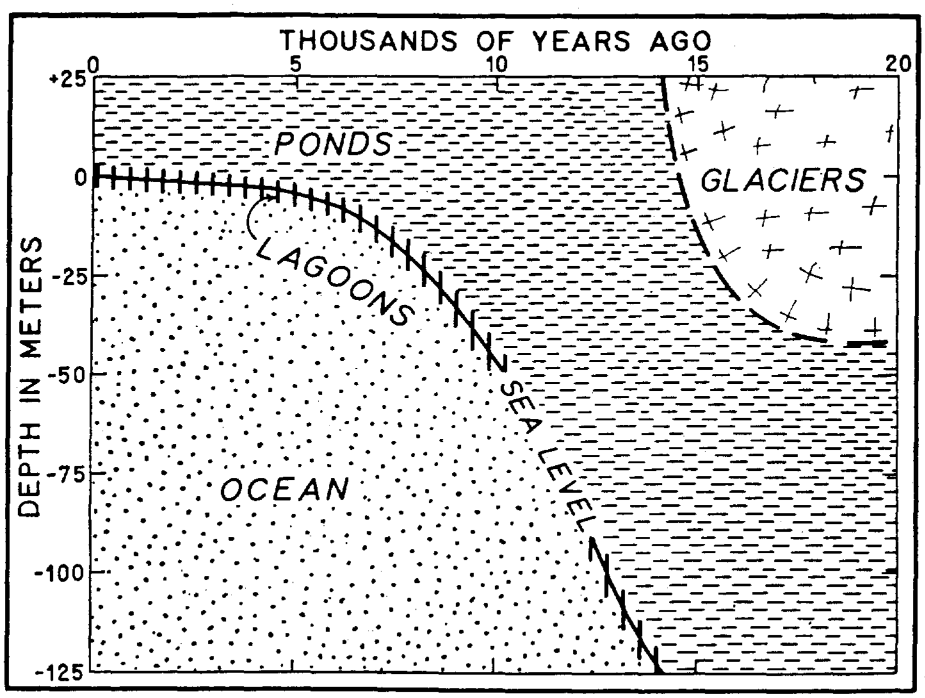


Fig. 7. Schematic diagram of the relation of freshwater ponds to other environments of New England. Areas marked *PONDS* are characterized by freshwater peats, *LAGOONS* by salt-marsh peats and oyster shells. *OCEAN* by marine sands and silts, and *GLACIERS* by till and outwash.

An interesting problem of plant physiology is raised by the finding that plants high on the salt-marsh have ratios of stable carbon isotopes similar to those of marine plants, in spite of the short length of time that they are submerged. The measurements that were made indicate that δC^{13} is a useful means of distinguishing between ancient salt-marsh and freshwater peats.

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23 June 1967

Radium-226 and Radon-222: Concentration in Atlantic and Pacific Oceans

Abstract. *Measurements of radon-222 in seawater suggest the following. The radium-226 content of surface water in both the Atlantic and Pacific oceans is uniformly close to about 4 × 10⁻¹⁴ gram per liter. The deep Pacific has a concentration of radium-226 that is four times higher and the deep Atlantic a concentration twice as high as that of the surface. These distribution profiles can be explained by the same particle-settling rate for radium-226 from surface to depth for the two oceans and by a threefold longer residence time of water in the deep Pacific than in the deep Atlantic. The vertical distribution of the deficiency of radon-222 in the surface water of the northwest Pacific Ocean suggests a coefficient of vertical eddy diffusion as high as 120 square centimeters per second and a gas-exchange rate for carbon dioxide in surface water between 14 and 60 moles per square meter per year. Vertical profiles of the excess of radon-222 in near-bottom water of the South Atlantic give coefficients of vertical eddy diffusion ranging from 1.5 to more than 50 square centimeters per second.*

Shipboard analysis of the concentration of radon gas in samples of seawater offers three important types of information: (i) the distribution of Ra^{226} in the world ocean, (ii) the exchange rates of gases across the air-sea interface, and (iii) the rates of vertical mixing near the surface and near the bottom of the ocean. Briefly, Rn^{222} (half-life, 3.85 days) is produced in seawater by the decay of its parent Ra^{226} (half-life, 1600 years). Well away from the air-sea and sediment-sea interfaces, the rate of radioactive decay of radon is equal to that of its parent radium.

Thus, a measurement of the radon content of such a water sample is a measurement of its radium content. As the radon content of the atmosphere is negligible, compared to that in surface seawater, radon continually escapes from the sea. By analyzing the vertical distribution of radon deficiency in the surface ocean it is possible to determine the rates of both vertical mixing and gas exchange. Water in the pores of deep-sea sediments contains 10^4 to 10^5 times more radon than the overlying seawater. Hence, radon diffuses from the sediment into the sea. The vertical distribution of excess radon in near-bottom water provides an index of the rate of vertical mixing. This report extends an earlier study (*1*) by presenting positive results for each of these applications.

Radon was extracted from 20 to 40 liters of seawater by circulating He gas in a closed system at the rate of 2 liter/min for 90 minutes. The condensable gases (including radon) were continuously collected in traps cooled with liquid air. The radon was then separated from CO_2 and H_2O by circulating the condensed gas through ascarite. Next it was quantitatively transferred to a 30-cm^3 scintillation cell where the count of its α-particles was determined. Overall recovery yields averaged 90 percent; accuracy of the measurements is about ±10 percent. Details of the procedure have already been published (*1*).

Although our results change neither the average content of radium content in the ocean nor the broad picture of its distribution from that given by previous workers (*2*, *3*), they do show far less scatter and suggest that radium is uniformly mixed throughout a given water mass. The radium content of surface water in both the Atlantic and Pacific oceans is 4×10^{-14} g/liter (Table 1 and Fig. 1). In both oceans a smooth increase in radium takes place downward through the main thermocline; in the Pacific the increase is fourfold (to 16×10^{-14} g/liter) and in the North Atlantic, twofold (to 8×10^{-14} g/liter).

Two explanations have been offered for the deficiency of radium in surface relative to deep water. Koczy (*2*) suggested that it reflected radioactive decay during the period in which surface water was isolated from the deep sea. The mixing rates required by this hypothesis are an order of magnitude lower than those that explain the vertical distribution of natural radiocarbon [see Broecker (*4*)]. Chow and Goldberg (*5*) have suggested that the deficiency is generated in much the same way as that for silicon and phosphorus. Radium in surface water is fixed onto particulate matter that sinks to the deep ocean where the radium redissolves. Their demonstration that, in the Pacific, barium shows a fourfold enrichment in deep relative to surface water strongly supports this alternate hypothesis.

Despite the difference in the deep-to-surface anomaly for radium in the two oceans the same particulate extraction rate, I, is required for both. Material balance requires that $I = R(C_D - C_S)$. The rate of transfer, R, of water across the main thermocline is given by

$$R = \frac{\bar{h}}{t_M(C_D' - C_S'/C_D')}$$

where $\bar{h}$ is the mean depth of the ocean; C_D' and C_S' are the C^{14}/C^{12} ratios in the deep and surface ocean;

Table 1. Concentrations of Ra^{226} and Rn^{222} in the oceans. *A*, specific activity.

Sample No.	Depth (m)	Position: Latitude	Position: Longitude	Sample volume (liters)	Ra^{226} (10^{-14} g/liter)	$A_{Rn^{222}}/A_{Ra^{226}}$
			Northwest Pacific Ocean (Vema-21, leg between Hawaii to Tokyo)			
29	150	28°47′N	158°50′E	~ 39	3.7 ± 0.1	*
26	300	27°05′N	166°04′E	~ 39	3.8 ± .1	*
20	450	25°31′N	172°45′E	~ 39	3.7 ± .2	*
17	600	24°58′N	176°16′E	~ 39	5.3 ± .2	*
27	600	27°54′N	162°31′E	~ 39	5.0 ± .2	*
23	800	26°26′N	169°02′E	~ 39	6.9 ± .4	*
5	1000	22°14′N	165°14′W	~ 39	9.1 ± .3	*
22	1250	26°26′N	169°02′E	~ 39	10.9 ± .4	*
24	1500	26°26′N	169°02′E	~ 39	11.8 ± .4	*
19	2000	25°31′N	172°45′E	~ 39	12.9 ± .2	*
7	3000	22°51′N	169°41′W	~ 39	14.2 ± .2	*
15	4000	24°31′N	179°21′E	~ 39	16.1 ± .4	*
10	4600	23°27′N	173°14′W	~ 39	16.1 ± .4	*
25	5000	27°05′N	166°04′E	~ 39	15.1 ± .3	*
			East Equatorial Pacific Ocean (Conrad-10, leg between Panama to Monzanillo)			
48	200	02°48′N	113°36′W	36	4.2 ± 0.3	*
45	400	02°41′S	115°54.5′W	36	5.0 ± .3	*
47	720	01°19.6′N	114°50.5′W	36	5.6 ± .3	*
39	1060	01°49′N	91°14′W	36	10.0 ± .4	*
41	1510	05°36′N	96°10′W	36	10.9 ± .4	*
49	2500	03°33′N	113°12.5′W	36	12.8 ± .4	*
50	3100	06°50′N	110°27′W	36	13.7 ± .4	*
37†	3230	03°51.5′N	85°57.5′W	36	14.2 ± .5	1.82 ± 0.07
47†	3790	01°19.6′N	114°50.5′W	18	15.6 ± .8	1.56 ± .09
46†	4270	02°41′S	115°54.5′W	18	15.6 ± .8	1.66 ± .09
			Northwest Atlantic Ocean (Conrad-10, leg between Bermuda to Jamaica)			
9S	0	24°47.2′N	54°59.5′W	36	4.0 ± 0.3	0.65 ± 0.05
9	200	24°47.2′N	54°59.5′W	36	4.1 ± .3	*
8	530	25°31.5′N	55°14.5′W	36	4.0 ± .3	*
7	1070	25°10.8′N	56°06.5′W	36	5.2 ± .3	*
11	2250	21°44.2′N	61°27.8′W	36	6.2 ± .3	*
10	3290	22°50′N	57°52.3′W	36	7.3 ± .3	*
3	4820	29°46′N	62°26′W	36	8.1 ± .4	*
5	5110	26°25.8′N	58°37.8′W	36	9.0 ± .4	*
12†	5600	21°44.2′N	61°27.8′W	36	8.1 ± .4	1.64 ± 0.09

* Assumed to be unity. † Samples taken 22 m above the sea bottom.

Table 2. Concentrations of Ra^{226}–Rn^{222} in near-surface water from the Northwest Pacific Ocean (*Vema*-21, leg between Hawaii to Tokyo). *A*, specific activity. Radon concentrations are given in radium equivalents.

Sample No.	Depth (m)	Position: Latitude	Position: Longitude	Sample volume (liters)	Rn^{222} (10^{-14} g/liter)	$(A_{Rn^{222}}/A_{Ra^{226}})$*
1	Surface	20°51′N	158°09′W	~ 39	1.9 ± 0.1	0.48
3	Surface	21°36′N	161°26′W	~ 39	2.1 ± .2	.54
8	Surface	22°51′N	169°41′W	~ 39	1.6 ± .2	.41
13	Surface	24°31′N	179°21′E	~ 39	2.5 ± .2	.64
14	Surface	24°31′N	179°21′E	~ 39	2.2 ± .2	.56
16	Surface	24°58′N	176°16′E	~ 39	3.1 ± .1	.80
18	Surface	25°31′N	172°45′E	~ 39	1.9 ± .2	.48
21	Surface	26°26′N	169°02′E	~ 39	2.1 ± .1	.54
28	Surface	28°47′N	158°50′E	~ 39	2.0 ± .1	.51
30	Surface	29°28′N	154°36′E	~ 39	2.1 ± .1	.54
31	Surface	29°51′N	150°58′E	~ 39	2.0 ± .1	.51
32	Surface	30°04′N	147°41′E	~ 39	2.2 ± .2	.56
33	Surface	30°25′N	144°30′E	~ 39	1.9 ± .1	.48
2	25	20°51′N	158°09′W	~ 39	2.5 ± .2	.65
4	25	22°14′N	165°14′W	~ 39	2.8 ± .2	.72
11	25	23°27′N	173°14′W	~ 39	2.5 ± .2	.65
12	75	23°58′N	176°51′W	~ 39	3.0 ± .1	.77
29	150	28°47′N	158°50′E	~ 39	3.7 ± .1	1.95
26	300	27°05′N	166°04′E	~ 39	3.8 ± .2	1.98

* Assuming Ra^{226} is 3.9×10^{-14} g of radium per liter.

and t_M, the mean life of radiocarbon (that is, 8040 years).

$$I_P/I_A = [(C_D - C_S)_P/(C_D - C_S)_A] \times [(1 - C_S'/C_D)_A/(1 - C_S'/C_D')_P]$$

As shown above $C_D - C_S$ is 12×10^{-14} g/liter for the Pacific, and for $\times 10^{-14}$ g/liter for the Atlantic. Radiocarbon data (*4, 6*) yields C_S'/C_D' of approximately 0.85 for the Pacific and 0.95 for the Atlantic, hence

$$I_D/I_A = [(12 \times 10^{-14})/(4 \times 10^{-14})] \times [(1 - 0.95)/(1 - 0.85)] \cong 1$$

Therefore, the threefold longer residence time of water in the deep Pacific allows three times more radium to accumulate.

In this calculation the difference in concentration of radium generated by radioactive decay was neglected. If the mixing rates based on radiocarbon data are valid, then the decay of radium introduces only a 12 percent difference in its concentration between deep and surface water of the Pacific. The fact that, despite its shorter half-life, radium is predicted to show a smaller decay effect than radiocarbon results from its addition to the deep rather than the surface ocean (the deep ocean has a volume roughly 10 times greater than the surface ocean).

The equality of the concentrations of radium between the surface waters of the two oceans may have significance to the problem of interocean mixing. Unless it is a coincidence, it suggests that the surface waters of the Atlantic and Pacific intermix with each other more frequently than they intermix with the underlying deep water masses.

Finally, there is no evidence for any significant gradient in radium away from the sediment interface. Within the limits of error, our measurements indicate that the radium content of the deep sea is constant below 3000 m. Any gradient that is present probably reflects the same phenomena that produce salinity and temperature gradients [see Munk (*7*)]. To gain any further information from radium would require a knowledge of the vertical distribution of the resolution of falling particles. At the present time we do not even know the nature of these particles.

The next step in understanding the distribution of radium in the sea requires the precise measurement of the ratio of Ra^{226} to barium. If these two elements have identical chemistry, these ratios can be used in the same manner as C^{14}/C or Si^{32}/S ratios. As shown by Lal *et al.* (*8*) transthermocline mixing rates (that is, deep water residence times) calculated from such ratios are independent of the effects of downward particulate transport.

A series of 13 measurements made on surface ocean water (depth 1 m) between Hawaii and Japan (Table 2) clearly demonstrate that a significant amount of radon escapes to the atmosphere. As shown in Fig. 2, the radon concentration in surface water averages 0.54 of that in water from 100 to 300 m. Three measurements from 25 m average 0.68 in the equilibrium value and one measurement from 75 m, 0.77. The depth at which the anomaly reaches one-half its surface value is thus about 75 m. The seas were calm during the entire period of these measurements; the wind force averaged 1 to 2 and did not exceed 4; and the seasonal thermocline averaged 25 m.

As previously shown (*1*), the fraction of equilibrium, f_x, between radon and its parent radium at any depth, x, below the sea surface is given by

$$f_x = \frac{C_x}{C_{\text{equil}}} = \frac{1}{D_M + Z\sqrt{\lambda D_E}}\left[D_M \exp\left(-x\sqrt{\frac{\lambda}{D_E}}\right) + Z\sqrt{\lambda D_E}\right]$$

where Z is the thickness of a hypothetical boundary layer through which gases must pass by molecular diffusion; D_E, the coefficient of molecular diffusion; D_M, the apparent coefficient of vertical eddy mixing; and λ, the decay constant for radon. If $x_{1/2}$ is defined as the depth at which the radon anomaly becomes half of that at the surface, that is, where $f_x = [(f_0 + 1)/2]$

$$D_E = \left(\frac{x_{\frac{1}{2}}}{0.693}\right)^2 \lambda$$

If $x_{1/2}$ is 7.50×10^3 cm and λ is 2.1×10^{-6} second, D_E turns out to be 120 cm^2/sec.

The rate of exchange, R, of CO_2 gas will be given by

$$R = [D_M(CO_2)]/Z = D_M P_{CO_2} C_S')/Z$$

Since for $x = 0$

$$f_0 = \left(1 + \frac{D_M}{Z\sqrt{\lambda D_E}}\right)^{-1}$$

we have

$$R = P_{CO_2} C_S' \sqrt{\lambda D_E}\,(1 - f_0)/f_0$$

Finally, writing D_M in terms of $x_{1/2}$

$$R = [(P_{CO_2} C_S' x_{\frac{1}{2}} \lambda)/0.693] \times [(1 - f_0)/f_0]$$

The partial pressure in the atmosphere over the ocean and in mid-latitude seawater is about 3.2×10^{-4} atm. The solubility of CO_2 in seawater at 25°C is 30 mole m^{-3} atm^{-1} and λ is 66 $year^{-1}$. If $x_{1/2}$ is 75 m and f_0 is 0.54, R turns out to be 60 mole m^{-2} $year^{-1}$.

Although similar in magnitude, this result is about four times larger than the average demanded to replenish the radiocarbon undergoing radioactive decay in the sea (4).

The CO_2 exchange rate can be calculated in another way. Instead of assuming an exponential drop-off with depth, let us assume that the deficient zone lies above the seasonal thermocline and is roughly uniform over this interval. Taking the depth to the seasonal thermocline to be $\hbar$, we have

$$R = P_{CO_2} C_S' \hbar \lambda [(1 - f_0)/f_0]$$

Since $\hbar$ averages 25 m (compared to $x_{1/2}/0.693 = 108$ m), R becomes 14 mole m^{-2} $year^{-1}$, a value consistent with the distribution of natural C^{14}. This question cannot be resolved until detailed vertical profiles of the radon deficiency have been obtained.

The last column in Table 1 proves our previous prediction that easily measured excesses of radon exist in near-bottom waters. In these samples excesses ranging from 5 to 12×10^{-14} gram equivalent of Ra^{226} per liter were found 25 m above the sea floor [with the use of the 200-liter sampler developed by Gerard *et al.* (*9*)]. In order to obtain bottom profiles, four 30-liter Niskin samplers (Von Dorn type) were placed at 7-m intervals on the camera wire and triggered from the surface by messenger. The results (see Table 3) show that, as expected, the excess decreases away from the bottom.

Table 3. Concentration of Ra^{226}–Rn^{222} in near-bottom water from the South Atlantic Ocean (*Conrad*-11). All samples of water were 19 liters. Numerals in parentheses are assumed values. Radon contrations are given in radium equivalents.

Sample No.	Distance above bottom (m)	Position		Rn^{222} (10^{-14} g/liter)	Ra^{226} (10^{-14} g/liter)
		Latitude	Longitude		
R1-A	10	22°47'S	32°37'W	40.1 ± 2	7.1 ± 0.5
R1-B	17	22°47'S	32°37'W	22.0 ± 1	7.3 ± .5
R1-C	24	22°47'S	32°37'W	14.1 ± 0.7	7.3 ± .5
R1-D	31	22°47'S	32°37'W	8.0 ± .5	6.6 ± .5
R3-A	5	39°04'S	52°41'W	20.7 ± 1	(7)
R3-B	12	39°04'S	52°41'W	20.9 ± 1	(7)
R3-C	19	39°04'S	52°41'W	20.0 ± 1	(7)
R3-D	26	39°04'S	52°41'W	16.5 ± 0.8	(7)
R4-A	9	47°02'S	43°41'W	21.6 ± 1	(7)
R4-B	18	47°02'S	43°41'W	18.2 ± 1	(7)
R4-C	26	47°02'S	43°41'W	17.0 ± 0.8	(7)
R4-D	1050	47°02'S	43°41'W	6.6 ± .5	(7)

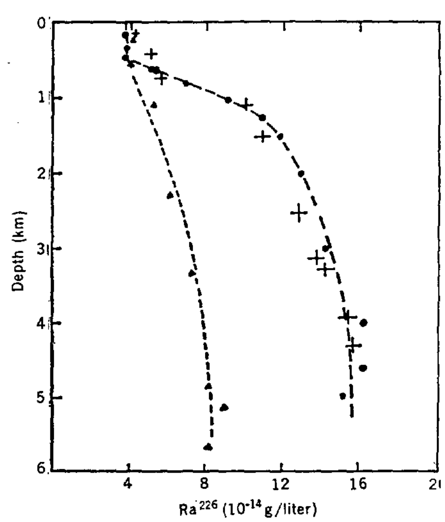

Fig. 1. The vertical distribution of Ra^{226} in the oceans. ●, Northwest Pacific Ocean; +, east equatorial Pacific; and ▲, northwest Atlantic Ocean.

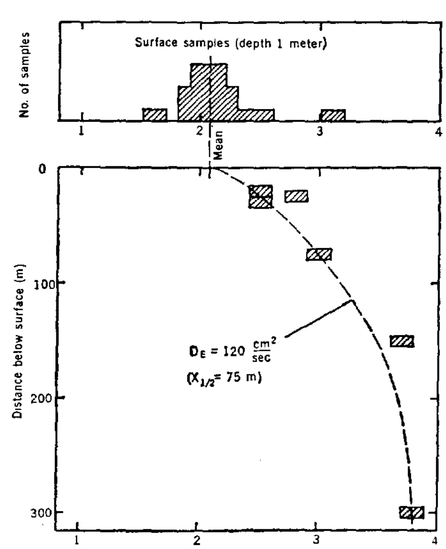

Fig. 2. The vertical distribution of Rn^{222} in surface waters of the northwest Pacific.

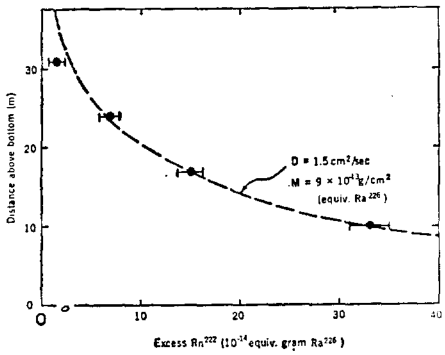

Fig. 3. Excess Rn^{222} as a function of distance above the sea bottom in the South Atlantic at 22°47'S, 32°37'W.

In our previous report it was shown that the following relation existed between the radon excess, C_x^*, and the distance from the bottom.

$$C_x^* = M \sqrt{\frac{\lambda}{D_E}} \exp\left(-x\sqrt{\lambda/D_E}\right)$$

where M is the standing crop of radon lost by the sediments, and λ and D_E are as defined above. Data for the profile 23°S, 33°W in the South Atlantic are plotted in Fig. 3. The points can be fit by the theoretical equation if D_E is 1.5 cm^2/sec and M is 9×10^{-13} gram equivalent of Ra^{226} per liter. As previously published (*1*) measurements of radon leakage from the tops of trigger-weight cores yield standing crops of from 1.5 to 35 $\times$ 10^{-13} gram equivalent of Ra^{226} per square centimeter. This amount of radon is also what would be expected from molecular diffusion from the radon-rich pore water [see (*1*)].

For the other two profiles roughly the same standing crop of excess radon is required, but the eddy diffusion rate must be about 30 times higher (that is, ~50 cm^2/sec). Hence the study of the distribution of excess radon near the ocean bottom will prove to be a powerful tool in determining rates of vertical mixing.

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Silica in Alkaline Brines

Abstract. *Analysis of sodium carbonate-bicarbonate brines from closed basins in volcanic terranes of Oregon and Kenya reveals silica contents of up to 2700 parts per million at* pH*'s higher than 10. These high concentrations of* SiO_2 *can be attributed to reaction of waters with silicates, and subsequent evaporative concentration accompanied by a rise in* pH*. Supersaturation with respect to amorphous silica may occur and persist for brines that are out of contact with silicate muds and undersaturated with respect to trona; correlation of* SiO_2 *with concentration of Na and total* CO_2 *support this interpretation. Addition of more-dilute waters to alkaline brines may lower the* pH *and cause inorganic precipitation of substantial amounts of silica.*

The SiO_2 content of natural waters that are not associated with areas of geothermal activity very rarely exceeds 100 parts per million (ppm) (*1*). Commonly accepted saturation values with respect to amorphous silica at 25°C and a *p*H lower than 9.2 are 110 to 140 ppm (*2*). Some chert deposits are thought to have formed by inorganic precipitation of silica (*3*). In recent studies of alkali carbonate brines of a number of closed basins we have encountered waters having exceptionally high silica contents—up to 2700 ppm. These data suggest a simple mechanism for the inorganic precipitation of chert.

Silica contents of brines from four closed basins, three of which belong to the Great Basin province of the western United States, have been plotted against *p*H (Fig. 1), Na (Fig. 2), and total CO_2 when sufficient sample was available (Fig. 3). Silica was determined colorimetrically as the β-silicomolybdate complex (*4*). We have paid special attention to *p*H control and elimination of reductants, and have used tartaric acid to eliminate phosphate interference (*5*). All analyses were repeated several times and checked against synthetic brines of similar composition. Interference by boron or fluoride was negligible. Exceptionally high values of SiO_2 were checked by gravimetric and fusion procedures.

Brines were stored in polyethylene bottles and filtered under pressure through 0.45-μ membranes prior to analysis, although filtration through pore sizes down to less than 0.1 μ showed no effect on silica content. Precipitation of silica during storage was checked by digestion of the complete bottles of duplicate samples. Differences were usually less than 5 percent of the silica content at high concentrations of SiO_2, and much less at low concentrations.

The western Great Basin has several intermontane areas of interior drainage in igneous rock terranes. Most of these basins contain saline lakes or playas with brines high in carbonate; the brines have been derived principally by evaporative concentration. Sodium and carbonate are the dominant ions in solution because alkaline-earth carbonates precipitate, and sources of sulfate or chloride are lacking.

Abert Lake of south-central Oregon, with an area of about 130 km^2, is one of several highly saline remnants of the large pluvial lakes that once occupied the western Great Basin (*6*). The present lake has no outlet, and its level and total surface area reflect the long-term balance between inflow, principally the Chewaucan River, and loss of water by evaporation. Sodium, carbonate species, and chloride ions comprise over 90 percent of the dissolved constituents in Abert Lake and associated springs. In addition to waters from Abert Lake itself, and interstitial solutions from associated lacustrine sediments, we have included a sample from a brine pond on the salt flats at the north end of the lake; here a small seep similar to the lake in solute composition, but of 1/100th the concentration, feeds a pool of highly concentrated chlorocarbonate brine.

Alkali Lake, in Alkali Valley, is a playa of approximately 13 km² immediately north of the Abert basin (*7*). More than half the playa area contains numerous circular depressions or potholes, some as much as 9 m across and 1 m or more in depth; the largest contain masses of crystalline sodium salts, chiefly carbonate. Many of them also contain extremely variable and highly concentrated carbonate brines, which apparently result from long-term evaporation of artesian waters at a rate roughly equivalent to discharge (*8*). Samples came from several potholes and the main playa pond.

Deep Springs Lake, in Deep Springs Valley, California, is an intermittent saline water body in a small basin (*9*); about a third of its 13-km² area is covered by saline crusts. Inflow is chiefly from groups of springs discharging from a prominent zone of recent faulting. Also within the fault zone are two sag ponds, one of which has no outlet at low stage. Carbonate species predominate in the ponds and springs but are subordinate to sulfate in the lake area.

In addition to the alkaline waters from Oregon and California, several samples from Lake Magadi in Kenya were studied. Baker (*10*) has summarized the geology, mineralogy, and geochemistry of the area; the lake lies in the Gregory Rift Valley and contains a vast deposit of trona ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$). It is intermittently dry, but has a number of perennial brine pools (lagoons) near the margins; it has no visible outlet and is fed primarily by a number of perennial hot springs and by runoff during rainy seasons. Samples were collected from hot springs, open brine pools, and brines interstitial to trona crusts.

Figure 1 shows that the silica content increases drastically for brines having a *p*H greater than 9.2; this finding agrees with the reported increase in solubility of amorphous silica with *p*H (*2*). With the exception of those for the interstitial solutions, most *p*H values plotted in Fig. 1 are based on field measurements at ambient temperature; for samples not in immediate contact with muds, *p*H may change by as much as 1 unit during subsequent storage.

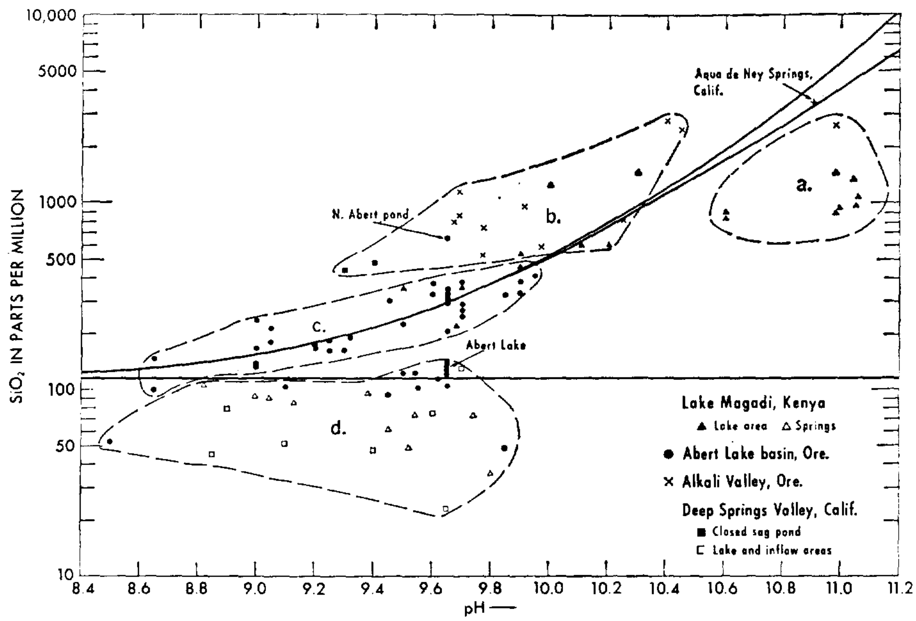

Fig. 1. Silica in solution versus *p*H. The three solid curves are (from low to high SiO_2) for $Si(OH)_4$, $SiO(OH)_3^-$, and $SiO_2(OH)_2^{--}$ Areas *a–d* are discussed in text.

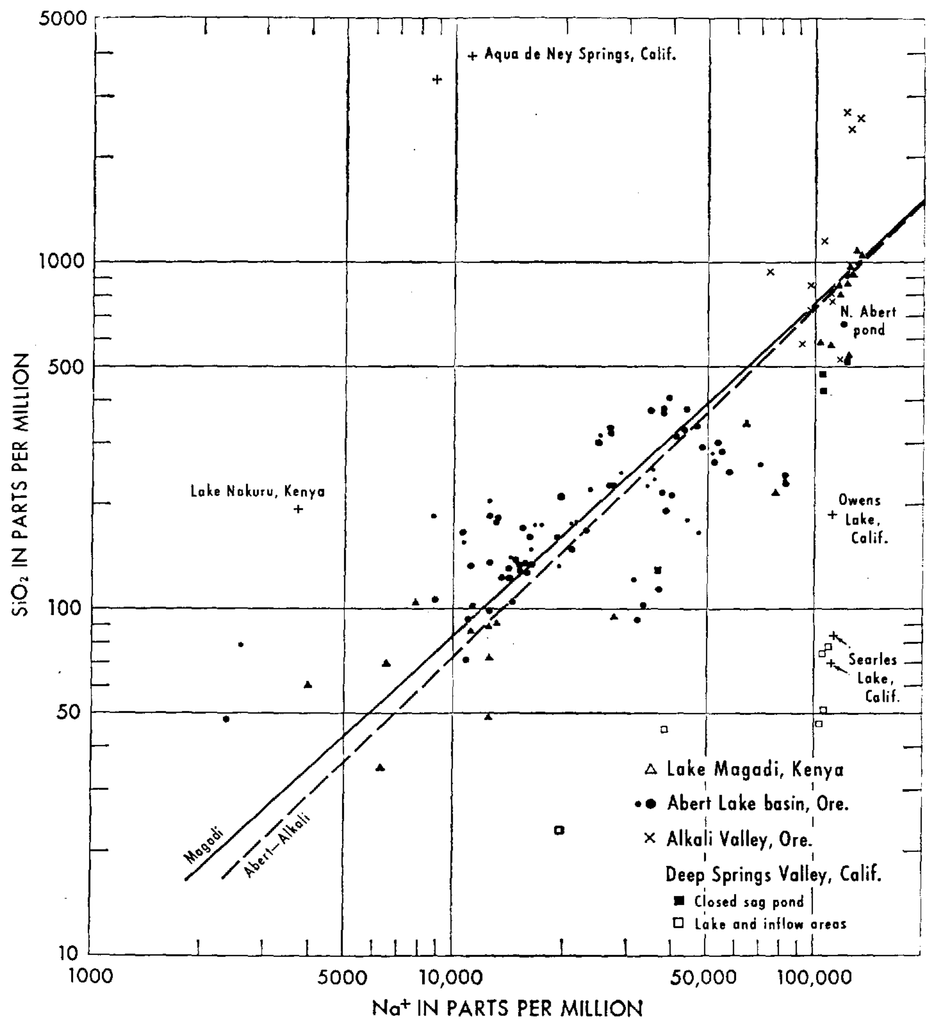

Fig. 2. Sodium versus SiO_2 for alkaline brines from Kenya, Oregon, and California. Regression lines have been derived independently for the Oregon and Magadi points. Small dots represent samples for which *p*H and total CO_2 data were not obtained.

In contrast, changes in total CO_2 during storage fell within the analytical error of 2.5 percent. The curves (Fig. 1) were calculated for 25°C from the data of Lagerstrom (*11*), as verified by Ingri (*12*), for equilibrium constants of silica species in solution.

According to Fig. 1, our data can be divided into four groups: (*a*) concentrated, intracrustral high-*p*H brines from Lake Magadi and Alkali Valley; (*b*) concentrated brines from open pools in Alkali Valley and Lake Magadi, from the brine pool north of Abert Lake, and from the closed sag pond of Deep Springs Valley; (*c*) brines of intermediate concentration, interstitial to saline muds from Albert and Magadi lakes; and (*d*) Abert Lake, plus saline springs and interstitial fluids from adjacent mud flats, inflow brines from springs of the Lake Magadi area, and brines from the area of Deep Springs Lake. No systematic correlation exists between silica content and temperature at the time of collection of each brine, although some of the scatter (Fig. 1) may be due to temperature differences.

Groups (*a*) and (*d*) are undersaturated with respect to amorphous silica, group (*c*) is of intermediate *p*H and near saturation, while group (*b*) is close to supersaturation or substantially supersaturated. The only other nongeothermal water reliably reported to have a very high *p*H and silica content, from Aqua de Ney Springs, California (*13*), plots very near the saturation curve for amorphous silica. The correlation between *p*H and SiO_2 for each group can be explained by their special history. We believe that the enrichment in silica in the brines is primarily due to evaporative concentration.

Points of group (*a*) show a high *p*H because of the depletion in HCO_3^-, caused by trona precipitation; the *p*H has increased more rapidly than evaporative concentration of SiO_2; exchange with the atmosphere is apparently too slow to check this trend.

The open pools of group (*b*) are either undersaturated with respect to sodium carbonate minerals or saturated with natron ($NA_2CO_3 \cdot 10H_2O$). Evaporative concentration of SiO_2 is apparently more rapid than nucleation and precipitation of silica.

The brines in contact with saline muds, containing abundant silicates [group (*c*)], plot near saturation with respect to amorphous silica. Higher SiO_2 values are from samples of bottom sediment near the water-mud interface; lower values, from interstitial waters deeper in the sediment. This fact suggests that initial equilibrium is established with respect to an amorphous surface layer on silicates (*14*); subsequent recrystallization lowers SiO_2 content.

The compositions of the springs of Lake Magadi [group (*d*)] are governed by their underground history. A reverse trend appears to exist between *p*H and SiO_2 and probably reflects adsorption of silica on freshly precipitated sesquioxides (*15*). The other points of group (*d*) are for waters of Abert or Deep Springs Lake; they are either dilute or have been concentrated from waters having distinctly lower SiO_2 content.

If silica is indeed concentrated by evaporation, this concentration should be reflected in a correlation between SiO_2 and sodium, the predominant cation of these brines (Table 1). As Fig.

Table 1. Representative alkaline brines from Alkali Valley (Alkali Lake, AIL) and Abert Lake (AL) basin, Oregon, Deep Springs Lake (DSL) and sag pond, Calif. (Deep Springs Valley, DSV), and the Lake Magadi (LM) area, Kenya. Included are brines with relatively high contents of CO_2, even though chloride or sulfate may in fact dominate the anions. Little Magadi Lake, Kenya, LML.

Sample				*p*H		Contents (ppm)							
Description	Source coordinates	Collection time	Water temp. (°C)	Field	Laboratory	Silica (SiO_2)	Sodium	Potassium	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Dissolved solids (calc.)
Brine from pit next to pothole near log road on SW side, AIL playa	120°03′W,42°57′N	8–6–63	25	9.97	10.0	590	91,400	5090	trace	99,500	20,200	19,800	237,000
Surface brine from pothole near log road on SW side, AIL playa	120°03′W,42°57′N	8–6–63	40		10.4	1270	121,000	8080	trace	133,000	25,000	27,900	318,000
At gage, AL	120°11′W,42°36′N	7–22–64	23	9.75	9.65	128	15,200	604	3840	6920	792	12,700	39,300
At mouth of Chewaucan River, surface, AL	120°15′W,42°31′N	7–25–64	30	9.82	9.85	48	2360	112	758	972	135	2190	6220
Brine from within very porous salt crust, central DSL	118°02′W,37°17′N	8–18–63	41		8.9	78	108,000	22,000	4990	20,700	56,200	120,000	332,000
Closed sag pond, DSV	118°1.5′W,37°17′N	8–15–61	33	9.90	10.0	524	119,000	10,900	3630	66,100	90,900	41,000	330,000
Interst. brine from bottom mud, S end, near W shore, AL	120°15′W,42°32′N	8–6–63	22		9.05	211	19,500	1360	10,200	6370	949	16,900	50,300
Interst. brine from bottom mud, SW end, AL	120°15′W,42°33′N	8–6–63	22		8.65	148	20.800	1350	14,600	4780	1270	16,800	52,300
Interest. brine from bottom mud, near mouth of Chewaucan River, AL	120°15′W,42°31′N	8–8–63	22		9.25	162	16,100	1200	4280	5180	1860	13,800	42,700
Hot spring, LML	36°16′E,01°44′S	6–66	81	9.05	9.05	90	12,600	239	15,600	3540	147	5950	30,200
Saturated brine, LM	36°15′E,01°54′S	6–66	34	11.06	10.25	1055	132,000	2280	trace	106,000	219	84,400	324,000
Saturated brine, LM	36°17′E,01°50′S	6–66	36	10.11	9.5	583	110.000	1530	trace	95,600	97	50,700	247,000

2 shows, most of the points for the Lake Magadi, Alkali Valley, and Abert Lake areas fall near a straight line having a slope of approximately 45° over the entire range of sodium concentration from 2400 to 132,000 ppm. The greatest scatter is in the points for the most dilute brines; they represent inflow waters not yet subjected to much evaporation. A number of the interstitial solutions, having SiO_2 contents below the general evaporative trend, may result from silica sorption during long-term contact with silicate solids. The highest sodium values reached are between 100,000 and 132,000 ppm and are for brines saturated with respect to sodium carbonate minerals. In these saturated brines, silica may be further enriched through fractional crystallization of trona or of natron and halite, or of all three.

The data for the Oregon and Kenya brines, in which carbonate and bicarbonate are the dominant anionic species, were examined by simple-regression analysis. The equations for the lines of best fit were (ppm):

$$Na^+ = 8180 + 127\ SiO_2 \text{ for the Lake Magadi area } (\sigma = 53{,}400 \text{ ppm } Na^+,\ r = .94)$$

$$Na^+ = 6316 + 113\ SiO_2 \text{ for the combined Abert Lake and Alkali Valley systems } (\sigma = 29{,}000 \text{ ppm } Na^+,\ r = .80)$$

Brines that contain much sulfate, chloride, and other anions in addition to HCO_3^- and CO_3^{--}, such as those from Deep Springs and Owens and Searles lakes (*16*), plot well below these lines; they do not reach the high *p*H values necessary to keep large amounts of SiO_2 in solution. Conversely, waters from Lake Nakuru, another closed basin in the rift valley 270 miles north of Lake Magadi, and Aqua de Ney Springs are high in silica relative to sodium, presumably because of initially higher *p*H values.

Figure 3 shows the correlation between SiO_2 and total CO_2. The equation for the regression line obtained from the combined Oregon and Magadi data, exclusive of the most supersaturated pools, is (ppm)

$$\text{Total } CO_2 = 1542 + 79 SiO_2 \quad (\sigma = 25{,}300 \text{ ppm total } CO_2,\ r = .92)$$

Again, evaporative concentration can account for the trend shown. The good correlation between total CO_2 and SiO_2 content of the brines also suggests that SiO_2 is derived from hydrolysis of silicates in the presence of CO_2, rather than by dissolution of free SiO_2, such as opal, cristobalite, or quartz. A schematic reaction such as

$$\underset{\text{in feldspar}}{NaAlSi_3O_8} + 6\tfrac{1}{2}H_2O + CO_2 = Na^+ + HCO_3^- + 3Si(OH)_4^0 + \underset{\text{in clay}}{\tfrac{1}{2}Al_2O_3}$$

illustrates this process (*16*). The atmosphere supplies the CO_2 necessary to maintain ionic balance during silicate breakdown. This simple reaction requires a direct relation between Na^+:H^+ and SiO_2. However, field *p*H's apparently are affected by factors other than the CO_2–SiO_2 equilibria, and a plot of Na^+:H^+ versus SiO_2 shows great scatter.

Saturation of solutions with respect to sodium carbonate minerals limits the CO_2 enrichment; the limits are dependent upon other anions present, such as chloride. The Alkali Valley brines have the highest total CO_2:Cl ratio throughout and reach the greatest concentration in SiO_2 and CO_2 species at saturation. In contrast, the CO_2 values of the Magadi brines do not exceed 70,000 ppm because they contain much Cl (Table 1). The brine pool north of Abert Lake is saturated with trona and halite and has still less CO_2 (43,300 ppm). The most concentrated brines show definite SiO_2 enrichment, compared with CO_2:SiO_2 trend set by evaporative concentration; this enrichment is probably caused by the fractional crystallization of sodium carbonate minerals.

As in Fig. 2, the silica value for Aqua de Ney Springs plots well above the trend for sodium carbonate brines. The sodium and silica contents of these waters probably result from the hydrolysis of silicate in the absence of CO_2.

In summary, evaporative concentration of sodium carbonate waters leads to high-*p*H brines, which can retain all the silica initially in solution. The final values of SiO_2, *p*H, and Na^+ and CO_2 species depend on the initial solution composition, on the extent of equilibration with the atmosphere and silicate muds, or with both, and on the fractional precipitation of sodium carbonate minerals. The amount of silica stored

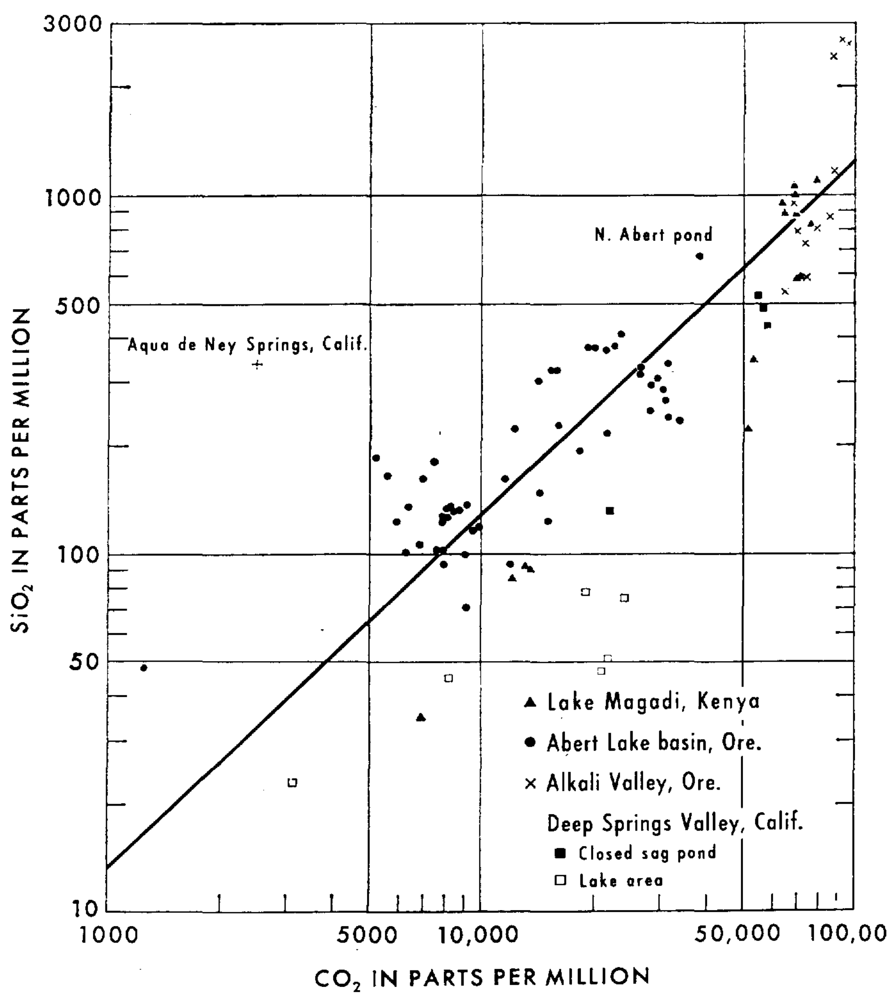

Fig. 3. Total CO_2 versus SiO_2 for alkaline brines.

in solution can be large. Interaction of silica-rich brines with flood runoff may cause relatively sudden supersaturation with respect to amorphous silica, and thereby lead to inorganic precipitation of chert. If there is rapid mixing of runoff with brine, much silica may remain in the diluted waters. If a stratified lake forms, however, biogenic CO_2 may be retained in the hypolimnion and reduce the *p*H of the bottom brines; in this manner the bulk of the dissolved silica can be precipitated. Figure 1 shows that a drop in *p*H from 11.0 to 8.5 can cause precipitation of as much as 3000 ppm SiO_2, which corresponds to a 1.5-mm-thick layer of chert for each meter of depth of brine. Silica layers that were probably formed by this mechanism have been found in the High Magadi beds, of Pleistocene age, and within the Alkali Valley playa deposits (*17*).

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Coccoliths as Paleoclimatic Indicators of Pleistocene Glaciation

Abstract. *Selected species of Coccolithophoridae from recent sediments and mid-Wisconsin glacial sediments of the North Atlantic were examined in an attempt to determine cooling effects. All species showed a definite shift southward during the glacial period. The average shift in this planktonic population was 15 degrees of latitude, with the greatest change in the eastern Atlantic. A paleoisotherm map can be drawn on the basis of the temperature boundaries of coccolithophorids. The species boundaries indicate a possible shift in position of the subtropical gyral to a glacial position roughly parallel to the 33-degree line of latitude.*

The dramatic fluctuations in Pleistocene climate are recorded in sediments in the Atlantic Ocean (*1*), but unfortunately the means of procuring these data are poorly developed. The only direct technique available at the present time is the use of oxygen isotopes (*2*). This report deals with a new approach —plotting the migration of biogeographic boundaries for temperature-restricted species of Coccolithophoridae due to Pleistocene glaciation.

Among all the microorganisms that leave fossil records in oceanic sediments, the Coccolithophoridae probably have the greatest potential as paleoclimatic indicators. In addition to their wide geographic distribution and stable mineral skeleton (calcite), these marine algae inhabit the upper euphotic zone (*3–5*) and consequently are under direct climatic control. In living species it is possible to correlate biogeographic boundaries with surface water isotherms (*4*), and this is the basis of my report.

The method of attack, being biogeographic, requires the widest possible geographical distribution of core material. This is not easily obtained, for, although the North Atlantic has been the site of intensive sampling, there remain large gaps in the core distribution. A limiting factor is that large areas of the North Atlantic basin are below the carbonate compensation level, with a consequent lack of coccolith flora. Thus the 23 cores sampled (Table 1) are restricted to three linear belts. Two cover the shelf, slope, and rise of both North America and Europe-Africa; the third, the Mid-Atlantic Ridge.

Choice of the particular species to be examined requires that two separate cri-

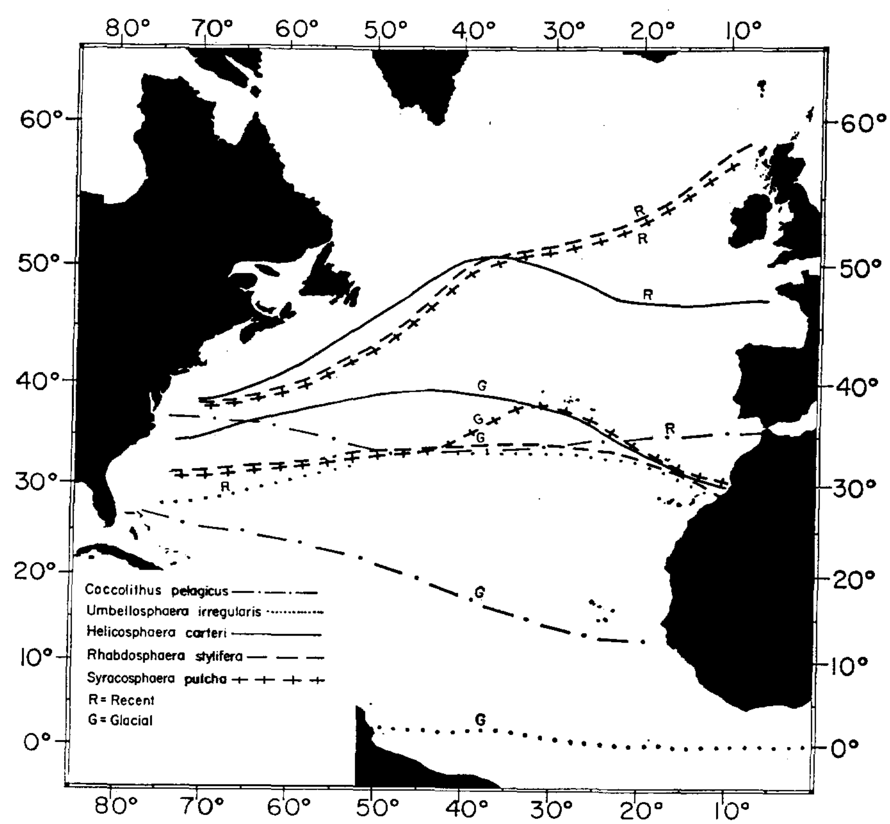

Fig. 1. Species population boundaries for Recent and mid-Wisconsin time.

teria be met. They must have relatively limited temperature ranges and a good paleontologic record. This is made difficult by the differential preservation of coccolith structural types. Some of the best temperature indicators are found among the delicate caneoliths where fossil recording is minimal.

Eight species, *Coccolithus pelagicus*, *Cyclococcolithus leptoporus*, *Helicosphaera carteri*, *Rhabdosphaera stylifera*, *Syracosphaera pulchra*, *Umbellosphaera irregularis*, *Umbellosphaera tenuis*, and *Umbilicosphaera mirabilis*, were selected on the basis of preservation and temperature range and their present distribution in the North Atlantic, compared with that of the mid-Wisconsin (last glacial period). Counts and identification of species were done with the electron microscope.

Synchronous samples from a finite time in the Wisconsin glaciation can be obtained by C^{14} dates or, where these are inadequate, by use of sedimentation rates established by radioactive dating. The rates for each core, expressed in centimeters per 1000 years, can be multiplied by a unit time in years (24 = 24,000 years of the glacial period) that would represent the mid-Wisconsin. This gives a depth in centimeters for each core from which synchronous samples are taken. While this technique is regularly used in geological oceanography, it is open to criticism since one must often assume that the sedimentation rate established for the upper portion of the glacial section in each core remains constant for the entire section. It is necessary to bear the limitations in mind since there is as yet no other means of obtaining the samples needed. The midglacial position of these samples was verified by planktonic foraminiferal stratigraphy.

The data (Table 2) from eight species, when plotted on distributional maps (Figs. 1 and 2), indicate a marked change in biogeographic distribution between recent and glacial sediments. The ranges of each species are delineated in Figs. 1 and 2 by two lines marking the boundaries of the recent and glacial populations. These lines are drawn on the extreme northern or southern appearances for warm and cold species, respectively.

Coccolithus pelagicus, the only species limited to cold water presently recognized in the North Atlantic (*4*), is restricted to subarctic and transitional waters. Its maximum southern limit coincides with the 14°C isotherm. At present this species extends to 35°N

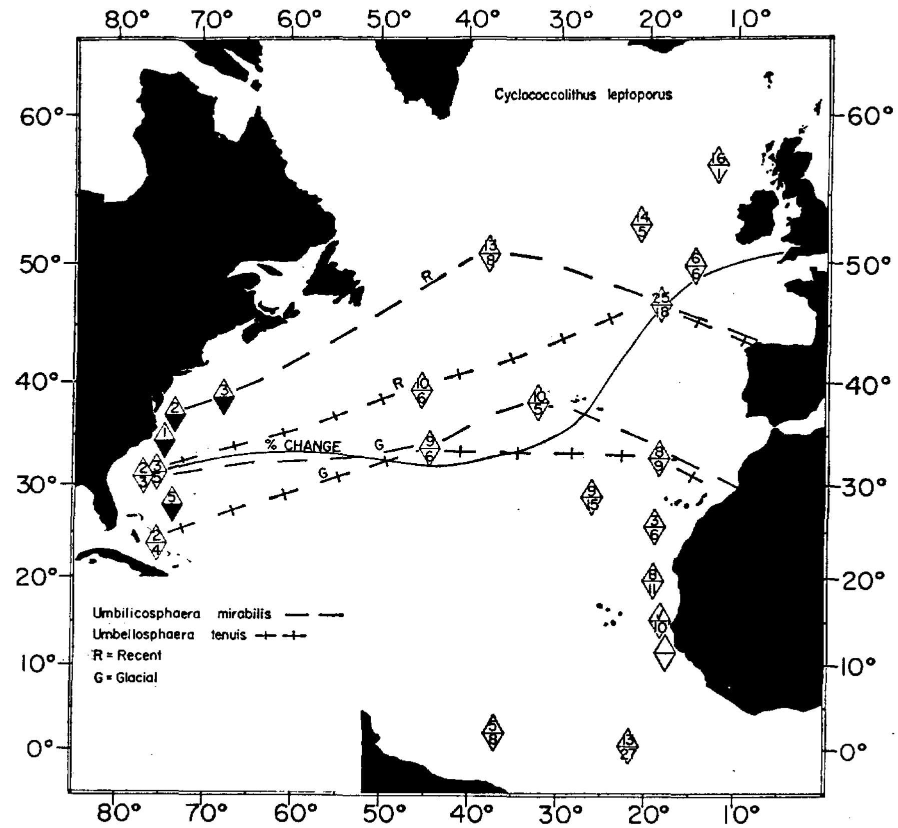

Fig. 2. Species population boundaries for Recent and mid-Wisconsin time and percent values for *Cyclococcolithus leptoporus* in diamonds with the upper recent and the lower glacial values.

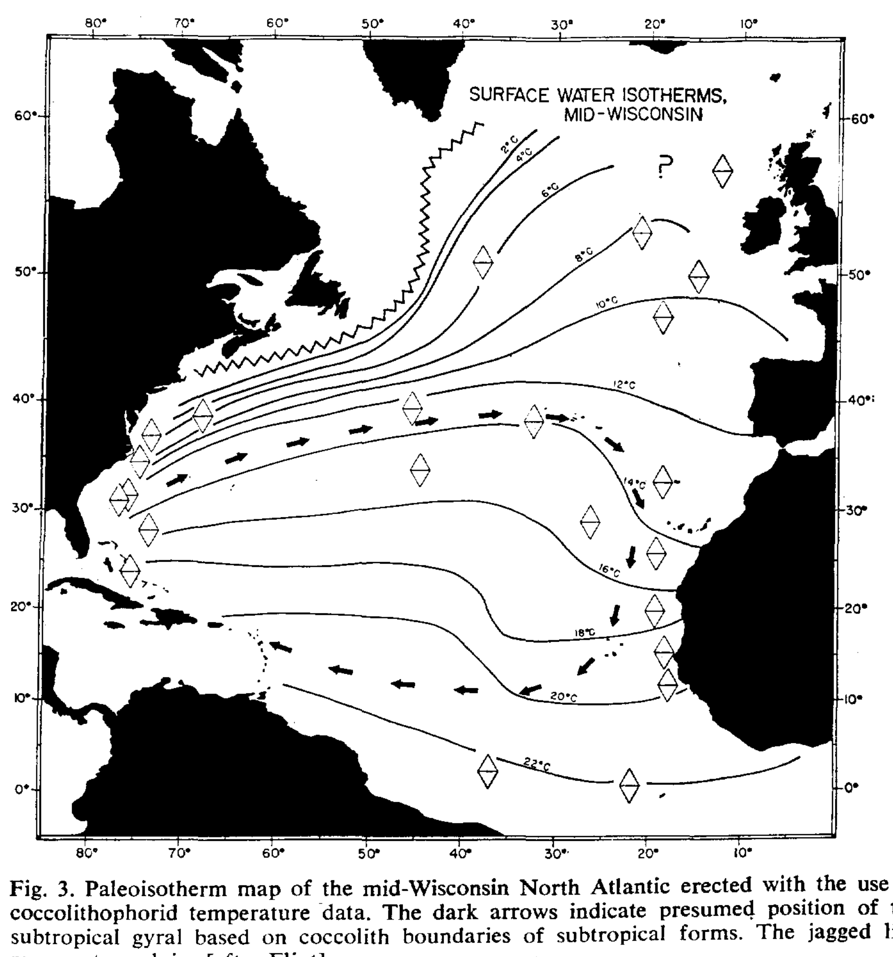

Fig. 3. Paleoisotherm map of the mid-Wisconsin North Atlantic erected with the use of coccolithophorid temperature data. The dark arrows indicate presumed position of the subtropical gyral based on coccolith boundaries of subtropical forms. The jagged line represents pack ice [after Flint].

latitude in the cold Labrador water found between the Gulf Stream and the coast of North America. In the mid-Wisconsin it ranged as far south as 13°N latitude along the African coast (Fig. 1). The average latitude shift between recent and glacial is approximately 15° latitude and even greater between living material and glacial (*4*).

At the opposite extreme in temperature tolerance is *Umbellosphaera irregularis* (Fig. 1), a tropical species. The minimum shift between recent and glacial boundaries for this form is approximately 20° latitude. The accuracy to which such shifts can be determined reflects the spacing of core samples. Between the glacial presence (core Nos. V16-200 and A180-72) and absence (core No. A180-56) there is a gap of 10° latitude (see Table 1).

The temperature ranges of *Helicosphaera carteri, Rhabdosphaera stylifera*, and *Syracosphaera pulchra* are not as limited as those of the two preceding species (Fig. 1). They are presently found in subtropical to transitional waters. All show a much more limited distribution during mid-Wisconsin time. *Helicosphaera carteri* has an average distributional difference of 10° latitude while *Rhabdosphaera stylifera* and *Syracosphaera pulchra* both have an approximate shift of 17° latitude. Note that in these three species the recent maximum distributional lines follow the northern border of the subtropical gyral (Gulf Stream) across the Atlantic Ocean. This agrees with plankton data from the North Atlantic, where the boundary between subtropical and subarctic species approximates the northern border of the Gulf Stream (*4*).

Umbellosphaera tenuis and *Umbilicosphaera mirabilis*, while having a satisfactory preservation record, do not show as distinctive a difference in their recent and glacial distributions as the preceding species.

Umbellosphaera tenuis is found at higher latitudes and is limited today by the 16°C isotherm; it is typical of subtropical waters. Its glacial to recent shift is from 10° to 15° latitude (Fig. 2). It is not as abundant in glacial as in recent sediments. This may be due to the fragility of its macrococcoliths.

The coccoliths of *Umbilicosphaera mirabilis*, like *Coccolithus huxleyi*, have temperature-dependent structural variations (*4, 6*). While these changes are gradational in *C. huxleyi, U. mirabilis* appears to have separate cold- and warm-water forms. The distribution of *U. mirabilis* is today bounded by the 18°C isotherm; this may be too high a value since the colder-stage coccoliths are present at higher latitudes in sediment samples from this study than was observed with either living or surface sediment material in the survey of modern forms. It is possible that the colder stage of *U. mirabilis* has a distribution similar to that of *R. stylifera* and *S. pulchra*. Nevertheless, the species shows a definite shift between recent and glacial sediments which averages 15° latitude (Fig. 2). Further evidence indicative of a cooling of the Atlantic in glacial times is the preponderance of cold-form coccoliths in glacial-age sediments from the mid-North Atlantic, a situation reversed in recent surface sediments.

Cyclococcolithus leptoporus (Fig. 2) is among the most eurythermal of the Coccolithophoridae. Today it ranges from the equator to Arctic waters. There is no apparent difference in maximum range between recent and glacial, although this is probably due to the lack of core material further north than the line Sp 10-1 through R 10-2 (see Table 1). There is a marked change in percentage distribution between recent and glacial populations, with the higher percentage (which today occurs in this species in transitional waters) indicative of the optimum range. Thus the line representing percentage change may be a rough indicator of the subtropical boundary in the Wisconsin. This type of subtle biogeographic change will require further work before definite conclusions can be drawn.

A number of other species showed some degree of biogeographic change by a shift in maximum boundaries; however, they are not plotted because of relative rarity in the core material. In the case of the ubiquitous eurythermal species (*Coccolithus huxleyi* and *Gephyrocapsa oceanica*), their distribution is similar to that of *Cyclococcolithus leptoporus*.

One interesting change, presently not usable for paleoclimatic work but important in systematics, is the reversal in dominance of *Coccolithus huxleyi* and *Gephyrocapsa oceanica* from glacial to recent (Table 2).

In today's ocean *Coccolithus huxleyi* usually constitutes over 50 percent of the flora, but in the mid-Wisconsin it shared and in some latitudes was dominated by *Gephyrocapsa oceanica*. I consider that *Coccolithus huxleyi* is a relatively recent form, none being found before the Pleistocene, and that it evolved from the *Gephyrocapsa oceanica* complex during the late Pleistocene. Similarities in form and ecology, combined with the finding of intermediate forms in Pleistocene core samples that I am now investigating, support this theory.

A comparison of the latitudinal change in flora from northern cold waters to southern warm waters in recent and glacial sediments indicates the dominance of cooler water forms in lower latitudes during the mid-Wisconsin. *Umbilicosphaera mirabilis* and *Syracosphaera pulchra* constitute a much larger percentage of the flora in glacial times in this area, while *Cyclococcolithus fragilis* and *Umbellosphaera irregularis*, subtropical to tropical forms, are nearly absent during glacial time from the North Atlantic.

The biogeographic boundaries of Coccolithophoridae species in today's seas can be correlated with surface water isotherms (*4*). If we assume that the present temperature ranges of the species held for the last glacial period, then the paleogeographic boundaries of species can also be assigned temperature values. If all these boundaries are

Table 1. Core locations in the North Atlantic and the depth of the glacial sample in each core.

Core No.	Location		Depth of glacial sample (cm)
	Latitude	Longitude	
A153-146	33°43′N	44°45′W	80
A156-4	34°49′N	74°41′W	844
A156-5	37°07′N	73°37′W	95
A164-59	38°42′N	67°52′W	245
A167-13	31°39′N	75°21′W	300
A167-14	31°28′N	76°28′W	300
A179-13	23°56′N	75°45′W	97
A179-17	28°00′N	73°47′W	280
A180-9	39°27′N	45°57′W	115
A180-16	38°21′N	32°29′W	140
A180-32	29°07′N	26°15′W	59
A180-48	15°19′N	18°06′W	488
A180-56	12°15′N	17°46′W	207
A180-72	00°36′N	21°47′W	120
R5-36	46°55′N	18°35′W	162
R5-54	25°52′N	19°03′W	35
R5-57	19°40′N	19°06′W	270
R10-2	56°59′N	12°28′W	100
SP8-4	32°50′N	18°32′W	65
SP9-3	53°53′N	21°06′W	220
SP9-4	50°02′N	14°46′W	200
SP10-1	51°23′N	38°04′W	150
V16-200	01°58′N	37°04′W	120

Table 2. Species composition of recent and glacial samples for each core (expressed as percentages). Since only eight species are reported from the total flora, the percentage values do not equal 100. Abbreviations: R, recent; G, glacial; x represents values that are less than 1 but greater than 0.5 percent.

Core No.	*Coccolithus pelagicus*		*Cyclococcolithus leptoporus*		*Helicosphaera carteri*		*Rhabdosphaera stylifera*		*Syracosphaera pulchra*		*Umbellosphaera irregularis*		*Umbellosphaera tenuis*		*Umbilicosphaera mirabilis*	
	R	G	R	G	R	G	R	G	R	G	R	G	R	G	R	G
A153-146	x	5	9	6	1	2	1	x	1	0.5	x		1	1	4	3
A156-4		x	1	x		x	1									
A156-5	x	x	2	x												
A164-59	x	x	3	x	6		x		2				2		4	
A167-13		1	3	5			1	1		1						x
A167-14		x	2	3	2	4	1	1					x			1
A179-13			2	4	2	3	2	6	2	4	2			2		7
A179-17		x	5	x	1	x	1		3		3		4		6	x
A180-9	18	7	10	6	2	1	x		1				x		3	
A180-16	x	1	10	5	1	2	x		1	2.5			2	1	3	1
A180-32		1	9	15	2	3	2	1	1	x			2	1	4	8
A180-48		3	x	10	4	1			1						1	2
A180-56								2		2						6
A180-72			13	27	2	2	1	1	1	1	2	1	x		7	11
R5-36	x	6	25	18	1		x		1				1		x	
R5-54		1	3	6	2	4	2	2	3	1	4		4	1	9	5
R5-57	x	1	8	11	3	1	1	1	9	1					2	1
R10-2	4	2	16	1			2		4							
SP8-4		0.5	8	9	1	0.5	1	x	1	1	x		2	2	3	1
SP9-3	1	1	14	5					2							
SP9-4	1	5	6	6			x		x							
SP10-1	30	3	13	8	4		x		6						2	
V16-200			5	8	2.5	3	2	x	x	2	4	1	3	1	14	22

plotted on a map and each boundary is given the present value of the maximum temperature (isotherm), it should be possible to draw a paleoisotherm map for the glacial period. Having laid out the temperature lines for the species and interpolating between overlapping ranges, I found it possible to draw a tentative paleoisotherm map (Fig. 3). Although insufficient core coverage makes any fine adjustment of these lines impossible (a gap remains in the northwest portion of the Atlantic), two lines, the 14° and the 22°C isotherms, are established on the basis of a number of overlapping species. The addition of more core material and the mapping of other species boundaries should result in a paleoisotherm map that will be an accurate representation of the average temperature of surface water of the glacial North Atlantic.

In seven species the amount of latitudinal shift between glacial and recent is greatest along the eastern side of the Atlantic. In the three species with subtropical to transitional ranges it is a factor of 2 to 3. This distributional difference is presumably the result of the main current system in existence today and in the Wisconsin. At present the distribution of *R. stylifera*, *H. carteri*, *U. tenuis*, and *S. pulchra* is encompassed by the northern boundary of the subtropical gyral (Gulf Stream). This boundary rises from approximately 40°N latitude off North America to over 55°N latitude off Europe. This is also true for other subtropical coccolith species not included in this report. In the mid-Wisconsin the line of species presence is relatively horizontal, running roughly parallel to the 30° latitude line with a slight southern turn along the eastern edge of the Atlantic (Fig. 3).

Admittedly the core density is somewhat low; nevertheless, the core coverage is sufficient to allow no more than a 5° fluctuation in latitude without a major change in azimuth of this line since it is bracketed by cores. If one compares data (Figs. 1 and 2), it is possible to say that the northern border of the subtropical gyral during mid-Wisconsin time flowed along or near the 33° latitude line.

From this first report, based on information gained from modern species of Coccolithophoridae, it appears that coccoliths can be used for paleoecologic studies and that the application of these studies to the problem in this report has led to the following conclusions about the effect of cooling on the North Atlantic during the Wisconsin glaciation: (i) That the maximum cooling in the mid-Wisconsin resulted in a southward shift of planktonic populations of approximately 15° latitude, with the greatest shift occurring in the eastern Atlantic; (ii) that it may be possible to erect paleoisotherm maps of surface water with the use of population boundaries of Coccolithophoridae species of known temperature range as isotherms, particularly if greater core coverage can be combined with data on additional species; and (iii) that the northern boundary of the subtropical gyral, from a present position of approximately 40° latitude off North America to over 55° latitude off Europe, was displaced to a position extending from approximately 30°N latitude off North America to approximately 38° off Europe.

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6 September 1967

Scanning Electron Microscope: Potentials in the Morphology of Microorganisms

Abstract. *Morphologic characteristics related to ecology and evolutionary sequences, and to specific, generic, and familial relations, can now be determined with the scanning electron microscope. These detailed characteristics will help to establish a more natural faunal classification and will enable more accurate ecologic and biostratigraphic correlations.*

Detailed study of microorganisms has always been hampered by our inability to observe minute structures of test morphology. The imaging capability of the scanning electron microscope now enables the researcher to observe effectively many of the fine details upon which faunal classifications are based; the microscope also provides information on and permits illustration of features that have not been observed previously (see cover).

This microscope became commercially available in 1966 and differs from the transmission instrument in many ways. The depth of field (500 times that of a light microscope) and high resolution (ten times that of a light microscope) are complemented by a very wide range of magnifications (× 50 to greater than × 100,000); development and operation of this microscope have been discussed (*1, 2*). Specimens can be observed directly within a few minutes of being mounted; troublesome delays, due to faulty replicas, normally experienced by the transmission electron microscopist are completely eliminated, and suitably prepared whole specimens are used rather than thin replicas.

The following technique is used for the study of various microorganisms such as foraminifers, diatoms, radiolarians, and ostracodes. Specimens are mounted with a diluted solution of tragacanth containing a small amount of glycerin. The mounts are allowed to dry at room temperature before being placed on a rotary turntable in a high-vacuum coating unit. Two coating runs (coating angles, 45° and 10°) are made, and the specimens are coated with gold to a thickness of 300 Å; conductive coatings of 100 to 200 Å also have been used. Photographs are taken at an accelerating voltage of 25 kv. Scanning time required to record the pictures, with a single-line scan, is 20 seconds. Panatomic-X 35-mm film is used. Morphologic characteristics of specimens are then studied in detail.

Fig. 1. *Globigerina bulloides* (d'Orbigny); Recent, Scotian Shelf at 200 m. Note narrow elongate spines on periphery, and thickened "flying buttress" spinal development in the apertural region (× 400).

The thinnest conductive coatings applicable to microorganisms have not yet been determined. Pease *et al.* (*2*) have photographed living insects without conductive coatings, but I was unsuccessful with foraminifers, radiolarians, diatoms, ostracodes, and dinoflagellates without use of conductive coatings. Much higher contrast in image of the specimen is possible if nonmetallic specimens are coated.

Expensive thin-film monitoring equipment is necessary to determine accurately the minimum thickness of coating that can be applied. New techniques incorporating high-vacuum evaporation are being devised for the deep penetration of metallic molecules within individual pore structures. Beam angle, beam collimation, and metal-particle speed, together with a variable substrate temperature, are a few of the many important aspects of high-vacuum evaporation now being investigated.

Differences in spinal development and shell strengthening with depth in the marine environment are exemplified by *Globigerina bulloides* d'Orbigny (Figs. 1 and 2). Strong spinal development in the apertural region is present in both specimens shown, but the specimen collected at 200 m (Fig. 1) displays distinct thickening and orientation of "flying buttress" support spines, which are evident in both the apertural and sutural regions. The specimen of *G. bulloides* collected at 50 m (Fig. 2) is characterized by extremely long, narrow, pointed spines lacking the thickening mentioned.

Most specimens of planktonic Foraminifera collected at depths greater than 100 m exemplify some form of primary bilamellar shell growth and secondary thickening. Bilamellar growth is shown in spinal thickening originating at the base of each spine and progressing to the apical end. Secondary growth (usually layering) consists of thick calcite crusts deposited over the primary shell.

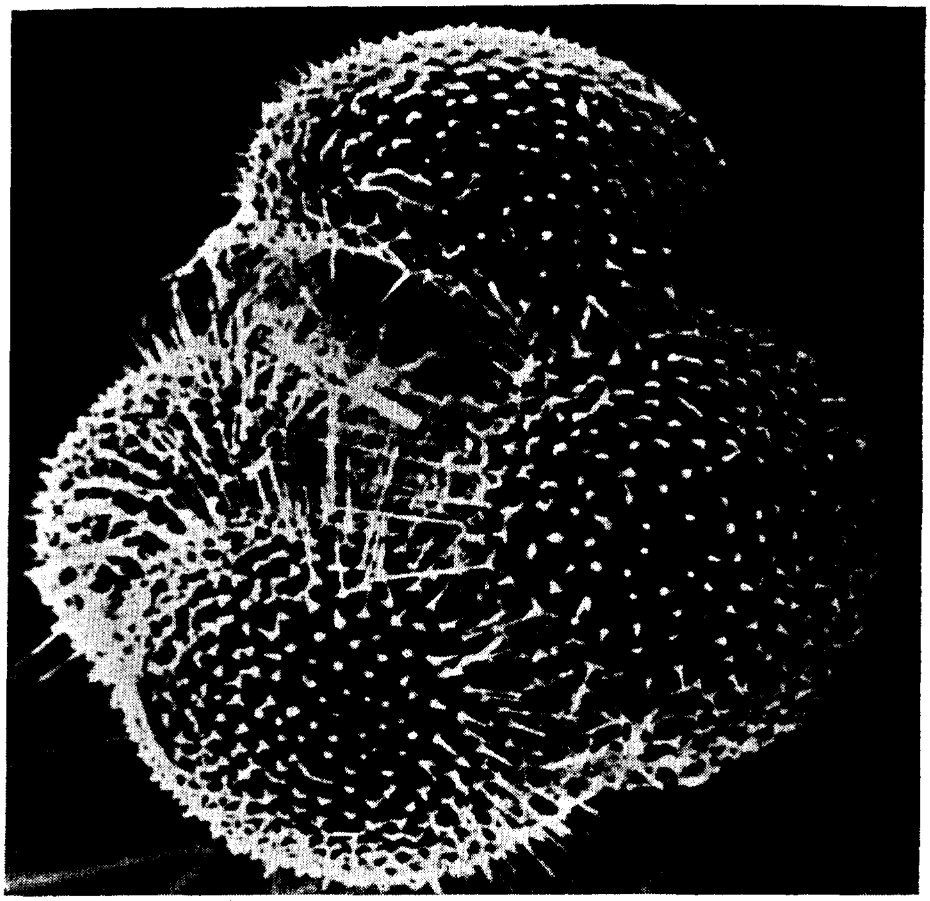

Fig. 2. *Globigerina bulloides* (d'Orbigny); Recent, Scotian Shelf at 50 m. Note narrow elongate spines over entire surface, concentration of spines in apertural region, and absence of any form of bilamellar or secondary thickening (× 400).

The secondary layers can be counted by focusing on individual pores. Both bilamellar and secondary thickening support the hypothesis (*3*) that shell thickening occurs at depth in adult stages of planktonic Foraminifera. Spinal development in *G. bulloides* at depth is contrary to findings of Bé and Hamlin (*4*), who found spines only in juveniles living at or near the surface of the ocean.

I have also investigated differences in microstructure of other foraminiferal species (*5*). *Globoquadrina dehiscens dehiscens* (Chapman, Parr, and Collins) differs radically from *Globigerina* in wall structure as well as in having prominent apertural flaps covering each aperture. *Globigerinoides trilobus trilobus* (Ruess) displays a heavy cancellate pore pattern, characteristic of the *Globigerinoides* group. However, *Globigerinoides trilobus immaturus* LeRoy, considered by many to be a member within the *G. trilobus* (s.l.) evolutionary sequence, has a surface covered with irregularly spaced knobs and small circular pores; this wall structure resembles that of *Globigerina*.

I have mentioned only a few morphologic characteristics. Many detailed features of various microorganisms, hitherto unavailable, are being investigated and will now add greatly to the determination of evolutionary sequences and specific, generic, and familial relations; they will enable more natural classification of these microorganisms. This new insight can be attributed to the scanning electron microscope.

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21 August 1967

Electrophoretic Variants of α-Glycerophosphate Dehydrogenase in Drosophila melanogaster

Abstract. *Two alleles of* Gdh, *the locus specifying the electrophoretic mobility of α-glycerophosphate dehydrogenase, are found in* Drosophila melanogaster. *The gene is located on the second chromosome at a map position of 17.8. Hybrid enzyme molecules are found in heterozygotes.*

The enzyme α-glycerophosphate dehydrogenase (GDH) catalyzes the oxidation of α-glycerophosphate to dihydroxyacetone phosphate and the reverse reaction. Extraordinarily high activity of this enzyme is found in thoracic muscle of insects (*1, 2*), where it plays an important role in the rapid production of energy from carbohydrate [see reviews by Sacktor (*3*) and Chefurka (*4*)].

Electrophoretic variants of at least 12 enzymes are known in *Drosophila melanogaster* [see review by Shaw (*5*)]. More than one electrophoretic type of an enzyme is more the rule than the exception in this species. The genetic loci responsible for the variations have in most cases been located on the linkage map of *Drosophila*.

A method for acrylamide gel electrophoresis of α-glycerophosphate dehydrogenase of *Drosophila* has been described by Sims (*6*). Hubby and Throckmorton (*7*) examined GDH electrophoretic patterns of several species of the virilis group of *Drosophila* and found differences between but not

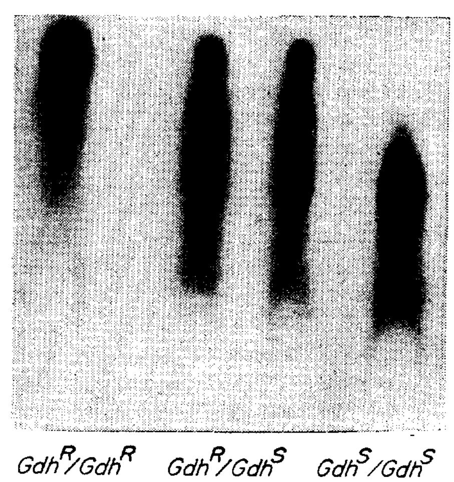

Fig. 1. Acrylamide-gel electrophoresis of α-glycerophosphate dehydrogenases of *Drosophila melanogaster.* On the left is the homozygote of the rapid type of GDH. On the right is the homozygote of the slow type of GDH. In the center are two heterozygotes of the two alleles.

within species. Hubby and Lewontin (8) surveyed many strains of *D. pseudoobscura* and found no electrophoretic variants of GDH, although variants of some other enzymes were common.

For this investigation, Sim's (6) technique was used with modifications to accommodate flat-bed electrophoresis equipment (EC Apparatus Corp.). Strips of polyacrylamide gel (5 percent acrylamide) were cast according to the method of Raymond and Wang (9). Before use, the gels were equilibrated with buffer of 0.025*M* tris brought down to *p*H 6.0 with H_3PO_4. Buffer in electrode vessels was 0.05*M* trisphosphate, *p*H 6.0. Flies were squashed on small squares of filter paper and inserted between cut ends of the gel. The top and bottom of the apparatus were cooled with running tap water. A potential of 24 volt/cm and a current of about 45 ma was applied across the gel for 2 to 4 hours.

The mixture to give color to regions of GDH activity contained 90 ml of tris buffer (0.05*M*, *p*H 8.5), 0.18 g of disodium dihydrogen ethylenediaminetetraacetate, 0.8 g of disodium glycerophosphate pentahydrate (α and β mixture; Calbiochem), 4 ml of nicotinamide-adenine dinucleotide solution (10 mg/ml), 4 ml of phenazine methosulfate solution (0.2 mg/ml), and 20 mg of nitro blue tetrazolium. Gels incubated in this mixture for about 1 hour at 20°C begin to show purple formazan in areas of GDH activity. One fly has sufficient enzyme activity to give dark areas. To insure that minor components were detected, the gels were incubated overnight in this mixture.

It was found that inbred strains of *D. melanogaster* may be divided into two types according to the electrophoretic mobility of their GDH. When the procedures described above are used, it is found that one type contains GDH that migrates more rapidly to the anode than the other. Canton-S, Samarkand, and Oregon-RC are examples of common wild-type strains that contain the more rapidly migrating enzyme. Swedish-c and Oregon-R have the slower migrating enzyme (see Fig. 1). There appears to be a family of enzymes in each inbred. There is a major component and two slower-moving minor components. The whole pattern is displaced when the slower and faster types are compared. Larvae, pupae, and adults have the same patterns. Whether these multiple forms are present in the living animal or are artifacts cannot be determined at this time. Sims (6) did not observe this heterogeneity in her experiment; however, Hubby and Lewontin (8) observed two areas of GDH activity in all strains of *D. pseudoobscura*.

Crosses between the two different types yield hybrids which have five visible components with GDH activity. There are three major components: the two parental ones and a hybrid with intermediate mobility (Fig. 1). The only minor components that are detectable are those of the slow-type parent. Other minor components in the hybrid are obscured by the three major components. The presence of a hybrid major component indicates that the GDH molecule contains at least two protein subunits. The parental major components contain two subunits that are alike; the hybrid contains two unlike subunits (10). Flies trapped from a wild population in Oak Ridge, Tennessee, are polytypic. The rapid, slow, and hybrid patterns of GDH are all found in this one population.

Genetic analysis shows that the differences in electrophoretic mobility of GDH are based on there being two alleles of a genetic locus. This locus (called Glycerophosphate dehydrogenase, symbol *Gdh*) is located on the second chromosome. On the standard linkage map of *D. melanogaster* (11) it has a genetic map position of about 17.8. It is between the loci of clot eye color (map position 16.5) and Sternopleural bristles (map position 22.0). Homozygotes of the allele Gdh^R have the rapid pattern. Homozygotes of the allele Gdh^S have the slow pattern of GDH. The hybrid pattern is produced by Gdh^R/Gdh^S heterozygotes.

The approximate cytological position of the *Gdh* locus is known from analysis of *Df(2L)GdhA*. This second chromosome deficiency was selected from x-irradiated chromosomes which lacked the wild-type allele of *cl* (clot eye color). In one case the irradiation induced a deficiency which included both *cl*+ and *Gdh*. The electrophoretic pattern of $Df(2L)GdhA/Gdh^S$ is like that of Gdh^S homozygotes, and $Df(2L)GdhA/Gdh^R$ is like Gdh^R homozygotes. In salivary gland chromosomes there are a few bands missing. On Bridges' (11) salivary chromosome map the left break of *Df(2L)GdhA* is between 25El and 25F1. The right break is between 26B1 and 26C1. The locus of *Gdh* must therefore be between 25E1 and 26C1.

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20 September 1967

Detergent-Solubilized RNA Polymerase from Cells Infected with Foot-and-Mouth Disease Virus

Abstract. *The foot-and-mouth disease virus RNA polymerase complex was dissociated from cellular membranes with deoxycholate in the presence of dextran sulfate. The soluble polymerase complex was active in the cell-free synthesis of virus-specific RNA; solubilization of the complex permitted direct analysis of the cell-free reaction mixtures without recourse to RNA extraction. A major RNA-containing component found early during cell-free incubation ranged from approximately 140 to 300S. The final major products of the cell-free system were 37S virus RNA, 20S ribonuclease-resistant RNA, and a 50S component containing RNA.*

Detailed studies of replication of animal virus RNA in cell-free systems have been hindered by high levels of nuclease or membrane-bound polymerase complexes, or of both (1, 2). The RNA polymerase induced by the foot-and-mouth disease virus (FMDV) is reportedly bound to cellular membranes in lysates of FMDV-infected baby hamster kidney cells (*3, 4*). This report concerns the dissociation of the active polymerase complex from these structures, and its activity in a cell-free system.

Direct analyses of the reaction mixtures which contain the soluble polymerase have shown a heterogeneous RNA-containing component (140 to 300*S*) and a 50*S* component containing RNA, in addition to virus-specific RNA (see *3*). The 140 to 300*S* RNA component is found before the appearance of 37*S* virus RNA.

The FMDV RNA polymerase was prepared according to Polatnick and Arlinghaus (*3*). It is known to be active in 0.5-percent deoxycholate (*3*). However, the virus-specific RNA synthesized in the presence of deoxycholate was largely degraded by contaminating nucleases, yielding 20*S* RNA resistant to ribonuclease, and 4 to 12*S* RNA fragments unless bentonite was present. By use of this deoxycholate-bentonite polymerase mixture, antibody to an antigen associated with FMDV infection (*5*) was found to inhibit FMDV-RNA synthesis by about 90 percent (*6*).

We used dextran sulfate-500 (*7*) to inhibit ribonuclease (*8*). Preliminary experiments showed that dextran sulfate at 10 to 20 μg/ml caused some stimulation of incorporation of ^{3}H-uridine triphosphate in the cell-free FMDV-polymerase system (Fig. 1 legend), whereas high concentrations (1 to 2 mg/ml) strongly inhibited incorporation. Addition of 0.25 percent of deoxycholate to an intermediate concentration of dextran sulfate (140 μg/ml) gave maximum incorporation. The sodium dodecylsulfate–extracted RNA products of the polymerase treated with deoxycholate–dextran sulfate in the cell-free synthesizing system contained all three virus-specific RNA's (*3, 9*): 37*S* virus RNA, 20*S* ribonuclease-resistant RNA, and a heterogeneous RNA.

Cell-free reaction mixtures were examined directly, without prior RNA extraction, by centrifugation on linear sucrose gradients of from 5 to 25 percent in 0.01*M* tris(hydroxymethyl) aminomethane HCl (*p*H 7.5) and 0.001*M* $MgCl_2$, (tris-$MgCl_2$) for 17 hours at 25,000 rev/min in the SW-25.1 rotor. The sucrose-gradient profile of the polymerase reaction mixture, containing neither deoxycholate nor dextran sulfate, after 60 minutes at 37°C (the time at which cell-free synthesis has stopped), showed that 90 percent of the radioactive RNA insoluble in trichloroacetic acid was in the pellet; no significant peak was seen in the gradient. The results were similar when the sample was centrifuged for only 2 hours. It was also determined that active polymerase forms pellets under the same conditions. These results indicate that the FMDV polymerase, as well as its attached RNA template, and its RNA products, are membrane-bound in cell lysates.

Direct sucrose-gradient analysis of reaction mixtures, containing polymerase and both 0.25-percent deoxycholate and dextran sulfate (140 μg/ml) gave the following results after 60 minutes at 37°C: The amount of ^{3}H-uridine triphosphate incorporated into RNA insoluble in trichloroacetic acid was 15 to 25 percent greater than in the absence of deoxycholate and dextran sulfate. The RNA products were released from the membrane, since 60 to 70 percent of the radioactive RNA insoluble in trichloroacetic acid was found in the gradient. The optical-density profile showed peaks of 18*S* and 28*S* ribosomal RNA that originated from ribosomal subparticles present in the polymerase preparation. This deproteinizing of ribosomes is attributed to the action of dextran sulfate (*4*). Three major zones were detected in the gradient (for example, Fig. 1B): a 50*S* component near the bottom of the tube, which was not found after treatment with sodium dodecylsulfate or pretreatment with either 0.01*M* ethylenediaminetetraacetate or 0.04*M* pyrophosphate; a 37*S* zone containing infectious virus RNA; and 20*S* RNA resistant to ribonuclease. No attempt has been made to demonstrate net synthesis of 37*S* infectious RNA in the cell-free system.

A minor peak of 26 to 30*S* heterogeneous RNA was always present in the reaction mixture (peak *D*; *3, 9*), but the amount varied with the activity of the polymerase (that is, activity presumably lost by denaturation of the enzyme and not by ribonuclease). The 50*S* and 37*S* zones were made soluble in trichloroacetic acid by treatment with ribonuclease (10 μg/ml) for 30 minutes at 37°C in 0.15*M* KCl and 0.1*M* tris-HCl, *p*H 7.0. Also, the infectivity of the 37*S* zone was lost on treatment with trace levels of ribonuclease. The 20*S* zone was almost completely resistant to ribonuclease, and

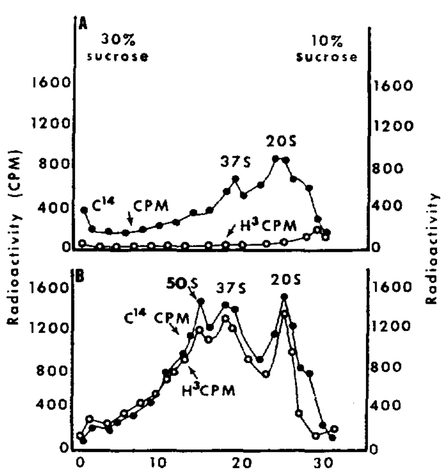

Fig. 1. Sucrose-gradient profiles of the in vitro chase of whole-cell, pulse-labeled, virus-specific RNA. Baby hamster kidney cells (6×10^8) were infected as in text. The soluble polymerase complex was isolated; it contained protein at 2.8 mg/ml and 125,000 count/min mg^{-1} protein of ^{14}C-uridine, as RNA insoluble in trichloroacetic acid, at 48-percent counting efficiency. The complete cell-free reaction mixture contained: 10 μmole of tris-HCl, *p*H 8.1 (23°C); 5 μmole of phospho(enol)-pyruvate; 20 μg of pyruvate kinase; 25 mμmole of each of adenosine triphosphate, cytidine triphosphate, uridine triphosphate, and guanosine triphosphate; 12.5 μmole of $MgCl_2$; 0.1 ml of polymerase; and water to a final volume of 0.7 ml. The mixture was incubated (see text). Casein (300 μg) and 10 ml of 5-percent trichloroacetic acid were added to each gradient fraction. After 20 minutes at 0°C, the precipitate was collected on type-B6 membrane filters (25 mm in diameter; Schleicher and Schuell), and the filter was washed five times with 5-percent trichloroacetic acid. Samples were counted in a liquid scintillation spectrometer (*9*). (A) The cell-free reaction mixture was held at 0°C for 60 minutes with 10 μc of ^{3}H-uridine triphosphate. The reaction mixture contained 100 μg of dextran sulfate, 0.05 percent deoxycholate, 0.1 ml of soluble polymerase complex, and all components of the cell-free system in a volume of 0.7 ml. The mixture was diluted to 2.2 ml with 0.01*M* tris-HCl, *p*H 7.5, prior to layering on the gradient. Two milliliters were applied, and the tube was centrifuged for 17 hours at 20,000 rev/min on a 10- to 30-percent linear sucrose gradient in tris-$MgCl_2$ in the SW-25.1 rotor. Carbon-14 at 35,344 count/min was applied to the gradient: 21,147 count/min was in the pellet; 12,336 count/min, in the gradient. (B) The reaction mixture was the same as for (A), and the tube was incubated for 60 minutes at 37°C, chilled and treated as for (A). Carbon-14 at 32,634 count/min was applied to the gradient: 5,862 count/min was in the pellet; 24,350 count/min, in the gradient.

most likely is double-stranded RNA. It has been reported that the 20*S* zone is only partially resistant to ribonuclease (*3, 9*); however, such results were obtained from RNA, extracted with sodium dodecylsulfate and phenol, that contained larger amounts of the abovementioned heterogeneous RNA. This heterogeneous RNA (peak *D*; *3, 9*) is partially sensitive to ribonuclease, and overlaps the 20*S* double-stranded RNA (*4*).

It was of interest to examine the RNA associated with the polymerase preparation; one could then discriminate between free, unbound, virus-specific RNA and active protein-RNA complexes (polymerase-template). The latter is the structural complex that replicates virus RNA. The polymerase was harvested, 3.5 hours after infection, from FMDV-infected baby hamster kidney cells pulse-labeled with ^{14}C-uridine under such conditions that only virus-specific RNA was labeled. Actinomycin D (5 μg/ml) was added 30 minutes before harvest, and 20 μc

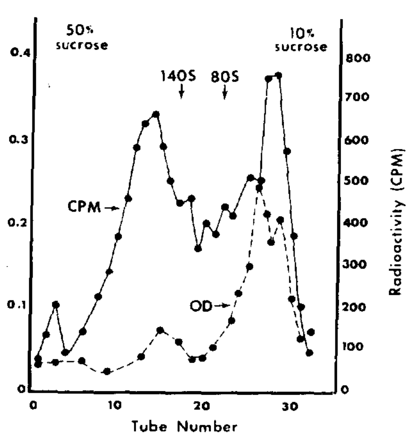

Fig. 2. Sucrose-gradient profile of the 140 to 300*S* RNA containing component of the soluble polymerase complex. The soluble polymerase complex (0.9 mg) was incubated in 2.1 ml of the complete cell-free reaction mixture (Fig. 1) for 5 minutes at 37°C, with 30 μc of ^{3}H-uridine triphosphate. The solution was rapidly chilled and adjusted to 0.1*M* tris-HCl, *p*H 8.1 (0°C). After addition of ammonium sulfate to 50 percent saturation and standing for 20 minutes at 0°C, the suspension was centrifuged for 15 minutes at 10,000*g*. The precipitate was suspended in 2.2 ml of tris-$MgCl_2$, and 2 ml was layered on a 10- to 50-percent linear sucrose gradient in tris-$MgCl_2$. The gradient was centrifuged for 17 hours at 15,000 rev/min in the SW-25.1 rotor. Tritium at 18,375 count/min was applied to the gradient; 4032 count/min was in the pellet; 12,662 count/min. in the gradient. Samples were precipitated with trichloroacetic acid as in Fig. 1.

of ^{14}C-uridine was added 15 minutes before harvest (*9*). This schedule of addition of actinomycin D caused no reduction in production of polymerase (*10*). The enzyme was prepared as usual (*3*) and made 1 mg/ml in dextran sulfate and 0.5 percent in deoxycholate before storage at −60°C; this preparation will be referred to as the "soluble polymerase complex." Activity of the soluble polymerase complex was stable for long periods at −60°C, even after repeated freezing and thawing.

The soluble polymerase complex labeled with ^{14}C-uridine was incubated in the complete cell-free system with ^{3}H-uridine triphosphate—specific activity, 400 μc/μmole (Fig. 1 legend). One tube was kept at 0°C; another was incubated for 1 hour at 37°C. The reaction mixture was analyzed directly (no RNA extraction) on a 10- to 30-percent linear gradient at 20,000 rev/min. The whole-cell material, pulse-labeled with ^{14}C-uridine, in soluble polymerase complex, contained both 37*S* and 20*S* virus-specific RNA, and a small amount of the 50*S* component appeared to be present (Fig. 1A). However, 65 percent of the ^{14}C radioactivity was found in the pellet (*S*-rate exceeding 100).

After incubation in the cell-free system at 37°C, nearly all the whole-cell RNA labeled with ^{14}C-uridine was found in the gradient in the three major zones (Fig. 1B). This test constituted a true chase experiment, since total counts per minute of ^{14}C in both the zero-time and the incubated sample were identical; only the distribution of radioactivity varied. This fact suggests that the pellet material (exceeding 100*S*) is a precursor to the 50*S*, 37*S*, and 20*S* components. Moreover, nearly all the polymerase complexes active in the whole cell (labeled with ^{14}C-uridine) are active in the cell-free system. The product of the cell-free synthesis of RNA (^{3}H-RNA) gave an identical profile, and 85 percent of the ^{3}H-RNA was found in the gradient (Fig. 1B).

Since the polymerase complex incorporates ^{3}H–uridine triphosphate into RNA for only 60 minutes at 37°C in the cell-free system, analysis of products formed early (after 5 to 10 minutes) should identify precursors to 37*S* virus RNA. Therefore a soluble polymerase complex was incubated for 5 minutes in the cell-free system containing dextran sulfate at 140 μg/ml. The reaction mixture was rapidly chilled to 0°C and adjusted to 50 percent of saturation with ammonium sulfate at *p*H 8.1.

Analysis of the precipitate material by zonal centrifugation gave the profile shown in Fig. 2. A peak of radioactivity is found ranging from 140 to 300*S*, and another is at the top of the tube. The 140 to 300*S* RNA component is not found after extraction with sodium dodecylsulfate; after treatment with ribonuclease at 1 μg/ml for 5 minutes at 37°C; or in reaction mixture incubated for 60 minutes. In all three instances all the RNA product occurred only at the top of the gradient. The RNA contained in the 140 to 300*S* complex (presumably of RNA and FMDV polymerase) appears to be identical with the heterogeneous RNA (peak *D*; *3, 9*). Difficulties in demonstration of the 140 to 300*S* component have been encountered because of aggregation in solutions containing magnesium. It should be noted that intact ribosomes are not detected in the soluble polymerase complex (Fig. 2). The methods of both isolation and storage of the soluble polymerase complex in dextran sulfate at 1 mg/ml and 0.5-percent deoxycholate destroy ribosomes and polyribosomes.

These results suggest that the 140 to 300*S* RNA containing component is a precursor to FMDV 37*S* RNA. Studies with poliovirus in intact HeLa cells indicated that synthesis of poliovirus RNA takes place in complex structures possessing an average *S*-rate value of 250 (*2*).

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20 October 1967

Bronchiolar and Large Alveolar Cell in Pulmonary Phospholipid Metabolism

Abstract. *The nonciliated bronchiolar cells (Clara cells) lining the terminal airways actively secrete a phospholipid. In contrast, the large alveolar epithelial cells (type II, granular pneumonocyte) are active phagocytic cells. It is proposed that the Clara cell is the main source of pulmonary phospholipid production (presumably surfactant) while the large alveolar cell is responsible for its subsequent breakdown.*

The lung has a large metabolic capacity for producing phospholipids (*1*). Presumably these phospholipids line the smaller airways and alveoli with a film capable of markedly reducing surface activity, thus promoting alveolar stability (*2*). As a result of this unique property to reduce surface tension, the material extracted from lungs has been named pulmonary surfactant (*3*).

It is widely accepted that the large alveolar cell is the source of pulmonary surfactant. This fact is based on indirect evidence (*4*) which fails to distinguish between the production of and breakdown of phospholipids. The present study supports the concept that the nonciliated bronchiolar cell [Clara cell (*5*)] is the source of surfactant and that the large alveolar cell is a phagocytic cell responsible for its subsequent clearance from the lung.

The large alveolar cell has been considered a secretory cell with the observation that lipid granules were extruded from the cell (*6*). However, in fixed tissue, it may be difficult to distinguish between the process of secretion and phagocytosis (Fig. 1). This problem was investigated by exposing unanesthetized mice to aerosolized carbon. The large sessile alveolar cells actively phagocytized carbon particles and lipid material from the alveolar space (Fig. 2). At a later stage, carbon particles were observed within osmiophilic lamellar bodies (Fig. 2), clear evidence that the lamellar bodies resulted from the ingestion of lipid material by, and were not a secretory product of, the cell. Acid phosphatase (*7*) was demonstrated at the membrane that lines many of the lamellar bodies, which indicates that these intracellular particles were lysosomes, that is, phagocytic vacuoles containing acid hydrolysates (*8*).

In contrast, the nonciliated bronchiolar cells which line the terminal and respiratory bronchioles, and which are rich in mitochondria and agranular endoplasmic reticulum, are active secretory cells. Secretory droplets appear to form in the Golgi area, to collect at the apex of the cell, and to be extruded into the bronchiolar lumen (Fig. 3). These cells demonstrated no

Fig. 1 (left). Large alveolar cell from a mouse exposed to 1 percent carbon monoxide for 12 minutes. Cell appears to be engulfing osmiophilic material (*OM*) with beginning indentation of the cell wall (arrows). However, the distinction between phagocytosis (material entering the cell) and secretion (material leaving the cell) cannot be made from such observations. *AS*, alveolar space.

Fig. 2. Large alveolar cell after unanesthetized mouse was exposed to aerosolized carbon for 30 seconds every 5 minutes over a 30-minute period. (A) Carbon particles (arrows) within membrane-limited osmiophilic granules. (B) Attenuated epithelial extension (arrows) enveloping osmiophilic material and carbon particle (arrow). Note normal lamellar bodies (*LB*) and attachment of cell to basement membrane (*B*). (C, inset) Lamellar body with carbon particles inside (arrow). *AS*, alveolar space.

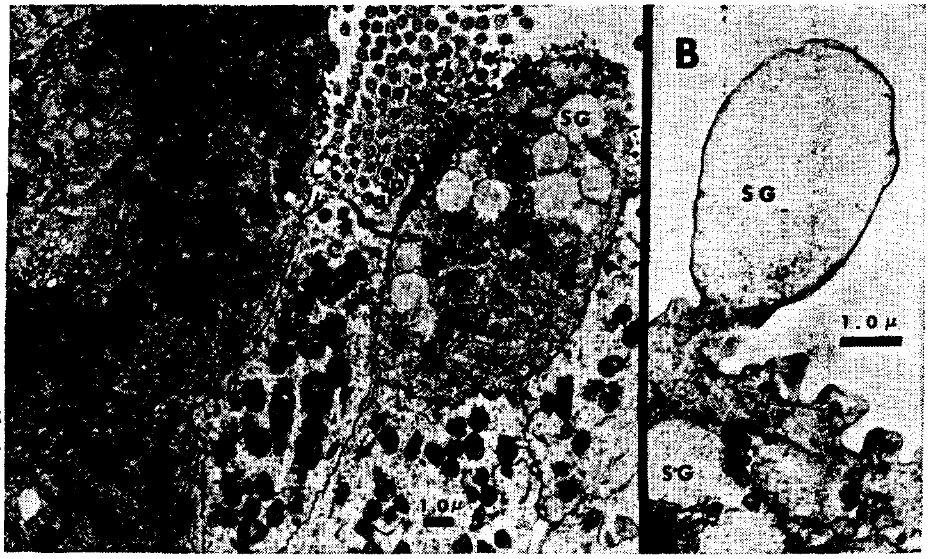

Fig. 3. Terminal bronchiole from normal mouse. (A) Bronchiolar cells at left with well-formed Golgi area and early development of secretion granules (arrows). Bronchiolar cell at right with secretory droplets collecting at apex of cell (*SG*). *C*, ciliated cells; *Ci*, cilia. (B) Extrusion of secretory granule from apex of bronchiolar cell. *SG*, secretory granule.

phagocytic activity. Ciliated cells are present in the terminal bronchiole but disappear in the respiratory bronchiole, well before the alveoli are reached. Thus the major portion of this bronchiolar secretion is not exposed to ciliary activity.

These secretion granules did not stain with periodic acid-Schiff, Alcian blue, or Sudan black, indicating the absence of mucopolysaccharides, acid mucopolysaccharides, and free lipids. However, the granules did stain with Sudan black–acetone, Baker's acid hematin, and silver hydroxylamine in an aqueous solution (Fig. 4A), indicating the presence of a phospholipid (*9*).

Following the injection of tritiated palmitate or acetate intraperitoneally, autoradiographically positive granules (*10*) were observed within 5 minutes at the apex of the Clara cells (Fig. 4B). The presence of positive granules after tissue extraction of free lipids demonstrates the ability of these cells to synthesize phospholipids from fatty acids.

Although pulmonary surfactant has not been completely identified, it has been characterized as a phospholipid (*11*). Thus, until pulmonary surfactant has been more precisely identified, it is only a presumption that the phospholipid produced by the Clara cell is surfactant.

The large alveolar cell was the only other cell which incorporated tritiated palmitate and acetate. Although the possibility that this alveolar cell is also capable of synthesizing phospholipids cannot be excluded, the present study demonstrating the phagocytic activity of this cell suggests that the radioactive material was ingested by the cell as a phospholipid lying free in the alveoli.

Thus it is proposed that the nonciliated bronchiolar cell is the major site of pulmonary phospholipid production (presumably surfactant), while the large alveolar cell is a phagocytic cell responsible for the clearance of lipids as well as other materials from the alveolar area.

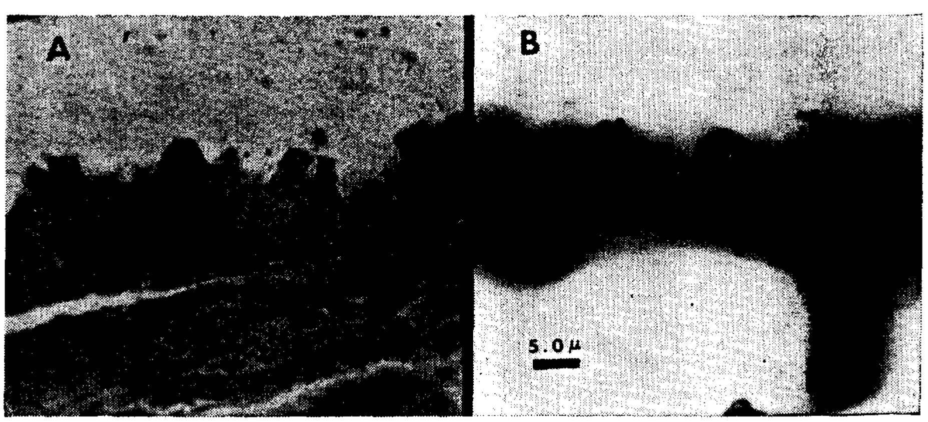

Fig. 4. (A) Nonciliated bronchiolar cells stained with silver-hydroxamate reaction, embedded in Epon and counterstained lightly with Toluidine Blue. Granules at apex of bronchiolar cell stain positive for phospholipid. (B) Autoradiography of terminal bronchus 5 minutes after injection of tritiated palmitate intraperitoneally. Positive granules are at apex of bronchiolar cell.

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12. Supported by grants from the National Heart Institute (H-6918) and NSF (GF-189). I am indebted to Professor E. Yamada, Kyushu University, Fukuoka, Japan, under whose guidance and encouragement this study was initiated. I am grateful to Phyllis Fogel for her technical assistance.

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Concanavalin A Reaction with Human Normal Immunoglobulin G and Myeloma Immunoglobulin G

Abstract. *Concanavalin A precipitated less than 5 percent of immunoglobulin G from human serum. It reacted with all of 42 myeloma serums of the immunoglobulin G type tested, but no more than approximately 50 percent of the total myeloma protein was ever precipitated. The fact that not all of the protein was precipitated and that the amounts precipitated varied from serum to serum may be interpreted as demonstrating heterogeneity of the carbohydrate in these myeloma proteins. Other glycoproteins precipitated by concanavalin A were identified, and subsequently separated from concanavalin A by chromatography.*

Concanavalin A, the globulin from jack-bean meal, reacts with serum glycoproteins (*1*, *2*), presumably because of its specificity for their nonreducing mannosyl- and *N*-acetylglucosaminyl end groups (*3*). Harris and Robson demonstrated that crude jack-bean meal extracts precipitated α_2-macroglobulin, γ_1-macroglobulin (IgM), β-lipoprotein, and ceruloplasmin; as judged by electrophoresis haptoglobins were also precipitated (*2*). Since no reaction with 7*S* γ-globulin (IgG) was noted, I attempted to use concanavalin A to separate IgM from IgG. I now present data demonstrating that, depending on the serum, variable amounts of IgG from normal and myeloma serums precipitated with concanavalin A.

Concanavalin A was prepared by a modification of Agrawal and Goldstein's procedure (*4*). The crude saline extract of commercial, defatted jack-bean meal was clarified by centrifugation at 25,000*g* (0°C) for 1 hour. After removal of the lipid layer, the supernatant was applied directly to a Sephadex G-75 column. Subsequent procedures were as described (*4*). The purified product was dialyzed against 0.1*M* phosphate buffer, *p*H 6.2, and kept in small vials at −70°C to prevent the precipitation noted on storage at 4°C.

To precipitate serum glycoproteins, 7 to 8 mg of concanavalin A were added to 1 ml of serum, and the mixture was incubated at 37°C for 1 hour. The flocculent precipitate was centrifuged at 4°C and then washed three times with cold saline. Overnight incubation at 4°C prior to centrifugation gave only slightly increased yields of glycoproteins. The washed concanavalin-glycoprotein complexes were dissociated at 37°C with 1 ml of saline containing 0.5*M* methyl α-D-glucoside.

Immunoelectrophoretic and immunodiffusion tests on the dissociated material were performed in agarose gels which contained 0.25*M* methyl α-D-glucoside to prevent recombination of concanavalin A with glycoproteins. Components in the dissociated precipitate, confirmed by immunodiffusion tests with specific antiserums or by specific biological activities, were IgM, IgA, α_1-antitrypsin, α_2-macroglobulin, transferrin, β_2-lipoprotein, β_2-glycoprotein, haptoglobin, ceruloplasmin, group-specific components, the serum inhibitor of C′1 esterase (*5*) and all the components of complement.

Although, by immunoelectrophoresis, no IgG was observed in the dissociated precipitate, both immunodiffusion and Gm typing (*6*) showed that a small amount (<5 percent) of IgG had precipitated with the concanavalin A. These data may be attributed to (i) the known heterogeneity of immunoglobulin carbohydrate (*7*) or (ii) differences in availability of IgG carbohydrate for reaction with concanavalian A as a result of conformational differences in IgG molecules with different amino acid sequences. Since homogeneous IgG of both reactive and nonreactive types would facilitate testing of these hypotheses, 42 IgG myeloma serums were examined for reactivity with concanavalin A (*8*). Precipitation, washing, and dissociation were performed as already described, except that 10, 30, or 60 mg of concanavalin A were added per milliliter of each serum.

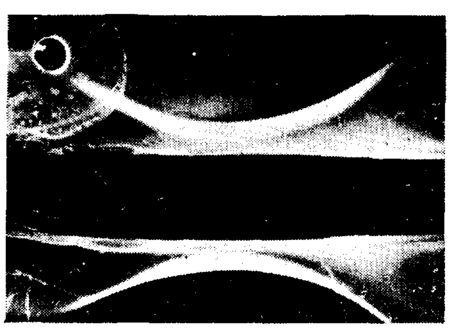

Fig. 1. Immunoelectrophoresis of precipitable (top) and nonprecipitable (bottom) fractions obtained from reaction of concanavalin A with serum of a patient with IgG myeloma of heavy-chain subtype γ_3. Both fractions are diluted 1 to 3 with respect to original serum. The antiserum is horse antiserum to human IgG.

Precipitable and nonprecipitable fractions were analyzed electrophoretically. Depending on the IgG myeloma serum, the quantity of IgG precipitated by concanavalin A varied from approximately 50 percent to mere traces of the total present. Immunoelectrophoretic patterns of the most reactive, an IgG myeloma serum of heavy-chain subtype γ_3, are shown in Fig. 1. Our limited data do not yet permit correlation of heavy-chain subtype with reactivity towards concanavalin A. In all reactive serums, the dissociated myeloma protein showed the same electrophoretic mobility as the myeloma protein of the original serum. Increasing the ratio of concanavalin to serum above 30 mg/ml did not significantly increase the amount of myeloma protein precipitated. If one accepts the theory that monoclonal myeloma protein in an individual serum is homogeneous with respect to amino acid sequence, then all molecules of myeloma protein have the same range of conformational possibilities in equilibrium. Carbohydrate chains attached to these molecules should show similar reactivity with concanavalin A provided that the carbohydrate chains are identical and are attached at the same position in the peptide chain. The partial precipitation of IgG myeloma proteins by concanavalin A, demonstrates existence of some type of heterogeneity of each IgG myeloma carbohydrate. The data further suggest that a given sequence of amino acids either does not uniquely determine the structure, or does not uniquely determine the location, of the carbohydrate attached to the peptide chain. These findings extend, by entirely different techniques, those reported of carbohydrate heterogeneity in an IgA myeloma globulin (*7*).

Despite the observation that small amounts of IgG are precipitated by concanavalin A, the preparation of IgM is greatly facilitated by a preliminary precipitation of the serum with concanavalin A. The chromatographic behavior of concanavalin A makes it readily separable from IgM and from most other serum glycoproteins. When the dissociated mixture of concanavalian A and glycoproteins is applied to diethylaminoethyl Sephadex at ionic strength above 0.02, in tris buffer at *p*H 8.0, the concanavalian A is not bound. A competitive inhibitor of concanavalin A such as 0.2*M* methyl α-D-glucoside must be added to block recombination of concanavalin A with serum glycoproteins in the column.

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Hormone-Dependent Differentiation of Immature Mouse Mammary Gland in vitro

Abstract. *Explants from the mammary glands of 3-week-old mice can be induced to synthesize casein in vitro in the absence of lobuloalveolar development. Maximum biochemical differentiation requires the presence of insulin, hydrocortisone, and prolactin in the culture medium. In contrast to explants from adult mice, the mammary epithelium of immature animals undergoes DNA synthesis and mitosis in vitro in the absence of exogenous insulin; however, such proliferation does not lead to the formation of differentiated daughter cells. Insulin acts in at least two ways during the proliferative phases of the cell cycle of differentiating mammary epithelial cells.*

Mammary gland epithelial cells in explants derived from pregnant or nonpregnant mature mice proliferate, assume a secretory appearance, and begin to synthesize certain milk proteins when cultured in the presence of insulin, hydrocortisone, and prolactin (*1–4*). This functional differentiation of the epithelial cells has been found to be necessarily coupled to their proliferation (*5–7*). Synthesis of DNA and subsequent cell division require only insulin; however, proliferation does not lead to differentiation unless hydrocortisone and prolactin are present in the culture medium. The sequence of action of the hormones in relation to the cell cycle in explants of mammary gland from pregnant mice has been described (*8*).

Although the relationships between hormone-dependent proliferation and differentiation have been characterized in the mature gland, the biochemical behavior of the immature gland in vitro has been less clear. We examined the capacity of the immature tissue to differentiate in vitro and compared the requirements for and responses to the hormones with those of the mature tissue.

Although the onset of "maturity" is variable, 21-day-old female weanling mice of the C3H/HeN strain are termed immature in our report. The glands of the 21-day-old mouse consist principally of branching ducts several cell layers thick with terminal buds. No alveoli are seen in serial sections, nor have any been seen in whole mounts in other laboratories (*9*).

Mammary epithelial cells in immature animals proliferate into the mammary fat; yet, as the animal matures, proliferation virtually ceases and does not resume until pregnancy. We confirmed this by injecting thymidine-H^3 (1 μc per gram of body weight) intraperitoneally and preparing autoradiographs of the mammary gland 24 hours later. Only about 1.5 percent of the epithelial cells from 3-month-old mice were labeled, whereas 18 percent of the epithelial cells from 3-week-old animals were labeled. It is unlikely that the results reflect a difference in pool size, because almost all the labeled nuclei had approximately 35 to 40 grains.

Synthesis of DNA in vitro by mammary epithelial cells from mature mice is completely dependent on the presence of insulin in the culture medium (*5–7*). In contrast, our studies indicate that DNA synthesis in vitro by mammary gland explants derived from immature mice [as reflected by the amount of thymidine-H^3 incorporated during 4-hour periods as previously described (*5*)] is quantitatively independent of the addition of insulin. Since these explants contain large numbers of fibroblasts whose DNA synthesis is insulin-independent, data on total incorporation of thymidine-H^3 must be interpreted with caution. To determine whether such incorporation of thymidine-H^3 into DNA reflected epithelial cell activity, we made autoradiographs of explants exposed to thymidine-H^3 (1 μc/ml) for 72 hours. Similar explants were cultured in the presence of colchicine (0.05 μg/ml) for 72 hours and were examined for mitotic activity.

The duct epithelium, especially the epithelium of smaller terminal branches, was heavily labeled, and mitotic figures were numerous in either the presence or absence of insulin in the cultures. In explants cultured without the addition of hormones, 12 percent of the cells were in metaphase (5000 epithelial cells counted); in those cultured in the presence of insulin, 9 percent were in metaphase (5000 epithelial cells counted); and in those cultured in the presence of hydrocortisone and prolactin, 11.5 percent were in metaphase (1000 epithelial cells counted). In contrast to tissue from mature mice (*5–7*) then, proliferation of mammary epithelial cells from immature animals occurs in vitro in the absence of exogenous insulin. However, proliferation in the absence of exogenous insulin does not lead to functional differentiation.

Figure 1 shows that explants of mammary glands of immature mice can be induced to synthesize the major casein components when cultured in the presence of insulin, hydrocortisone, and prolactin. During the first 24 hours, the synthesis of casein bands 2, 3, and 4 is virtually undetectable, but by the 4th or 5th day these proteins are synthesized at greatly accelerated rates in ratios similar to those observed in tissue from mature animals (*10*). Casein band 1, a more heavily phosphorylated component (*11*), is present from the start and is least affected by culture. This component persists longest in mature tissue cultured in incomplete hormone systems (*10*).

Figure 2 shows patterns of casein production during the 5th day of culture in several media. The full differentiative response is elicited only when the three hormones are present. Of the incomplete systems, only those containing insulin are even partially effective, and insulin alone is as effective as it is in combination with hydrocortisone or prolactin. In the absence of insulin, not even band 1 is sythesized.

The hydrocortisone-prolactin system (Fig. 2), in which proliferation occurs

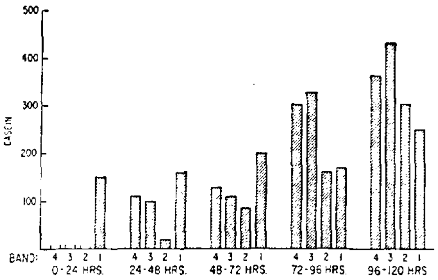

Fig. 1. Effect of culture on synthesis of the major casein components. Explants weighing 0.5 to 1 mg were prepared and cultured in sterile "Medium 199" (2). The medium contained 5 μg/ml each of crystalline beef insulin (Lilly), ovine prolactin (NIH Endocrinology Study Section), and hydrocortisone. Explants were exposed to P^{32}-labeled inorganic phosphate (75 μc/ml) during the times indicated and then were homogenized in the presence of mouse carrier casein. Total casein was isolated by precipitation with calcium and rennin and was further characterized with vertical starch-urea gel electrophoresis at *p*H 8.6 (*13*). Bars represent counts in gel sections corresponding to the four major casein bands with appropriate background subtracted (*10*). Ordinate refers to radioactivity in terms of counts per minute per centimeter per 10 mg of tissue.

in the absence of insulin, did not synthesize casein. Furthermore, when explants were cultured in such a hydrocortisone-prolactin system for 96 hours and insulin was then added during the final 24 hours, no effect on casein synthesis was observed. This suggests that actions of insulin other than postmitotic synergism with prolactin (*8*) and initiation of DNA synthesis (*7*) must occur before functional differentiation can be expressed. Insulin, then, exerts its influence on mammary tissue in at least three ways: (i) it is necessary for the initiation of DNA synthesis by epithelial cells of mature tissue as a prelude to functional differentiation (*5–7*); (ii) it must be present during the postmitotic action of prolactin (*8*) when phenotypic differentiation is expressed; (iii) it is required during the early proliferative phases of immature cells in some capacity other than initiation of DNA synthesis which, alone, cannot lead to differentiation.

Thus, even though immature tissue differs from the mature in displaying insulin-independent DNA synthesis and mitosis, such proliferation apparently does not lead to functional differentiation unless it occurs in the presence of insulin.

Although casein bands 2, 3, and 4 are not detectably synthesized by explants of immature mammary gland during the 1st day of culture in the presence of all three hormones, such explants synthesize α-lactalbumin and β-lactoglobulin. Tissue was exposed to C^{14}-labeled algal hydrolyzate (10 μc/ml). Explants were homogenized in mouse skim-milk carrier, and then α-lactalbumin and β-lactoglobulin were isolated by ammonium sulfate fractionation and electrophoresis on polyacetate strips as previously described (*2*). When the culture was exposed to the hydrolyzate from 0 to 24 hours, the rate of synthesis of α-lactalbumin was 310 count/min and of β-lactoglobulin 295 count/min per milligram of tissue. When the period of exposure was 72 to 96 hours, the rate of synthesis of α-lactalbumin was 880 count/min and of β-lactoglobulin 510 count/min per milligram of tissue. Thus, the emergence of the capacity to synthesize the various milk proteins is asynchronous in this immature tissue.

Ichinose and Nandi reported (*9*) that lobuloalveolar development in mammary explants from immature mice rarely occurs unless the mice have previously been primed with injections of estrogen, progesterone, prolactin, and growth hormone. Our work confirms this observation. Culture of unprimed explants in the presence of insulin, hydrocortisone, and prolactin elicits the biochemical differentiation described above, but there is little or no formation of alveolar structures. If, however, the animals are primed on each of 7 days with estradiol-17β (1 μg), progesterone (1 mg), and growth hormone (50 μg) before explantation of the mammary tissue into medium containing insulin, hydrocortisone, and prolactin, alveolar structures develop in vitro. Under these primed conditions, the rate of thymidine-H^3 incorporation into DNA was approximately doubled [perhaps due to a shortened S-phase (DNA synthesis) as suggested by Banerjee (*12*)], and the development of casein production was accelerated about 24 hours, compared to tissue from unprimed mice. Thus, it is possible to dissociate structural development from biochemical development in vitro with mammary tissue from unprimed immature mice.

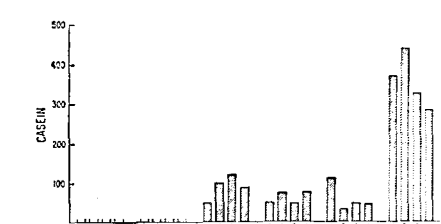

Fig. 2. Effect of culture on synthesis of casein components in incomplete hormone systems. Explants were cultured as in Fig. 1 but in the incomplete hormone system shown. Pulse labeling with P^{32}-labeled inorganic phosphate was from 96 to 120 hours in all cases. Because these experiments involve systems lacking insulin, the series was repeated with glucose replaced in the medium by D-fructose (100 mg/ml). No difference was noted. *NH*, no hormones; *I*, insulin; *F*, hydrocortisone; *P*, prolactin. Ordinate refers to radioactivity in terms of counts per minute per centimeter per 10 mg of tissue.

Our studies in vitro with mammary gland explants from immature mice revealed that: (i) the epithelium differs from that of the mature gland in that DNA synthesis and mitosis occur in the absence of exogenous insulin; (ii) this insulin-independent proliferation does not result in the appearance of differentiated daughter cells; (iii) addition of insulin to the cultures does not quantitatively affect DNA synthesis or mitosis but allows functional differentiation to occur when hydrocortisone and prolactin are present; (iv) emergence of the ability to synthesize casein bands 2, 3, and 4 is not synchronized with the appearance of whey-protein synthesis; and (v) it is possible in vitro to dissociate the capacity to synthesize secretory proteins from structural development of this tissue.

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20 September 1967

Cerebellar Purkinje Cell Projection to the Peripheral Vestibular Organ in the Frog

Abstract. *Neurones located 200 to 300 microns from the surface of the auricular lobe of the frog cerebellar cortex, and identified as Purkinje cells, were activated antidromically from the eighth cranial nerve. A parallel anatomical study confirmed the existence of this projection. On the basis of these findings the existence of a cerebello-vestibular efferent system is postulated, the precise significance of which is as yet unclear. However, since Purkinje cells in other species have an inhibitory action on their target cells, the Purkinje efferent system to the vestibular organ may have an action similar to that ascribed to the olivo-cochlear bundle upon the cochlea, that is, to serve as an inhibitory control system.*

An outstanding characteristic of the neural organization of the cerebellum throughout evolution has been the presence of only one efferent system from the cerebellar cortex—the Purkinje cell axons. While most of these axons project directly to the underlying cerebellar nuclei (*1*, *2*), anatomists have described many extranuclear projections in different species (*2*, *3*). Recent physiological evidence has confirmed the existence of these extranuclear projections (*4*) and, in addition, has shown that Purkinje cells have an inhibitory action on cerebellar and vestibular nuclei (*4*). Furthermore, the axon collaterals of Purkinje cells are inhibitory on cerebellar basket cells (*5*) and directly to Purkinje cells themselves (*6*).

So far, however, the cerebellar projections described have been restricted to systems involved in motor control, no direct relation having been found between cerebellar efferents and primary sensory systems. Our experiments, on the other hand, indicate that, in the frog, auricular Purkinje cells project directly to the peripheral vestibular organ.

The general experimental procedures have been described (*7*, *8*). Bullfrogs (*Rana catesbiana*) were anesthesized with pentobarbital sodium (60 mg per kilogram of body weight), and the eighth nerve was stimulated electrically by means of bipolar electrodes located extracranially in its anterior or posterior branches (Fig. 1A). Extracellular and intracellular recordings from Purkinje cells were performed with micropipettes filled with 4*M* NaCl and 3*M* KCl, respectively. The average direct-current resistance of the extracellular recording electrode was 5 megohms; that of the intracellular one was 10 megohms. As in previous experiments (*8*), the threshold current for electrical stimulation of the eighth nerve was measured at the initiation of the experiment and was never increased above 2.5 times threshold.

Electrical activation of the eighth nerve evokes activation of Purkinje cells in the frog auricular lobe via climbing and mossy fibers (*8*). The activation of cat (*9*) and frog Purkinje cells (*10*) by climbing fibers has been characterized by an all-or-none burst of spikes having a very regular pattern of discharge and an almost constant latency. Activation by mossy fibers, on the other hand, produces, in the cat, activation of Purkinje cells which has variable latency (*11*). Similar findings have been reported for the frog cerebellum (*7*, *8*, *12*). Our report, however, deals almost exclusively with Purkinje cell activation of short latency, which has been ascribed to the antidromic invasion of Purkinje cells (*7*, *12*).

Giant extracellular positive-negative action potentials were recorded from the frog auricular lobe after threshold electrical stimulation of the eighth nerve (Fig. 1, B and C). Four criteria were used to identify these action potentials as those generated by Purkinje cells: (i) their antidromic activation from extracerebellar regions (*6*, *10*, *12*, *13*), (ii) their characteristic large extracellular action potentials, the so-called "giant spikes" (*13*), (iii) their orthodromic activation by stimulation of parallel fibers (*7*, *10*, *14*), and (iv) in the auricular lobe, their depth from the piaglial membrane, that is, 200 to 300 μ from the surface (*8*). Forty-seven cells were studied; their latency is illustrated in Fig. 1K. A large number of Purkinje cells activated at longer latencies were not included since their latencies put them outside the scope of this paper.

There appear to be two groups of action potentials activated by stimulation of the eighth nerve (Fig. 1K). The

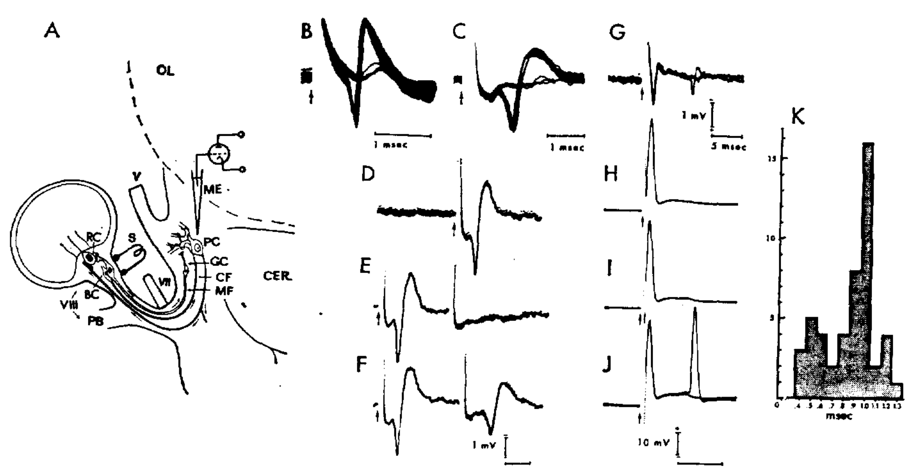

Fig. 1. (A) Diagram of frog brainstem, labyrinth, and experimental arrangement; *BC*, bipolar ganglion cells; *CER*, cerebellum; *CF*, climbing fiber; *GC*, granule cell; *ME*, recording microelectrode; *MF*, mossy fiber; *OL*, optic lobe; *PC*, Purkinje cell; *RC*, receptor cell; *S*, peripheral nerve stimulating electrode; *V*, trigeminal nerve; *VII*, facial nerve; *VIII*, stato-acoustic nerve; *PB*, posterior branch; arrows indicate the direction of impulse conduction. (B–F) Antidromic extracellular action potentials from Purkinje cells in the auricular lobe, recorded at a depth of 250 μ and evoked by stimulation of the eighth nerve. (B and C) All-or-none spike responses at threshold intensity from two different Purkinje cells. (D–F) Purkinje cell action potentials evoked by activation of the eighth nerve at 1.3 times the threshold. (D) Control. (E) Refractory period for antidromic invasion of the Purkinje cell after double shocks with a short interval between stimuli. (F) As in E, but with longer interval between stimuli, showing second Purkinje spike. (G and H) Extracellular and intracellular recording from a Purkinje cell in the auricular lobe at a depth of 300 μ activated antidromically and synaptically by stimulation of the eighth nerve. (G) Extracellular record. (H and I) Intracellular records of the same cell showing the antidromically excited action potential and an excitatory postsynaptic potential. (J) At slightly higher stimulus intensity the Purkinje cell shows also a transsynaptic response. (K) Latency histogram of the early spike responses after stimulation of the eighth nerve. Abscissa, time in milliseconds. Ordinate, number of Purkinje cells recorded. The arrows in B–J indicate stimulus artifact location. Time and voltage calibration as indicated. The polarity is expressed by the positive and negative signs on the amplitude calibrating bar.

first group has its peak at 0.5 msec, whereas the second has a peak at about 1.0 msec. Cell B is an example of a cell having an action potential with a short latency, which is about 0.5 msec; cell C has a latency of approximately 0.9 msec.

All the cells in Fig. 1K could follow repetitive activation ranging from 200 to 400 stimulations per second and demonstrated a refractory period in the range of 3 to 4 msec with a relatively small shift in latency for the second invasion near the refractory period (shift less than 0.5 msec). Figure 1, D to F, illustrates the refractory period of cell C which was 3 msec for the antidromic invasion. If the interval between the two stimuli was increased to 3.2 msec (Fig. 1F), a smaller action potential was recorded (see Fig. 1D) which had a larger initial segment-somadendritic (IS-SD) separation (*6*).

The extracellular antidromic action potentials evoked by stimulation of the eighth nerve have characteristics very similar to those already recorded by Matthews *et al.* (*12*) who demonstrated that, when a pair of stimuli are delivered at short intervals to the cerebellar white matter, there is a delay in the second response of the Purkinje cell. We frequently observed this phenomenon during our experiments (Fig. 1F). Furthermore, there was, in many instances, a large reduction of the amplitude of the second action potential, suggesting that the cell had not completely recovered from the preceding spike (Fig. 1F).

Figure 1, G to J, illustrates extracellular and intracellular recordings from other Purkinje cells after stimulation of the eighth nerve. In Fig. 1G, an activation of the eighth nerve with a stimulus 1.7 times greater than the threshold stimulus evoked an antidromic as well as an orthodromic action potential. In Fig. 1, H to J, a similar cell from the same electrode tract was impaled intracellularly. As the stimulus strength increased from 1.2 to 1.5 times the threshold stimulus, a subthreshold excitatory postsynaptic potential was seen (Fig. 1I). In Fig. 1J an orthodromic activation was obtained with a stimulus strength of 1.8 times the threshold strength. In Fig. 1, I and J, the stimulus artifact interfered with the rising phases of the antidromic action potential. As in previous studies, intracellular impalement of frog Purkinje cells proved very difficult, for which reason both the resting potential (approximately 40 mv) and the action potential were smaller than expected (*7, 12*).

The orthodromic activation of Purkinje cells after stimulation of the eighth nerve may be ascribed to at least three pathways; two originate directly from the vestibular bipolar cells (Fig. 1A), and the third is the vestibulo-cerebellar projection through the vestibular nuclei. The two direct pathways end as climbing and mossy terminals in the cerebellar cortex (*8*). However, since activation of auricular Purkinje cells by climbing fibers can be recognized by its short latency and characteristic burst activation (*8*), the aforementioned response must be evoked by mossy terminals. It has not been determined which of the two systems of mossy fibers, the direct vestibulo-cerebellar system or the disynaptic system through the vestibular nuclei, is responsible for the activation in Fig. 1, G and J. Since the latency is fairly long, (7.5 and 5.0 msec) however, these action potentials may be evoked by disynaptic vestibulo-cerebellar fibers.

On the basis of these data, we conclude that a number of Purkinje cells from the auricular lobe project directly

Fig. 2. Electron micrograph of retrograde changes in a Purkinje cell and degenerating synaptic terminal on to vestibular receptor cells. (Top) Retrograde changes in a Purkinje cell of frog auricular lobe 4 days after ipsilateral transection of the stato-acoustic nerve extracranially (*RPC*). Note the dark ring formed around the cell nucleus by the rearrangement of the endoplastic reticulum; note also the normal appearance of the adjacent Purkinje cell (*NPC*) (× 5500). (Bottom) Degenerating synaptic terminal 3 days after ipsilateral removal of cerebellar cortex in the frog (*DSB*). Note the darkness of the terminal and the clustering of the mitochondria. *RC*, vestibular receptor cell; *SC*, supporting cell (× 39000).

to the peripheral vestibular organ, and that there appear to be two groups with different conduction velocities. Moreover, a parallel light- and electron-microscopic study has confirmed the existence of the direct cerebello-vestibular pathway in the bullfrog by showing that section of the eighth nerve extracranially produces degeneration of both climbing and mossy fibers, as well as characteristic retrograde changes in the somas of Purkinje cells (*15*). The latter finding (Fig. 2, top) directly confirms the thesis that Purkinje cells send axons or axon collaterals to the vestibular organ. In addition, if the cerebellar cortex is removed, care being taken not to injure the cerebellar nuclei, one can demonstrate degenerating synaptic boutons in contact with the peripheral vestibular receptor cells (Fig. 2, bottom) (*15*).

The aforementioned results demonstrate the existence of a cerebello-vestibular efferent system in the frog. Previous anatomical and physiological studies have indicated the presence of an efferent system to the peripheral vestibular organ. In the case of the cat, light- (*16*) and electron-microscopical studies (*17*) have revealed efferent terminals on the vestibular receptor cells. Furthermore, direct-current potential changes have been recorded from the surface of the semicircular canals following stimulation of the central nervous system (*18*). In the frog, recent electron-microscopical studies have verified the existence of this efferent system (*19*), which had been suspected on the basis of earlier physiological findings (*20*). The origin of the efferent system was, however, unknown.

Since the cerebellum develops in very close relation with the stato-acoustic system and since a certain component of the vestibular projection to this center is direct in both lower (*21*) and higher vertebrates (*2*), it seems possible that the cerebellum has some direct action upon the peripheral organ. Occasionally we observed direct-current potential changes at the frog vestibular organ following the stimulation of the auricular lobe; however, no clear physiological meaning has so far been attached to this finding.

Although the functional significance of the cerebello-vestibular system has not been ascertained, this system may be inhibitory in nature, as is the olivocochlear bundle (*22*), particularly since Purkinje cells inhibit all target cells so far studied (*4*). The demonstration of a direct cerebello-vestibular pathway in the frog implies that, at least in this form, the cerebellum is not involved in motor control exclusively, but has a sensory regulatory role as well.

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Erythrocyte Transfer RNA: Change during Chick Development

Abstract. *Radioactive aminoacyl transfer RNA's isolated from erythrocytes in the blood of 4-day-old chick embryos and from reticulocytes of adult chickens were analyzed by chromatography on methylated albumin kieselguhr and freon columns. Embryonic and adult methionyl transfer RNA's showed qualitative and quantitative differences in both chromatographic systems. The patterns for arginyl, seryl, and tyrosyl transfer RNA's in the two cell types were similar, while the leucyl transfer RNA patterns suggested a difference.*

Structural modification of transfer RNA (tRNA) may play a regulatory function in cell differentiation and metabolism (*1*). With methylated albumin kieselguhr (MAK) chromatography, Kano-Sueoka and Sueoka (*2*) demonstrated an alteration in leucyl-tRNA after bacteriophage T2 infection of *Escherichia coli*; this finding was confirmed by Waters and Novelli (*3*), using the reversed-phase chromatography developed by Kelmers *et al.* (*4*). Kaneko and Doi (*5*) found a change during sporulation of *Bacillus subtilis* in the elution pattern of valyl-tRNA from MAK columns.

To look for changes in specific tRNA's during development, we used avian immature red cells as a test system and compared the chromatographic profiles of aminoacyl-tRNA's from red cells present in the blood of 4-day-old chick embryos and of reticulocytes of adult chickens. The techniques in this study were MAK (*2*) and freon columns (*6*). Of the five aminoacyl-tRNA's examined, only the methionyl-tRNA gave a strikingly different elution pattern.

Adult chickens (White Leghorn) were made anemic by daily injection (for 5 days) of 15 mg of phenylhydrazine [in 0.1*M* tris(hydroxymethyl)aminomethane (tris) buffer, *p*H 7.2] and were bled on the 6th day. Eggs from the same strain were incubated at 37°C for 4 days, and blood cells were collected by bleeding the embryos. Blood cells from either source were washed twice with 0.145*M* NaCl, $5 \times 10^{-4}M$ KCl, and 0.0015*M* $MgCl_2$, and once with 0.145*M* NaCl, $5 \times 10^{-4}M$ $FeCl_2$, and 0.01*M* phosphate buffer (*p*H 7.4); 0.12 ml of packed embryonic cells was suspended in the latter medium supplemented with glucose (200 mg/ml) with a total volume of 0.5 ml. For adult cells, 0.5 ml of packed cells was similarly incubated in a total volume of 2.0 ml. To cells previously incubated at 38°C for 10 minutes, ^{14}C- or ^{3}H-labeled amino acid (5 to 10 μc) and the 19 remaining nonradioactive amino acids (1 μmole of each) were added. After incubation for an additional 12 minutes, cycloheximide ($10^{-4}M$) was added to inhibit protein synthesis (*7*) and thus prevent the transfer of amino acids from aminoacyl-tRNA's. After 10 minutes more, the cells were lysed by suspension in 5 volumes of 0.01*M* tris, 0.01*M* KCl, and 0.0015*M* $MgCl_2$ containing 15 mg of purified bentonite per milliliter (*8*) and by repeated freezing (in a mixture of dry ice and acetone) and thawing. The lysate was extracted with a half volume of carbon tetrachloride, and the upper phase was shaken for 15 minutes with an equal volume of twice-distilled, buffer-saturated phenol. The aqueous phase was extracted again with phenol, and traces of phenol were removed with cold, peroxide-free ether. The solution was then adjusted to 0.1*M* with sodium acetate buffer (4*M*, *p*H 6), and then 2 volumes of cold ethanol were added. After several hours at −20°C, the precipitated RNA was collected by centrifugation, washed with cold ethanol, and dried. The yields of tRNA from the above-mentioned volumes of packed cells were 1.3 optical density (O.D.) units (260 mμ) and 0.85 O.D. units for embryonic and adult cells, respectively.

The MAK column (1 by 3 cm) was similar to that of Kano-Sueoka *et al.* (*2*); it contained 1 g of kieselguhr and 0.25 ml of 1-percent methylated albumin, because only small quantities of material were available for analysis. The second change was the use of a shallower gradient of 0.20 to 0.65*M* NaCl (250 ml in total volume).

The freon column used was a modification of the method of Weiss *et al.* (*6*). Radioactive aminoacyl-tRNA's, together with 5 mg of carrier unlabeled tRNA's (*9*), were applied to a column (0.5 by 250 cm). Elution was effected with a concave NaCl gradient containing 0.01*M* sodium acetate and 0.01*M* $MgCl_2$ (*p*H 4.5) at room temperature. Fractions (2 ml) were collected at 12-minute intervals.

Optical density was measured at 260 mμ on alternate fractions. A sample (1 ml) of each fraction was then mixed with 10 ml of Bray's solution (*10*), and the radioactivity was measured in an Ansitron liquid-scintillation counter.

Aminoacyl-tRNA's isolated from erythrocytes of 4-day-old chick embryos and from reticulocytes of adult chickens were compared first by chromatography on the MAK column and then on the freon column. The specific tRNA's examined were: arginine, leucine, methionine, serine, and tyrosine. Typical results of the MAK chromatographs are shown in Fig. 1. With the exception of the methionyl-tRNA, which gave a clear alteration in the elution profiles, there were no significant differences in the profiles between the aminoacyl-tRNA's from the two sources. Under the present chromatographic conditions, both the adult- and the embryonic-cell methionyl-tRNA showed two major peaks in MAK chromatography. However, a dramatic change during development in the proportion of methionyl-tRNA in the two major peaks was observed. The ratio of the areas under the peaks which was 1.1 in the embryonic cells shifted to 3.8 in the adult cells.

Figure 2 shows the elution patterns of the aminoacyl-tRNA's on the freon column. The better resolution of this chromatographic system revealed the presence of multiple peaks for several of the amino acids tested (arginine, leucine, and methionine). No significant difference was observed between the elution patterns of the embryonic and adult cells of the amino acids arginine, leucine, serine, and tyrosine. However, the elution profiles of the methionyl-tRNA's from cells of the two different developmental stages showed a striking alteration. Although both the adult and the embryonic methionyl-tRNA's gave two resolvable peaks, the proportions of the two peaks differed. The ratio of the peaks was 1.3 for the embryonic cells and 2.7 for the adult cells. These results were similar to those found with the MAK column. In addition, the two peaks for the embryonic cells were further apart; a small third peak was observed, but its significance is doubtful.

The chromatograph of leucyl-tRNA from avian reticulocytes differed strikingly from that from *E. coli* B on both

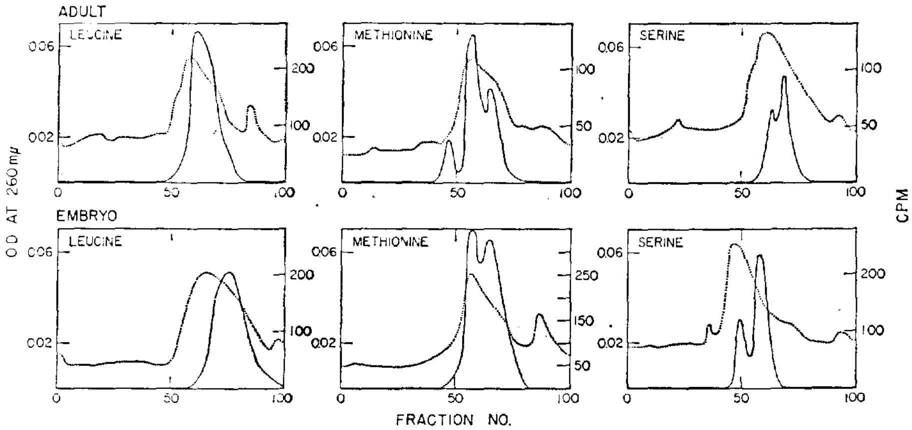

Fig. 1. Elution profiles of aminoacyl-tRNA's of blood cells from embryonic and adult chickens on MAK columns. Dotted lines, optical density at 260 mμ; solid lines, radioactivity. Amino acids labeled with ^{14}C were used in the preparation of all aminoacyl-tRNA's.

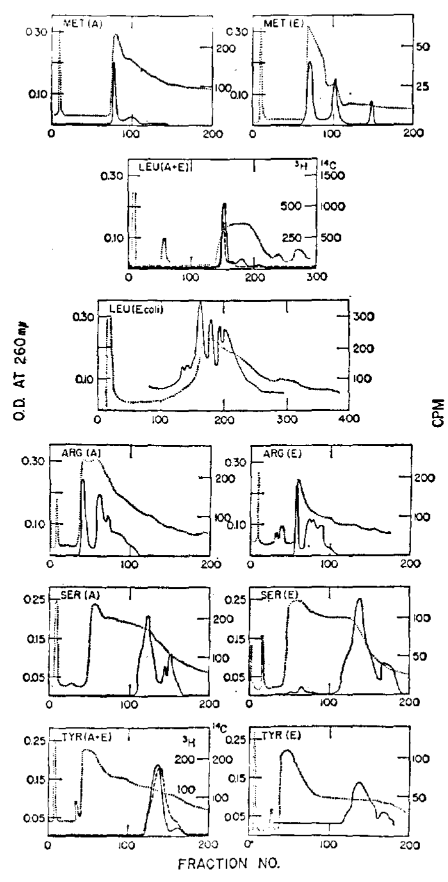

Fig. 2 (right). Elution profiles of aminoacyl-tRNA's on freon columns. Avian aminoacyl-tRNA's were prepared as described. The following samples were prepared with ^{14}C-labeled amino acids: arg (A), arg (E), leu (E), met (A), ser (E), and tyr (A), whereas leu (A), met (E), ser (A), and tyr (E) were acylated with ^{3}H-labeled amino acids. *Escherichia coli* leucyl-tRNA was prepared as described by Kano-Sueoka and Sueoka (*2*). Dotted lines, optical density at 260 mμ; solid lines, radioactivity. (In the double-labeling experiments, ^{14}C is shown by a solid line, and ^{3}H is shown by a dashed line.)

the MAK and the freon columns. A typical elution profile of the bacterial leucyl-tRNA on the latter column is shown in Fig. 3. There were at least four major peaks in the bacterial system, but only two were detected in the avian system. Moreover, the elution profiles of adult and embryonic leucyl-tRNA's appeared to differ slightly. The two embryonic peaks were further apart. However, the significance of this difference is not clear at the moment.

Thus, the analysis of aminoacyl-tRNA's from immature erythrocytes of chick embryos and from reticulocytes of adult chickens by chromatography on the MAK and freon columns has revealed that the elution pattern for methionyl-tRNA changes during development, whereas the patterns for the four other amino acids studied remain essentially unaltered with a possible difference for leucyl-tRNA. However, it is possible that changes in other untested tRNA's may exist. The fact that remarkably similar elution patterns of the other aminoacyl-tRNA's were observed apparently eliminates the possibility of ribonuclease activity as a major factor in the observed change in methionyl-tRNA. In a later experiment, we examined the embryonic methionyl-tRNA with the use of the same ^{14}C-methionine sample as we had used for the adult tRNA in Fig. 2. Because the expected embryonic pattern was observed, it seemed unlikely that the difference illustrated in Fig. 2 is due to contamination in the ^{3}H-methionine. The identical elution profiles obtained either by ^{14}C-, ^{3}H-, double-, or single-labeling techniques (as in the case of tyrosyl-tRNA) demonstrated that these profiles are reproducible and reliable.

The actual mechanism and biological significance of this change are not clear at the moment. The observed modification in methionyl-tRNA during development may be a change of either the tRNA molecules or of the specificities of the aminoacyl-tRNA synthetases involved. The tRNA may also be involved in the regulation of protein synthesis at the translational level (*1*). Moreover, our finding is of particular interest because *N*-formyl-methionyl-tRNA from *E. coli* plays a crucial role in the initiation of protein synthesis in bacteria (*11*). Two methionyl-tRNA's of *E. coli* have been reported (*12*); one of these can be converted to *N*-formyl-methionyl-tRNA, and the other does not accept formyl groups. Our finding that methionyl-tRNA's are modified during development agrees with the expectation based on the model of regulation that a change in tRNA molecules may lead to an alteration in their functional capacity and thus may affect translation.

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A Mutagenic Effect of Visible Light Mediated by Endogenous Pigments in Euglena gracilis

Abstract. *Mutant cells lackng chlorophyll, chloroplasts, and chloroplast DNA were produced by irradiating* Euglena gracilis *in aerobic conditions with visible or red light (greater than 610 nanometers) of an intensity equivalent to that of direct sunlight. The photosensitizer is apparently the endogenous chlorophyll present in the chloroplasts. These mutants are comparable to those induced by ultraviolet light, x-rays, heat, or streptomycin. Our findings indicate that visible light can serve as a mutagenic agent in the absence of exogenous photosensitizers, thus directly effecting the course of evolution of organisms containing chlorophyll.*

In the presence of a suitable exogenous photosensitizing dye, cells exposed to visible light and air display a photodynamic action, which can be lethal (*1*) or mutagenic (*2*) in nature. In the latter case the photosensitizer can be preferentially bound to nucleic acids (*3*) and may act directly as a "photomutagenic" agent, whereas, in other cases, the mutagenic mechanism is not clearly understood (*4*). In the absence of an exogenous photosensitizer, it has not been possible to demonstrate mutagenesis with visible light under normal physiological conditions. Kaplan and Kaplan (*5*) have reported the appearance of *S*-mutants of *Serratia marcescens* from cells which had been initially dehydrated and then rehydrated and exposed to visible light. Except for this experiment, it is generally held that light with wavelengths above 300 nm has primarily lethal action but very little mutagenic action (*6*), although there is no doubt that near-visible light (320 to 400 nm) can be mutagenic (*7*). The conditions which limit mutagenesis with visible light include the absence of endogenous photosensitizers or the development of suitable protective mechanisms such as those which operate to prevent the damage caused by aerobic photosensitivity (*8*). We report here the induction of a mutation (that is, a stable, heritable change expressed in the phenotype) by visible light in *Euglena gracilis* in the absence of exogenous photosensitizers.

Euglena gracilis var. *bacillaris* was cultivated on Hutner's medium (*p*H 3.5) with continuous shaking under visible light (275 lumen/m^2) (*9*). Cells taken during the logarithmic phase of growth were transferred to flat-sided tissue-culture flasks and immersed in an aquarium tank maintained at 23°C. Air was bubbled through the flasks for the duration of the experiment, both to insure adequate aeration and to avoid settling of the cells. Illumination was by means of a Sylvania Sun Gun II (650 watts), and the intensity was determined with a Yellow Springs Industry radiometer, Model 65. For those experiments involving red-light irradiation, a Corning C.S. No. 2-61 glass filter which transmits light only above 610 nm, was placed in front of the culture flask. Illumination was continued for as long as 6 hours, during which time the temperature within the flask, monitored with an electronic thermometer, was maintained between 23° to 24°C. Energies of illumination were as high as 8.5×10^6 erg cm^{-2} sec^{-1} in visible light and 6.9×10^6 erg cm^{-2} sec^{-1} in red light. At appropriate time intervals, samples were removed and plated on agar as described previously (*10*). The number of colonies were counted after a 7-day incubation at 26°C under 880 lumen/m^2.

Euglena gracilis cells illuminated with white light under aerobic conditions demonstrate a photosensitized oxidation or bleaching of chlorophyll. Under anaerobic conditions there is no loss of pigment (Fig. 1). The bleaching process in air consists of an initial lag period followed by a rapid disappearance of chlorophyll. This lag period can be shortened or abolished by the use of 95 percent O_2 and 5 percent CO_2 as the gas phase. These patterns are similar to those described for *Chlorella pyrenoidosa* (*11*). The lag period presumably represents the time during which the normal protective mechanism is still capable of operating. Based on their studies with carotenoid-deficient bacteria, Sistrom *et al.* (*12*) have suggested that this mechanism involves carotenoid pigments acting as "chemical buffers" to protect cells against photosensitized oxidations. In *E. gracilis,* Krinsky (*13*) has proposed that the carotenoids zeaxanthin and antheraxanthin (5,6-epoxy-zeaxanthin) function as protective pigments. This mechanism would only remain effective as long as antheraxanthin deepoxidase (*14*) reduced antheraxanthin to zeaxanthin at a rate commensurate with the epoxidation of zeaxanthin to antheraxanthin by visible light and O_2 (*15*). Under conditions of high light intensity, this protective mechanism could no longer cope with the rate of oxidation, and various effects of aerobic photosensitivity, including pigment bleaching and death would occur.

The duration of the lag period seen in Fig. 1 and the time needed for complete bleaching depend on light intensity, cell concentration, and the growth phase of the culture. Cells in the early exponential phase bleach more rapidly than do cells in the late exponential phase. Similar results have been reported for photosensitization in *Rhodotorula glutinis* (*16*).

Previous attempts to photosensitize *E. gracilis,* with the light from a continuous-wave gas laser (29 mw) emitting at 632.8 nm in the absence of exogenous photosensitizers, have failed (*17*). Even after a 90-minute exposure to this intense laser beam, no cell death could be demonstrated, and MacMillan *et al.* (*17*) concluded that the cells did not contain a photosensitizer which could absorb at 632.8 nm. As shown below, however, a broader source of red light can bring about photosensitization in the absence of exogenous photosensitizers in *E. gracilis.*

White mutant colonies developed from cells surviving either high light intensities (8.5×10^6 erg cm^{-2} sec^{-1}) or intensities equivalent to bright sunlight (4.5×10^6 erg cm^{-2} sec^{-1}) (Table 1). No such white colonies were observed when cells were exposed to the optimum light intensity for chlorophyll synthesis (3×10^5 erg cm^{-2} sec^{-1}), an indication that the spontaneous mutation rate was less than 0.00003 percent. High-intensity rad light (> 610 nm) also led to the development of white mutant colonies, a strong suggestion that the endogenous chlorophyll functions as the photosensitizer for this phenomenon.

These white colonies could be subcultured on either agar plates or in liquid medium, giving rise to cells which are identical in appearance to the albino mutants induced by ultraviolet light, heat, or streptomycin (*18*). Fluorescence microscopy did not reveal the presence of any red fluorescence, indicating not only the absence of chloroplasts containing chlorophyll but also of proplastids containing protochloro-

Table 1. Mutagenic effect of visible light in *Euglena gracilis* var. *bacillaris* grown in air.

White-light irradiation: erg cm^{-2} sec^{-1}	Hours	Cells plated (No.)	Colonies surviving (No.)	White mutant colonies (No.)
3.0×10^5	6	28,000	28,000	0
8.5×10^6	6	60,000	150	75
4.5×10^6	2	27,000	2,000	15
4.5×10^6	5	27,000	281	20
*6.9×10^6	5	60,000	127	63

*Red light (> 610 nm) used to irradiate sample.

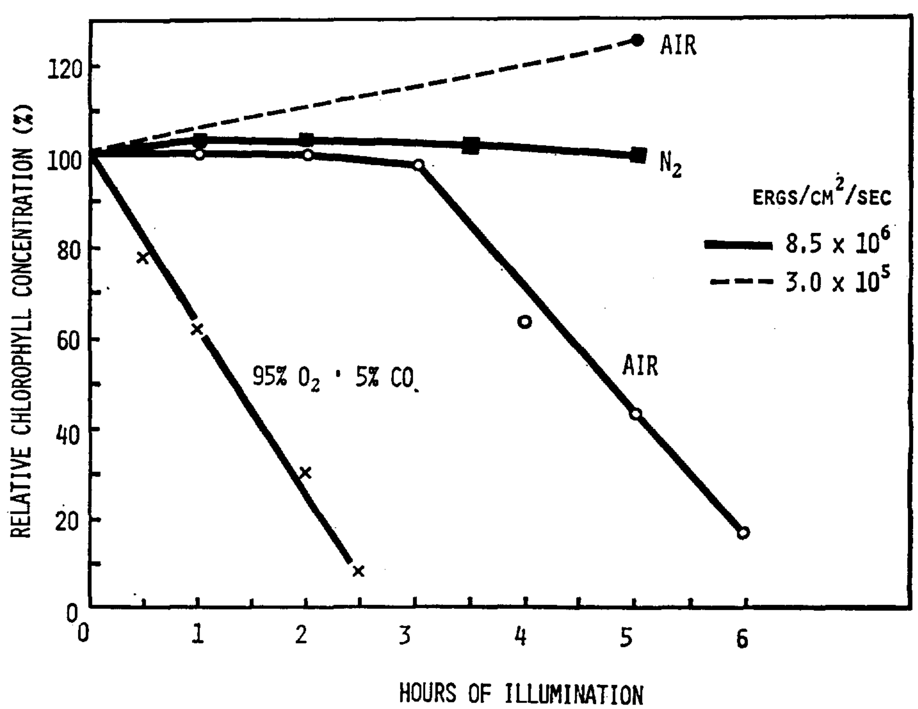

Fig. 1. The effect of illumination with high-intensity visible light on the relative chlorophyll content of *Euglena gracilis* var. *bacillaris* cells in the logarithmic phase of growth exposed to a nitrogen atmosphere (■), air (○), or 95 percent O_2 and 5 percent CO_2 atmosphere (X). The control sample (●) was exposed to 3×10^5 erg cm^{-2} sec^{-1} white light (the optimum light intensity for chlorophyll synthesis) in an atmosphere of air, whereas the other samples were exposed to 8.5×10^6 erg cm^{-2} sec^{-1} white light. At the indicated times, samples were removed and analyzed for chlorophyll as described by Arnon (*28*). The results are expressed relative to the concentration of chlorophyll present at the beginning of the experiment.

phyll. With one exception these white colonies have not reverted to green cells. The exception was observed in a stationary-phase liquid culture of one of the white colonies, where green cells started to appear. These were abnormal *Euglena,* about five times the size of the parent wild-type strain and containing approximately three times the usual number of chloroplasts. Further subculturing has resulted in cells which have reverted to a normal size but have kept their additional number of chloroplasts.

To determine whether the mutation consisted of interference with either chloroplast development or chloroplast replication, we extracted DNA from both the wild-type strain and mutant strain, W_1BVL (*19*), by the Marmur method (20) as modified for *Euglena* by Leff *et al.* (*21*). The preparation was analyzed for chloroplast DNA by

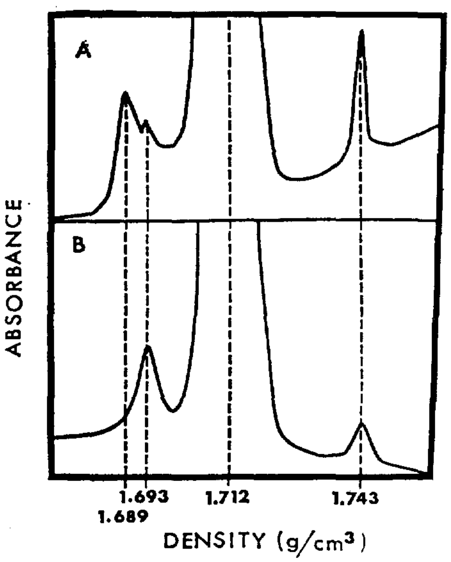

Fig. 2. Tracings of ultraviolet absorbing material separated by CsCl density-gradient centrifugation of DNA from *Euglena gracilis* var. *bacillaris.* The samples were centrifuged at 44,770 rev/min at 20°C for 40 hours. The band at ρ = 1.743 g/cm^3 is a marker DNA of known density from phage SP-8. As both samples were overloaded, only the ascending and descending limbs of the nuclear DNA band can be observed at ρ = 1.712 g/cm^3. (A) represents DNA extracted from wild-type *E. gracilis* var. *bacillaris* and is similar to previously reported patterns with the nuclear DNA band at ρ = 1.712 g/cm^3 and a double satellite representing both chloroplast DNA (ρ = 1.689 g/cm^3) and mitochondrial DNA (ρ = 1.693 g/cm^3). (B) is the tracing obtained from the DNA of the mutant strain W_1BVL, which has only a single satellite band at ρ = 1.693 g/cm^3 representing mitochondrial DNA and lacks any trace of a chloroplast DNA satellite.

density-gradient centrifugation carried out in a Spinco Model E ultracentrifuge for 40 hours at 44,770 rev/min. So that we might see the satellite bands, we overloaded the centrifuge cells with DNA, 160 to 170 μg being added to each cell. A sample of SP-8 phage DNA was used as a density marker (*22*), and the DNA buoyant densities were calculated according to the procedure of Schildkraut *et al.* (*23*). Figure 2 represents the tracing of patterns obtained directly from the ultracentrifuge using a photoelectric scanner attachment (*24*).

As in previous studies of DNA extracted from either wild-type *E. gracilis* or certain colored mutant strains, two satellite bands are observed in addition to the main band of nuclear DNA. These satellite bands appear at buoyant densities (ρ) of 1.693 g/cm^3 and 1.689 g/cm^3 and represent mitochondrial DNA and chloroplast DNA, respectively (Fig. 2A) (*25*). The DNA of the mutant strain contains only a single satellite band (ρ = 1.693 g/cm^3) representing mitochondrial DNA (Fig. 2B). This type of pattern has been reported for various bleached mutant strains of *E. gracilis* and is considered to represent those cells which can no longer produce chloroplasts by virtue of having lost their chloroplast DNA.

In these experiments it appears that visible light, acting through the endogenous chlorophyll pigment, is responsible for the disappearance of DNA associated with chloroplasts and consequently for the disappearance of all plastid structures from the mutant cells.

The mechanism is unknown, but could involve photosensitized oxidation of DNA directly or photooxidation of some of the crucial enzymes involved in DNA replication. The mutagenic mechanism does not appear to be due to localized heating brought about by the absorption of intense visible radiation, for the induction of white mutant colonies by heat requires active cell division over several generations (*26*). At the high light intensities we used, there was no cell division during the 6-hour irradiation period.

Thus, visible light, in the absence of an exogenous photosensitizing pigment can produce viable and stable mutations. Our ability to observe this mutation instead of the killing effect reported previously for visible light, is due to the fact that *E. gracilis* can live equally well on a heterotrophic or autotrophic medium. The growth and development of aplastidic colonies is made possible by the use of a heterotrophic medium which provides the cells with nutrients usually made available through photosynthesis. In an autotrophic medium this type of mutation would appear as an increase in cell death inasmuch as survival of the cells depends on their ability to photosynthesize.

We therefore conclude that in the case of microorganisms containing chlorophyll, sunlight may act as a natural mutagenic agent and thus serve as an important factor in the evolution of these organisms (*27*).

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26 July 1967

Neurons in Paradoxical Sleep and Motivated Behavior

Abstract. *Single-cell recordings were taken with electrodes permanently implanted in unrestrained rats during normal sleep, paradoxical sleep, quiet awake, and highly motivated awake periods. In most areas, neuronal activity increased when normal sleep changed to paradoxical sleep. The hypothalamus showed a significantly greater increase than most other areas. The hippocampus differed strikingly from all other areas by showing a decrement in all cases. The average firing rates in paradoxical sleep exceeded those of the quiet awake state as well as those of normal sleep. Comparison of paradoxical sleep with motivated behavior illustrated that changes in brain activity during paradoxical sleep were related to anatomically specifiable groupings, but no such differentiation appeared in motivated behavior.*

The state of paradoxical sleep in animals has been a matter of keen interest because of its relation to the state of dreaming in man. The work of Dement and Kleitman (*1*) established that a paradoxical arousal of electroencephalographic activity occurred periodically during sleep in man and that it was correlated with the state of dreaming. Later Dement (*2*) showed the similarity of paradoxical sleep in animals and man. The question of the function of the two states of sleep does not have a clear answer. Freud (*3*) thought dreams constituted a kind of fantasied wish fulfillment, satisfying strong motivational urges and permitting sleep to continue. Motivational interpretations have received some support from work on deprivation of paradoxical sleep in animals (*4*); these studies might be considered to suggest that dreams constitute the discharge of the brain's unspent motivational energies as a sort of built-in psychotherapeutic mechanism. The notion of information processing also figures prominently in a nonmotivational interpretation, namely that dreams function in the laying down of memory stores, being involved in the dissipation of weak bits of associational information prior to the placing of stronger bonds in a long-term store (*5*). From a less theoretical point of view, there are significant questions related to the similarities and differences between dream-sleep and waking; if the brain is active during dream sleep as it is in waking, why is there no behavioral output, and why does experience in this period lack the coherent organization of that of the waking brain?

Contributions toward the understanding of the questions involved have derived from physiological research on paradoxical sleep in man and animals. During paradoxical sleep, as in waking, low-voltage, fast activity appears in the electroencephalograms (EEG) taken from most forebrain and midbrain points, and a higher more rhythmic and slower "theta" pattern with higher voltage is recorded from the hippocampus and related areas. There is also a powerful downstream inhibitory process acting toward the spinal cord; this process expressed in a depressed muscle tone which is even lower in this state than it is in normal sleep and is quite unlike anything observed in the awake animal. These patterns taken together are the defining characteristics of paradoxical sleep (*4*).

There is a very large increase in neuronal activity in the midbrain and forebrain (*6*). There is often a greater discharge frequency during paradoxical sleep than during either quiet sleep or quiet awake periods. It is most marked in the reticular formation and thalamus but is also apparent to a lesser degree in caudate, putamen, hippocampus, amygdala, cochlear nucleus, and colliculi.

While the large downstream inhibitory process may account for the lack of output from a generally activated brain there are still unanswered questions about the relation of the dream state and awake states. We have compared neuronal activity during paradoxical sleep not only with that of sleep and quiet awake states but also with that of a highly motivated period in order to answer the following questions. First, can any detailed differences be specified between the dream state and the quiet and motivated awake states? Second, does the whole brain participate in the activity increments during paradoxical sleep, or do the slow, theta rhythms which characterize hippocampal recordings and those from some other areas during this period indicate an actual depression of activity in some areas? Third, is there a clear and significant predominance of some areas over others during this period of general activation which might help to clarify the relation between informational and motivational interpretations of the process?

In these studies, we implanted six to eight fixed wire microelectrodes in male albino rats. The electrodes were stereotaxically aimed and guided by single-unit recording. Animals were trained to remain motionless for a period of 2 seconds while depressing a pedal to obtain food or water. Recording sessions occurred during a period of 3 to 4 weeks. Units were identified on the basis of amplitude and wave form. Movement was detected by a hearing-aid wire which was wrapped loosely around the cable that carried the microelectrode signals; movement of the cable generated voltages in it. A more complete description of the unit-discrimination procedure has been reported (*7*).

During sleep and quiet wakefulness, samples were taken at a rate of about one sample every 3 seconds, but they were accepted for computations only if no movement occurred during the 2-second sample period. Records were also obtained during successful 2-second movement-free pedal presses for food. The digital output of five unit-discriminators was recorded on EEG paper during sample periods together with three channels of EEG, a record of movement, and indications of the completion of a successful 2-second sample and pedal pressing (Fig. 1). The same information was punched on paper tape.

Records were taken during extended periods of sleep, usually 2 to 3 hours long. During this time, the animal was monitored visually. Records were also obtained during periods of quiet behavior when the animal was awake and during pedal pressing for food. The EEG records were used to categorize sleep samples as slow-wave sleep or paradoxical sleep. Most of the EEG recordings were monopolar from subcortical locations, and theta activity (6 to 8 cycle/sec) occurred characteristically during paradoxical sleep. The cyclical relation of sleep with slow

Table 1. Median values and ranges for ratios of mean unit activity during three behavioral conditions to mean unit activity during sleep with slow waves for 52 electrodes. *N*, number; Md, median.

Location	Paradoxical sleep			Quiet awake		Bar-Press, food	
	N	Md	Range	Md	Range	Md	Range
Lateral hypothalamus	11	3.52	0.95– 5.17	2.06	0.83– 4.81	2.84	0.89– 9.28
Reticular formation	9	2.80	.97–20.50	1.51	.79– 4.25	1.53	.95–16.25
Ventral tegmentum	6	1.94	.63– 2.75	1.37	.55– 3.41	1.13	.32– 6.20
Lateral preoptic	9	1.79	.49– 3.15	1.31	.92– 1.76	1.57	1.11– 2.44
Anterior thalamus	7	1.49	.73– 3.46	1.48	.94– 3.40	2.45	0.75– 3.30
Parietal cortex	4	1.42	.88– 2.09	1.23	1.01– 1.26	1.21	.98– 1.53
Dorsal hippocampus	6	0.62	.34– 0.87	1.03	0.87– 1.26	0.99	.34– 1.26
Total	52	1.93	.34–20.50	1.37	.55– 4.81	1.58	.32–16.25

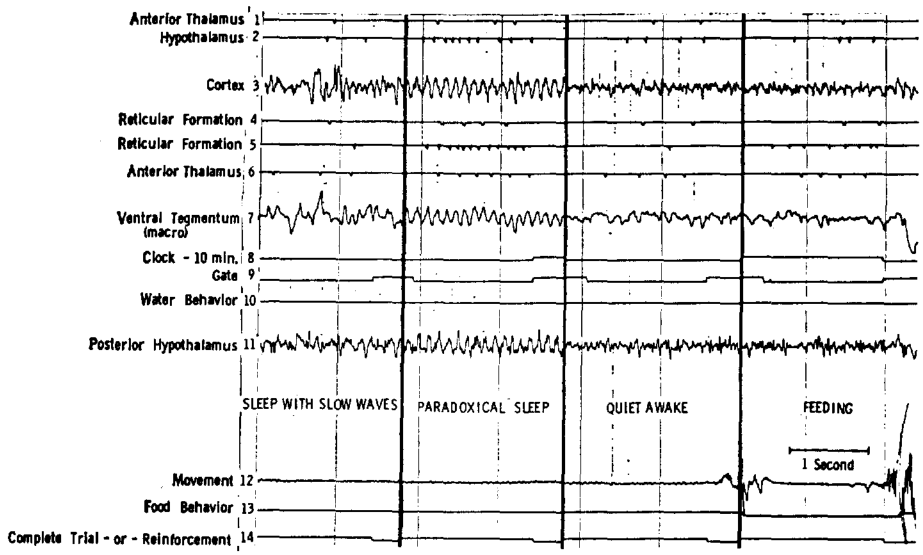

Fig. 1. Sample records of one complete sample interval for the four conditions which were observed. Analog channels are EEG tracings (3, 7, 11) and movement (12); digital channels indicate the readout of unit counters (1, 2, 4, 5, 6) and the state of the behavior sampling system (8, 9, 10, 13, 14).

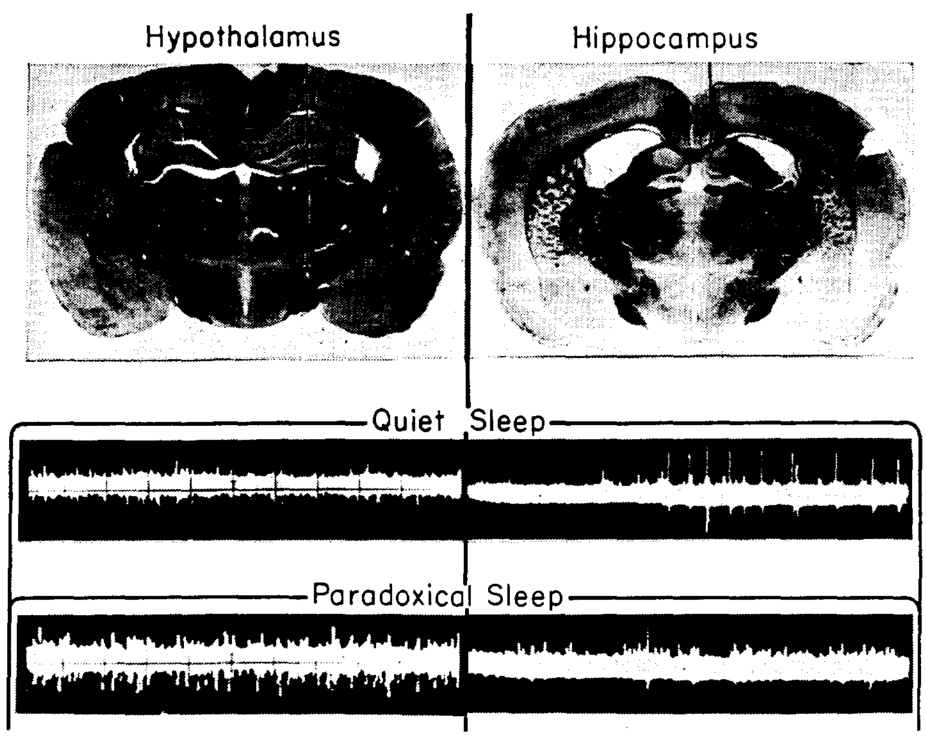

Fig. 2. Samples of neuronal activity in lateral hypothalamus and dorsal hippocampus during normal sleep and paradoxical sleep. Histological sections show the location of the two recording points.

waves to paradoxical sleep in our animals was similar to that reported in rats (*8*).

A group of 12 animals was observed, providing a total of 52 unit recordings. Electrodes were aimed at the following areas: lateral preoptic area, lateral hypothalamus, reticular formation, ventral tegmentum, anterior thalamus, dorsal hippocampus, and parietal cortex.

The number of 2-second samples varied from 350 to 2000. Because rates of response per 2-second period were greatly different from unit to unit, absolute response rates were not used in comparisons but were converted to ratios of a baseline average response rate obtained during sleep with slow waves. The analyses of results were based on these ratios. The medians and ranges of the ratios were tabulated for each of the stereotaxically defined brain areas (Table 1).

In total neuronal activity, paradoxical sleep surpassed the quiet awake state ($P < .05$), and the latter surpassed quiet sleep ($P < .05$). The motivated awake condition was highly variable, falling above the quiet awake state and below paradoxical sleep in mean value but statistically not differing from either.

The pattern of changes in rate of firing from normal to paradoxical sleep was highly differentiated by brain locus. The hypothalamus and reticular areas showed the highest increments; both changes were statistically significant. The median response rate in hypothalamus was more than 350 percent of the normal sleep rate, and that in reticular formation was more than 250 percent. The thalamic, preoptic, tegmental, and cortical groups had median increments ranging from 42 to 94 percent; each of the latter three groups was significantly below the hypothalamus in the size of the increments. Histological material showed that the highly augmented cases of hypothalamus occurred in the lateral part, in or near the medial forebrain bundle. The involvement of the medial forebrain bundle was also indicated by the characteristic recordings which usually had a small ratio of signal to the background, making units difficult to distinguish from one another (Fig. 2, left-hand column). The units of hippocampus showed a consistent decrease in rate of firing during paradoxical sleep. In fact, a decrease was observed in the rate of every hippocampal unit. The hippocampus as an area was significantly different from all the others, being the only case to show a consistent decrement (Fig. 3). The hippocampal

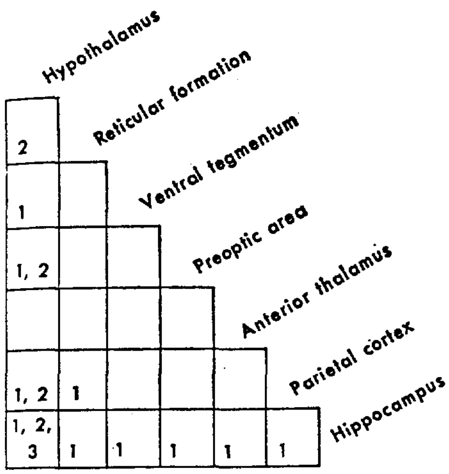

Fig. 3. Difference between groups of neurons in different brain areas significant at P equal to or less than .05 by the Mann-Whitney test. Entries are as follows: (1) changes from quiet to paradoxical sleep were different between the two areas, (2) changes from quiet sleep to quiet awake were different between the two areas, (3) changes from quiet sleep to the motivated awake state were different between the two areas.

recordings were regularly taken from the layer of hippocampal pyramidal cells in the dorsal anterior part. Neurons here were identified by their large ratio of signal to background (Fig. 2, right-hand column).

The increments over quiet sleep rates observed in the quiet awake state were not only smaller than those observed in paradoxical sleep, but were also less differentiated by anatomical structure. Units in the lateral hypothalamus again had the largest increments in rates, with an average increase of more than 200 percent, itself significant by statistical tests. Also, the hypothalamic group of neurons differed with respect to the size of the increase from those in reticular formation, parietal cortex, preoptic area, and hippocampus. The other brain areas had average rate increments of 50 percent or less. There were no average decrements and no other significant differences between areas.

There was an almost total absence of differentiation according to anatomical structure when differences between quiet sleep and motivated awake behavior were considered. From the 21 paired comparisons of the seven groups, taken two at a time, only one yielded a statistical significance; this was between the lateral hypothalamus which had the largest increments and the dorsal hippocampus which was unchanged.

Clearly, paradoxical sleep emphasized regional groupings of neuronal activity based on anatomical structure, whereas motivated behavior emphasized individual differences between units. If one might assume that a differentiated pattern of excitation and inhibition would occur within a structure under the influence of an information process, this would suggest a reduced information content in paradoxical sleep. It might nevertheless be involved in the clearing of temporary information registers on the one hand or in discharging unspent motive force on the other. The clear lead of hypothalamic process might favor a motivational interpretation because of the known "drive and reward" centers housed there. On the other hand, the reduction in hippocampal discharges might contribute to the clearing of any reverberatory processes involved in temporary information stores often suspected to occupy that region. One appealing supposition combines the two views. It is that the organism generates drive processes on the basis of physiological needs, but that there is an excess of drive which provides a cushion or safety factor. Paradoxical sleep would occur after it was established that the needs were filled, and it would function to dissipate the excess drive.

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Successiveness Discrimination as a Two-State, Quantal Process

Abstract. *The duration of the "psychophysical time quantum" measured through the application of a two-state model of successiveness discrimination is equal in magnitude to the modal zero-crossing interval of the alpha rhythm. The two quantities have similar distributions and they are correlated over individuals.*

The most recent review of the concept of a psychological unit of duration is the monograph by White (*1*). He considers many lines of evidence which indicate the existence of such a unit somewhere within the range from 50 to 100 msec and he raises again the speculation that the unit may be related to some rhythmic brain process. The alpha rhythm of the electroencephalogram has a period of approximately 100 msec and it is often suggested as a correlate. Later experiments by others (*2*) support this connection by showing associations between certain temporal characteristics of alpha rhythm and of behavior.

I have also presented some reasons for thinking of psychophysical time in quantal terms (*3*). In that paper, the time quantum is identified with three different behavioral parameters, and measurements show that the magnitude of the quantum is very close to 50 msec in all three cases. This is approximately the same as the interval between zero-crossings of the alpha rhythm, and additional measurements are given which indicate a positive correlation over individuals between this alpha interval and the behavioral quantum. However, the number of experimental subjects was small, and the average values of the behavioral parameters exceeded the average alpha interval by 6 or 7 msec in all three cases.

The present report is concerned with a further analysis of one of the three behavioral parameters and with its relationship to the alpha interval. Additional empirical relationships which support the time quantum hypothesis are also set forth. The parameter under consideration is called M and it is defined in terms of the successiveness discrimination function: the relationship between (i) the probability of discriminating a successive pair of sensory events from a simultaneous pair of sensory events and (ii) the time interval between the members of the successive pair (*4*).

A two-choice, forced-choice method is used in which a single trial consists of the presentation of two light-sound pairs. For the standard pair, a circular spot of light and a 2000-hertz pure tone begin simultaneously and terminate simultaneously. For the variable pair, the signals begin simultaneously but the light is terminated t msec before the sound. The rationale for using simultaneous terminations for the standard is discussed elsewhere (5). On half the trials, chosen at random, the standard is presented first; on the remaining trials the variable occurs first. The subject responds by indicating whether the offset of the light occurred before the offset of the tone in the first pair or in the second pair. When he indicates the variable he is scored correct and the proportion of correct responses is determined for each of a number of values of t. This proportion, $P(c)$, as a function of t, is the successiveness discrimination function.

The shorter member of each pair of signals has a duration of 2.0 seconds and the empty interval between pairs is also 2.0 seconds. An auditory signal immediately following the subject's response tells him whether the response was correct. Trials are run at the rate of one every 12 seconds. Usually only one 20-minute session is conducted each day for each subject. Equal numbers of the different values of t are randomly assigned to trials.

Under some conditions the successiveness discrimination function can be described adequately by a single straight-line segment (6). A line fitted to data intersects the level of chance performance; that is, $P(c) = 0.5$, at a value of t which is called x. The line reaches $P(c) = 1.0$ at a value of t of $(x + M)$ msec. The parameter M is the minimum amount of time which must be added to the interval between the light and sound offsets to bring $P(c)$ from 0.5 to 1.0.

I have reported (3) an average value of 54 msec for M from data obtained by using highly practiced subjects under conditions which were designed to maximize performance. This value was suggested as one estimate of the duration of a quantum.

However, with several subjects I have observed a strikingly different result under certain conditions. Instead of a "one-quantum" function they yield data which, while still linear in form, span about 100 msec. These "two-quantum" functions have always been observed early in practice, before the subject has ever attained the higher level of performance associated with the one-quantum state. And in every case a one-quantum function has been obtained in later sessions. A subject who enters a two-quantum state typically remains in that state for many sessions. Switching to the one-quantum state ordinarily requires some change in the experimental procedure.

These observations suggested the possibility that there are two distinct states such that when a subject is in state 1 his value of M is one quantum and when he is in state 2 his M is two quanta. Further, under some experimental conditions the probability of being in state 2, P_2, may be close to unity, while under other conditions the probability of being in state 1 may be close to unity.

If this conception is correct, then it becomes apparent that the earlier measurements of M were based on the assumption that a state 1 probability of unity was actually achieved. To the extent that this condition was not met, values of M would exceed the duration of one quantum.

These considerations lead to a two-state model of successiveness discrimination in which the successiveness discrimination function is the weighted mean of two linear functions having the same x but spanning one quantum in one case and two in the other. The weighting factor is P_2, the probability of being in state 2. The function consists of the following four regions:

when:	$P(c)$ equals:
$(x - M') < t < x$	0.50
$x \leq t < (x + M')$	$\frac{(t-x)}{2M'}(1 - 0.5\,P_2) + 0.5$
$(x + M') \leq t < (x + 2M')$	$\frac{(t-x)P_2}{4M'} + (1 - 0.5\,P_2)$
$t \geq (x + 2M')$	1.00

in which M' is the quantum size in milliseconds.

This two-state function rises from $P(c) = 0.5$ to $P(c) = 1.0$ as two linear segments, one connecting the points $(x, 0.5)$ and $(x + M', P)$ and the other connecting $(x + M', P)$ and $(x + 2M', 1.0)$. The intersection of these segments occurs at $P(c) = P = 1 - 0.25\,P_2$.

To apply this model requires obtaining data points over the range of t between x and $(x + 2M')$. In the earlier experiments this range was limited to the first quantum above x and most subjects did not quite attain a $P(c) = 1.0$ even for the greatest value of t. Therefore, a new experiment was done to test the adequacy of the two-state model. The ten values of t from 30 to 120 msec in 10-msec steps were used and the interval between offsets for the standard was fixed at 20 msec. All of these intervals have a positive sign which indicates that the light preceded the sound.

Twenty-three young, adult subjects participated, 14 male and 9 female. We eliminated four of them at the beginning because we were unable to obtain alpha in their electroencephalograms. The remaining 19 were run through one session per day and an electroencephalogram was taken before and after each session. Analysis of the electroencephalogram consisted of selecting monorhythmic single cycles of alpha and measuring the period of each to the nearest millisecond under a comparator. Twenty such samples were measured in each record, giving forty measurements per session. All of this analysis was performed by assistants who had no knowledge of the psychophysical analysis (7).

Obtained values of $P(c)$ are presented in Table 1 for 13 subjects. The other six subjects are not analyzed further, one because the two-state model failed to fit and five because they did not reach $P(c) > 0.90$ even at $t = 120$. An even wider range of values of t should be used.

The combination of the three parameters of the two-state model which yields the minimum squared-error fit was determined for each of the subjects. For this solution, values of x and M' were found to the nearest millisecond and P was determined to the nearest one hundredth. The results of these computations are listed in Table 2 along with the modal (peak) alpha interval.

The two-state function fits the data satisfactorily, as Fig. 1 demonstrates. This figure is a composite of all the subjects with each one entered in relation to his own parameters as explained in the caption of Fig. 1. The two segments of the function are both described adequately by the model, consistent with the deductions that there are two segments and that they span equal distances on the abscissa.

The quantities M' and alpha are very similar. They have the same mean, although the standard deviations suggest that M' is somewhat more variable.

Table 1. Two-state experiment. Proportion of correct responses for each value of the interval (t) between offsets of the variable. N is the number of trials upon which each proportion in the row is based.

Subject	Variable interval t (msec)										
	N	30	40	50	60	70	80	90	100	110	120
JE	200	0.55	0.55	0.60	0.67	0.72	0.83	0.89	0.97	0.96	0.98
MK	240	.56	.64	.75	.80	.93	.96	.96	.98	.99	.99
RW	220	.58	.62	.69	.81	.87	.92	.96	.96	1.00	.99
PR	90	.58	.68	.71	.76	.87	.88	.91	.98	0.98	.97
KH	140	.55	.56	.69	.74	.83	.91	.91	.97	.97	.96
VK	240	.56	.66	.60	.73	.81	.88	.94	.96	.99	.99
SK	160	.56	.61	.72	.84	.88	.93	.98	.98	1.00	.99
JA	180	.62	.67	.74	.90	.91	.94	.98	.99	0.97	.99
JS	150	.55	.66	.76	.82	.89	.94	.96	.98	1.00	.99
JK	230	.53	.58	.59	.68	.75	.84	.84	.95	0.93	.97
DU	128	.52	.54	.66	.66	.76	.84	.87	.93	.93	.98
TN	320	.53	.57	.61	.70	.74	.76	.84	.89	.92	.96
JM	224	.52	.56	.55	.70	.74	.83	.90	.93	.96	.99

Table 2. Parameters of the two-state model computed from the data of Table 1. M and x are to the nearest millisecond, P to the nearest 0.01; $P = 1 - 0.25\ P_2$. Peak alpha is the most frequently occurring interval between zero-crossings based upon the indicated sample size.

Subject	x (msec)	P	M' (msec)	Peak alpha	Alpha sample size
JE	23	.67	40	44	800
MK	24	.95	49	57	960
RW	24	.91	49	44	880
PR	20	.88	53	50	360
KH	27	.93	56	50	560
VK	20	.74	41	43	960
SK	25	.94	49	49	640
JA	20	.89	42	50	720
JS	23	.88	41	42	600
JK	33	.83	47	48	920
DU	34	.85	47	46	320
TN	26	.77	51	50	800
JM	36	.94	60	51	560
		Mean =	48.1	48.0	
		Standard deviation =	5.9	4.0	

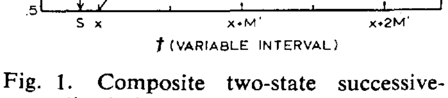

Fig. 1. Composite two-state successiveness discrimination function for 13 subjects. The line is the theoretical function with $P = 0.86$, the obtained average value. For each data point for each subject, t was converted into $(t - x)/M'$, and $\bar{P}(c)$, the value of $P(c)$ predicted by theory, was calculated all from the individual's own parameters. Then the error of prediction $[P(c) - \bar{P}(c)]$ was calculated. These errors were grouped together in intervals of 0.2 on the $(t - x)/M'$ scale and averages were taken of them and of their corresponding values of $(t - x)/M'$ within each group. These averages determine the coordinates of the points in this figure.

Their ranges are similar, 40 to 60 for M' and 42 to 57 for alpha.

As in the earlier study (*3*), the correlation between the quantum size and alpha is significant, the rank-order coefficient being 0.74. If one uses position with respect to the median of alpha to predict position with respect to the median of the quantum size and combines the results of the two studies, 19 of the 21 subjects are classified correctly.

In interpreting the degree of association between these two quantities one should consider the errors of measurement. I cannot estimate the reliability of M' at the present time; however, the reliability of alpha is something short of perfect. If one compares peak alpha obtained in the before-session records with that obtained at the ends of the sessions, the means are 47.7 in both cases and the rank-order correlation is 0.86 for the same 13 subjects (*8*).

The values of P which were obtained imply a range of P_2 extending from 0.20 to 1.0. No subject exhibited pure state 1 performance under the conditions of this experiment. The variables which influence the percentage of trials on which a subject is in state 1 rather than state 2 have yet to be identified. One possibility, for which I have some evidence, is that the range of values of t is itself such a variable. When the range is narrow, making the task a more difficult one, as in the earlier experiments, the probability of being in state 1 is higher than it is when the task is relatively easy. Another effective factor may be whether or not the subject is informed of the correctness of his decisions.

My interpretation of successiveness discrimination has recently been presented elsewhere (*3*). Briefly, the suggestion is that discriminating two independent signals as successive requires that attention switch from the channel containing the first signal to the other channel after the first signal occurs but before the second. If attention can switch only at the end of a time quantum, and since the first signal is equally likely to occur at any time during a quantum, then the successiveness discrimination function should be linear and it should span one quantum. This accounts for the state 1 function. The two-state model requires some elaboration of this view. One could speculate that state 2 occurs when an additional quantum of time is inserted in the visual information pathway prior to the display area or when the switching of attention can occur only in every second quantum (for example, only at positive-going zero crossings) (*9*). Either of these assumptions brings the two-state hypothesis into the theory but there seems to be no basis for a choice between them at this time.

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7. Since these data were analyzed we have begun computing electroencephalographic power spectra with autocorrelation functions. Comparisons between this computer analysis and the visual analysis used in this report indicates that they agree very well in determining peak frequencies and individual differences in peak frequency.
8. Nine of the original subjects are female. Three of these were excluded by the electroencephalogram screening and three failed to give adequate psychophysical data in the time that was available. The remaining three (MK, JA, and JM in Table 2) are the ones for whom the discrepancies between M' and alpha are the largest.
9. Statements of this kind do not imply a causal role for the electrical changes which constitute the electroencephalogram. In fact, there is evidence that contradicts such a view. For example, G. K. Smith and H. Langsam of this department have experiments under way which show that the spontaneous spike activity in single cortical neurons is unaffected by voltage clamping of the cells' environment.

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Black Pigmentation: Adaptation for Concealment or Heat Conservation?

A recent report by Hamilton and Heppner (*1*) on some possible functions of surface coloration (albedo) in birds once again states the possible involvement of physiological processes with varying light or energy absorption in organisms having differing coefficients of reflectivity.

Because the theoretical conclusions that might be drawn from these data could be interpreted as disproving or at least as denigrating the classical views of the definitive function of surface coloration, and its function under natural selection and in evolution, I am constrained to argue that despite the demonstrable 22.9 percent metabolic conservation obtained (*1*) in insolated blackened birds, other conclusions can be derived from the experimental results on white and artificially blackened Australian zebra finches (*Poephila castanopsis*).

Many workers have repeatedly noted and confirmed the selective value of concealing albedos and coloration. Of course even extremes in albedos might serve one, two, or even more selectively effective roles in nature; nonetheless, even if one (or more) function is served, this fact does not by itself require substitution of one for the other, and especially not of a lesser use for a greater one, nor especially for the overlooked, but probably definitive effects.

In this instance difficulties chiefly due to semantics may have contributed to the conflicting viewpoints and interpretations of otherwise unarguable experimental observations. As long as inappropriate or confusing words are used, there will probably be additional conflicts in the interpretation of data. In discussions of energy conservation and body temperature it is semantically advantageous to substitute the dynamically expressive terms endotherm and endothermic (*2*) which direct attention to the source of energy and heat, for homoiotherm, which merely denotes a more or less static condition resulting from endothermy. This usage has particular value in the comparison of the internally heated mammals and birds with the externally heated reptiles and amphibia (the ectotherms) or with the basking heliotherms. Under the usual conditions prevailing in and around endotherms, and particularly in birds, the thermal gradient usually slopes steeply from the body toward the environment. Under these conditions, excessive heat loss from birds is prevented chiefly by the notable insulative qualities of their feathers.

Interpreting the observations of Hamilton and Heppner, according to the picture evoked by use of the concept of endothermy, and in conjunction with the insulative effectiveness of bird plumage, I find it scarcely possible that even the notable metabolic economy amounting to 22.9 percent could be attributed to the transfer into the body of surface heat impinging on black feathers. Such transfer is implied by the statement, "These results indicate that homeothermic animals can absorb and utilize radiant solar energy and that dark pigmentation facilitates this process." Is it not equally possible that the heated surface might reverse the normal thermal gradient and thus interpose a barrier to an otherwise extravagant heat loss?

In the absence of any temperature measurements of the body at the skin surface, and outwardly to the insolated surface layer of feathers, it is impossible to follow and evaluate the precise processes of heat movement. In the absence of this thermal information and with due regard to the minute amounts of solar energy available at dawn and dusk, when external heat is supposedly needed and used, the feathers, regardless of color, might even occlude the needed supplementary external heat precisely when it would be most beneficial.

An additional conclusion is drawn by the authors, "The same evidence is applicable to the coloration of man. Dark human skin coloration may maximize the absorption of solar radiation in situations where energy must be expended to maintain body temperature, as at dawn and dusk in otherwise hot climates."

It seems probable that just because solar energy is so effectively absorbed by the dark skins of most tropical races, a low albedo (which might not be helpful even for brief periods at dawn and dusk) also would expose the possessor to the handicap of an excessive external heat load for all the rest of the daylight hours. This alternative effect raises a serious objection to the theoretical energy-conserving benefits of blackness in man or finch. To me it seems scarcely possible that maximizing the absorption of solar radiation in animals living in hot climates in summation could have any but a deleterious effect.

Under the conditions in which dark pigmentation is supposed to exert a favorable effect it would be necessary to have a readily changeable albedo from light-absorbing dark hue, to a heat-reflecting white so as to modulate the absorption of environmental heat. Without such a mechanism black pigment would be a distinct disadvantage, not only in direct proportion to its efficiency for heating during the fleeting "dawn" and "dusk" hour or so, but also according to the number of hot hours per day. In hot climates where the sunlight is very intense, a dark skin might cause a serious heat burden for as many as 10 hours a day, or more, over a period of at least several months each year. And these hot hours of intense insolation also are precisely those when many diurnal creatures often must generate internal heat while foraging, evading enemies, defending territories, and even in conducting respiratory cooling, or, except for man, carrying on most of the mating activities. Blackness in conjunction with the notable penalties of heat absorption and overheating would seem to outweigh the evanescent benefits by at least ten or more times. But even the suggested benefits at dawn and dusk of surface heating as a result of black color seem exceedingly dubious, since the light intensities and the total insolated energy at these critical hours are, except for total darkness, at their lowest levels. The facts concerning the effects of black pigmentation on energy conservation can be ascertained only by plotting the metabolic and external heat conditions throughout a 24-hour period under natural radiative and behavioral circumstances.

If some other explanation for black plumage and pelage and for the dark skins of human beings in tropical countries must be sought, then that of concealment seems most plausible. Viewed from this classical interpretation of natural selection via effective concealment, the surface coloration or albedo which absorbs most of the incident light and reflects the least, simultaneously results in providing minimum visibility in an object. Thus dark or black bodies that reflect almost none of the incident light rays that would be necessary for stimulation of the retinal cells of a potential predator, will be least visible or invisible. Furthermore, under crepuscular conditions when predation is usually most intense, a black object is more apt to be overlooked than one that reflects light. If a dark object is detectable at all, it is only against a light or reflective background. My observations (3) in hot climates lead me to believe that even during the daylight hours man, other mammals, and birds frequent the shade during the heat of the day, and that in the somnolent midday hours and in shady retreats either a color matching with the environment or one with low light reflectivity would offer maximum concealment.

Despite the fact that black color also might expose its possessor to serious thermal problems in deserts and other intensely insolated areas, it is significant that the sedentary inhabitants of black lava landscapes, the hottest known environments, have evolved a concealing dark-to-black coloration whereas their adult, varietal, or subspecific equivalents living only a short distance away, sometimes only a few meters, still match the prevailing desert pallor of their environment. Even if color or albedo matching changes occur sometime during the ontogeny of certain reptiles and insects, this requisite matching and concealment despite the entailed exposure to heat, would constitute even more emphatic evidence of the definitive factor in the evolution of light-absorbing surfaces.

Other arguments in favor of the theory of concealment rather than for any definitive physiological advantages (these doubtless occur but are less important) have been proposed (3), but it seems probable that need for concealment almost invariably takes precedence over any attendant metabolic benefits or dangers and that this may have been true for the evolution of some prototypal human skin color.

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16 March 1967

The direction of a species' evolution is guided by the total effect of all the selective forces acting upon it. An optimum response to one selective force can be disadvantageous with respect to another, and a compromise may be required. An animal's color is a case in point.

Predator pressure may force selection for a concealing color. However, a drab concealing color is not the most effective one for visual communication in sexual or group behavior. Two opposing pressures can thus act in the selection of color. The camouflaged animal must have some compensation, either behavioral, physiological, or morphological, to overcome its communication handicap. Conversely, the brightly colored animal must have compensation for its greater exposure to predation. We would argue that in addition to the pressures exerted by the need to avoid predation and to communicate, a third pressure, energy conservation, may be able to influence color. In some cases, energy conservation may be of prime importance; in others it may be of no importance. We do not think that any one of these factors is "definitive" for all animals, nor do we rule out the possibility that other forces can influence color under certain conditions. Only study of a particular animal can show which, if any, of these pressures is of primary importance for that animal.

We stated that "homoiothermic animals can absorb and utilize radiant solar energy." We believe that the experimental results show that this is a reasonable conclusion; the means by which the energy absorbed by the surface is translated into a metabolic economy is still subject to investigation. Cowles's suggestion of a reversal of thermal gradient may well be correct, and does not rule out our conclusion. We found the term homoiotherm to be more useful than endotherm in this particular case because we needed a term to describe a state of relative temperature constancy without making a commitment to the source of heat.

Cowles's suggestion that the surface which absorbs the most incident light is the least effective visual stimulus does not seem to consider that discontinuities and contrasts are important visual stimuli, and in most terrestrial environments black animals provide a rich supply of these cues. The basic principle of concealment by matching the general background appears to be that maximum concealment is obtained by reflecting the same quantity and quality of light as the background. In some special environments, such as lava flows, burnt vegetation, or dark soils, this may involve dark or even black coloration, but black birds, mammals, and men are not restricted to these environments. In other environments black animals are relatively more conspicuous than species that match the background, and some other explanation for their blackness must be offered. Nor does the principle of concealment by background matching change at low light intensities, as Cowles implies. Discontinuities and contrasts with the environment continue to be effective stimuli at night. However, at night our own eyes provide less reliable information about the situation. There are relatively few black nocturnal birds and mammals. Most nocturnal animals heavily involved in predator-prey relationships are background matching rather than black. Since these nocturnal animals generally obtain shelter during the day and are thus not exposed to "the notable penalties of high [radiation] absorption and overheating" we are led to ask why they have adopted their background-matching colors rather than black. For these reasons Cowles's conclusion that black coloration is in the vast majority of cases an adaptation to concealment seems vulnerable.

Cowles is probably right in stating that a sunbathing black animal would face a heat load problem at midday in the tropics. The solution to this problem, as he pointed out, is to get out of the sun. In the shade, color is probably irrelevant to heat exchange, since both black and white animals have similar radiative properties in the far infrared, as Kelly, Bond, and Heitman (1) observed. In the early hours of the day, solar radiation may enable homoiotherms not only to reduce maintenance metabolism requirements but also to restore body temperatures which have fallen during the night. In hot climates, particularly at dawn, a wide variety of sunbathing homoiotherms can be found, many of them orienting black surfaces to the sun.

We wish to take this opportunity to correct an error in the second sentence of the caption of Table 1. It should read, "Units are milliliters of oxygen per gram of body weight per *hour*." This correction in no way influences the conclusions from the experiment.

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27 October 1967

"The Intelligent Man's Guide" to the 1967 AAAS Meeting

Walter G. Berl, *Meeting Editor*

It will no longer do for scientists to convince each other of the importance of what they are doing and ask the tax payer to take it on faith.—DONALD F. HORNIG

Like many cultural institutions with a long history, the AAAS Meeting carries within its structure and as its objectives remnants of the past and seeds of the future. It is a mixture of the old, happily remembered and of the new, as yet untried. It brings with it some untidiness in organization which even loyal followers find difficult to understand. However, it permits flexibility and freedom to experiment. It is, therefore, full of promise.

My purpose is to introduce the reader briefly on how the pieces of this year's AAAS Meeting fit together and to persuade him that he would find much pleasure in attending, no matter whether he comes as a representative of the Lay Public, as an Apprentice, a Research Man, Teacher, Administrator, Reporter, or Critic.

First, a statistical bird's-eye view. About 1200 persons will give lectures, participate in panel discussions, contribute to more than 100 symposia and specialized sessions. There will be discussions of national problems (Crime, Science and Technology; Man and Transportation; Marine Science; Defense Against Ballistic Missiles; Political Decision Making; Delivery of Health Services). There will be discussions of many specific subjects (among them Extraterrestrial Life, Evolution of the Earth's Atmosphere; Animal Communications; Web-Building Spiders; Psychochemical Research Strategies in Man; Molecular Approaches to Learning and Memory; Adhesion in Biological Systems; Measuring Group Achievement in Education; The Role of Museums in Communications).

To fit this material into a manageable framework it is arranged in three distinct patterns. Most of the specialized topics originate either with the 20 AAAS Sections (ranging from Astronomy to Zoology) or with Affiliated Societies joining in with the AAAS Meeting. Topics and participants are chosen according to the individual best judgments and needs of these groups. Clearly, no uniformity in approach and style can be expected (or even wished for). The result, as shown in the summaries of symposia beginning on page 1347 (and in greater detail in the Meeting Program) is a coverage of scientific and technical problems in breadth and, often, in depth.

Added to this extensive program are a much smaller number of symposia and discussions of such a nature that their assignment into the sectional framework is either unwire or unworkable. These "General Symposia" are organized by AAAS Committees with specific responsibilities or originate spontaneously elsewhere. Many address themselves to questions of the broadest significance and relevance. This year's choices (summarized on pages 1345 to 1347) illuminate some achievements and unresolved problems facing our nation and the world.

A substantial number of Invited Lectures on a variety of subjects, given by some of the most thoughtful people in this country and abroad, are scattered through the 5 days of the AAAS Meeting (listed on pages 1343 and 1344). They are aimed, together with several panel discussions, at the lay public which expects to be instructed skillfully about important questions posed or answered by science and technology.

In addition to the lectures and discussions the AAAS Meeting, for the first time after a long pause, offers to registrants several Tours and Open Houses (Rockefeller University, New York Botanical Garden, New York Zoological Park, Boyce-Thompson Institute for Plant Research, Haskins Laboratory, Lamont Geological Laboratory of Columbia University, and the Aquarium of the New York Zoological Society). Senior members will review phases of work under way and lead visits to the laboratories.

Several exhibits and special lectures are planned. For instance, at the Rockefeller University, in conjunction with the symposium on "Michael Faraday—Natural Philosopher" and a lecture demonstration by Ronald King of the Royal Institution (London) an exhibit will commemorate the centennial of the death of Michael Faraday. The John Pierpont Morgan Library, the New York Public Library, and the New York Botanical Garden will show special displays from their extensive collections. The Sierra Club, IBM Galleries, New York Historical Society, and American Museum of Natural History will invite registrants to visit their current exhibits. Lastly, the AAAS Science Film Theatre will show many award-winning films from the recent XXIst International Science Film Festival, the complete series of "Lewis Mumford on the City" and film-illustrated lectures by Gerald Holton (Harvard) on "People and Particles," by Walter A. Starck II (University of Miami) on "A Fish-Eye View of Alligator Reef," and by Peter Morris (Canadian Film Institute) on "Seventy-five Years of Scientific Films: 1890–1965" (see pages 1366 and 1367).

In summary, then, the technical program ranges from subjects of broad and general interest to a large number of more specialized topics. The "mix" that any one participant will select for himself depends on his particular interests and resiliency. The specialized sessions should give pleasure to those who have a direct professional interest in them. The objectives of the AAAS Meeting would *not* be served, however, if participation at such sessions were the only reason for attending for, then, the hundreds of meetings of professional societies would serve as well or better. Rather, the AAAS Meeting, in its variety, offers opportunities to people who do not want to be restrained by rigid and artificial boundaries on their outlook and who wish to observe and participate in the much wider purpose of the AAAS. One is intelligent "cross-linking" among the professionals. The other is to give the public (and the individual professional) an opportunity to take part in the discussions, to discover connections, to ponder causes, and to glimpse a bit of the future.

The following pages list, in summary fashion, the lectures and symposia to be given at the 1967 AAAS Meeting. In previous and subsequent issues of Science, *some of them are described in more detail, as are the research interests of institutions where tours are offered.*

AAAS INVITED LECTURES

Frontiers of Science: Lecture I

26 December, evening.

Speaker: Carroll M. Williams (Bussey Professor of Biology, Harvard University).

Hormones, Genes, and Metamorphosis.

One of the larger and more intractable mysteries of present-day biology is epitomized by the transformation of an egg into a full-fledged organism. What we witness is an orderly enlargement and diversification of the cellular community according to an individual-specific construction manual which the fertilized egg inherited from the previous generation. By analogy to microbial systems, differential gene repression and derepression are central to all present theories of cytodifferentiation. Moreover, we can state with assurance that the orderly diversification of the community of cells is under close-up as well as overall chemical control.

Particularly illuminating are recent investigations of the metamorphosis of insects. Insects that metamorphose are especially interesting subjects because in them the formative processes continue long into the postembryonic period instead of being restricted to the period of embryonic development, as in most other animals.

The cellular events which comprise metamorphosis are tightly coupled to endocrine signals administered by two hormones—ecdysone and juvenile hormone—both of which have recently been identified and synthesized. Present indications are that, by an apparently indirect mechanism, these hormones play upon the chromosomes to control the flow of genetic information and its implementation by the synthetic centers of the cells.

Frontiers of Science: Lecture II

27 December, afternoon.

Speaker: Dame Kathleen Lonsdale, F.R.S. (Professor of Crystallography, University College, London, W.C.1; President, British Association for the Advancement of Science).

Some Studies of Human Stones.

A general review is given of the occurrence of urinary calculi from historical and geographical standpoints, taking into consideration location, composition, and age distribution. Some kinds of stones are dying out in some localities, others are on the increase, especially for certain groups of people. The various methods of determining composition are reviewed and comparative data given. The formation of a nucleus can be related to various causes of crystal growth and the reasons for subsequent development of the stone are considered, especially where the composition of the stone changes from time to time. Collections of nearly 1000 bladder and kidney stones mainly from Britain (going back to 1770), India, Indonesia, Spain, Thailand, and Turkey have been examined by x-ray diffraction techniques. The results of these and other investigations are compared graphically, to see whether any conclusions can be drawn about the possible causes of stones, including the possibility of kidney stone formation as an occupational hazard. Results of a few interesting studies of gallstones are also given.

Frontiers of Science: Lecture III

28 December, afternoon.

Speaker: Roger Revelle (Center for Population Studies, Harvard University).

Can the Poor Countries Benefit from the Scientific Revolution?

Panel Discussion. Athelstan Spilhaus, *Chairman.*

E. A. Mason (Massachusetts Institute of Technology).

William Paddock (Consultant in Tropical Agricultural Development, Washington, D.C.).

Hans W. Singer (United Nations Industrial Development Organization).

Distinguished Lecture

27 December, evening.

Speaker: Athelstan Spilhaus (President, Franklin Institute, Philadelphia).

The Experimental City.

George Sarton Memorial Lecture

28 December, afternoon.

Speaker: Cyril Stanley Smith (Institute Professor, Massachusetts Institute of Technology).

The Revival of Qualities, Corpuscles, and Phlogiston in the Modern Science of Materials.

Views on the nature of materials will be traced from workshop discoveries, through the forms and elemental qualities of Greek philosophers, Paracelsian principles, Cartesian corpuscles, and phlogiston to the rigid molecular chemistry of the nineteenth century. Some of each of the old views seems to have been revived in today's emphasis on properties based on the behavior of electrons within complex structures.

Address of the Retiring President

28 December, evening.

Speaker: Alfred Sherwood Romer (Alexander Agassiz Professor Emeritus of Zoology, Harvard University).

Major Steps in Vertebrate Evolution.

Special Lecture

29 December, morning and afternoon.
Speaker: Herman Kahn (Director, Hudson Institute).
Speculations on the Next Thirty-three Years.

Among the important respects in which industrial society differs from all the societies that went before are the unprecedented degree of affluence, the extraordinary development of technology, and the institutionalization of secular, manipulative rationality, and thus of further economic and technological development. These basic trends of Western society can be seen as part of a common, complex trend of interacting elements—most of which can be traced back as far as the 12th or 11th centuries. For analytic purposes, we have separated them into 13 rubrics.

These processes of change, each facilitating the other, have become routinely—one might even say inexorably—cumulative. It is notorious that as a result the rate of change of many aspects of economic and social life has become exponential; and it is not likely that many of the changes that are in process will begin to decelerate during the next third of a century. Some of these trends present serious issues; indeed some of the problems created by our successes in achieving unprecedented kinds of economic and technological powers may even be overwhelming. An attempt will be made to present a general framework designed to facilitate speculation and discussion about both the opportunities and the dangers that seem likely to arise in the next 33 years.

Panel Discussion. Philip M. Hauser, *Chairman*
Daniel Bell (Professor of Sociology, Columbia).
Harrison Brown (Professor of Geochemistry, California Institute of Technology).
Walter Sullivan (Science Editor, The New York *Times*).
Hans H. Landsberg (Resources for the Future, Inc., Washington, D.C.).

Scientific Research Society of America (RESA) Annual Address and Procter Prize

29 December, afternoon.
Speaker: Abel Wolman (Professor of Sanitary Engineering Emeritus, Johns Hopkins University)
Environmental Pollution.

In the last five years Federal, State and regional legislation have vied with abatement in a push toward upgrading the quality of the air. In the haste toward action, it is not surprising that objective evaluation of the impact of all measures has fallen well behind desires and hopes. It is now timely and desirable to take a look at biologic, economic, scientific, technologic, and administrative consequences of the activities stressed by legislative action and public opinion. Such an orderly appraisal is obviously difficult, but at least a preliminary approach to an assessment seems about due.

Chauncey Starr, Philip H. Abelson, E. J. Cassell, John R. Goldsmith, and B. Weinstock.

General Lecture

29 December, afternoon.
Speaker: B. F. Skinner (Harvard University).
Teaching Science in High School—What Is Wrong?

Fewer and fewer students go to college planning to become scientists and of those who go, more change to other fields. Perhaps science has become harder to teach. The status and role of the scientist may have changed. But another possibility is that those concerned with the improvement of teaching have not made sufficient use of recent advances in educational technology. Classroom experience is still accepted as a major source of wisdom. Consequences will be analyzed. The teacher who tries to make his subject interesting to the beginning student, for example, may not prepare him for the kind of thing which interests the informed scientist. The teacher who encourages the student to discover science for himself may neglect to transmit what is already known. The scientific analysis of learning and teaching has been neglected in spite of the fact that scientists above all others should turn to it for help.

Sigma Xi–Phi Beta Kappa Lecture

29 December, evening.
Speaker: John A. Wheeler (Princeton University).
Our Universe: The Known and the Unknown.

The formation of new stars and the explosion of old stars and the greatest variety of events, gigantic in scale and in energy, make the universe incomparably more interesting than any fireworks display that anyone could imagine in his wildest dreams. However, in all this wealth of events not one single effect has been discovered which has led to a new law of physics, and not one single finding has ever been obtained which is generally recognized to be incompatible with existing law. On the contrary, Einstein's relativity and the quantum principle and the lesser laws together predict astonishing events—some of them like the expansion of the universe already observed and others on "the most-wanted list" of many present-day investigators. Among these are the "missing matter" predicted to be present by Einstein's theory and the "black holes" predicted to result from the "continued gravitational collapse" of an over-compact mass. No prediction of standard well-established theory is more revolutionary than "superspace," the dynamical arena of Einstein's general relativity, and none seems more likely to have consequences for all of physics, from elementary particle physics to the dynamics of the universe.

Illustrated Lecture of the National Geographic Society

30 December, evening.
Speaker: Bradford Washburn (Boston Museum of Science).
Mapping Mount Kennedy.

The motion picture *Mapping Mount Kennedy* covers the story of Dr. Washburn's expedition to map the St. Elias range of Canada's Yukon Territory in 1965. This expedition was sponsored by the National Geographic Society and Boston's Museum of Science, and its success was made possible by the cooperation and assistance provided by the government of Canada. Dr. Washburn also led the Society's 1935 expedition which discovered the peak named by Canada in honor of the late president John F. Kennedy in 1964. The film includes a section on this 1935 expedition as well as covering the first ascent of Mount Kennedy made in March 1965.

AAAS COMMITTEE SYMPOSIA

Norman Bauer Memorial Symposium on the Hazards of Iodine-131 Fallout in Utah (27 Dec.)

Arranged by E. W. Pfeiffer (University of Montana).

Studies now being conducted in Utah and elsewhere by the U.S. Public Health Service, the University of California, and other agencies are contributing significantly to the understanding of certain biomedical effects of radioactive fallout. It is the purpose of this symposium to bring to the scientific community and the lay public results of studies on the biomedical effects of acute and chronic exposure to radionuclides emanating from nuclear explosions and other sources of radiation.

The need for such studies was first brought to public attention in Utah in 1957 by the late Norman Bauer, Professor of Chemistry, Utah State University. This symposium is held in honor of the memory of Bauer and will emphasize the responsibility of such independent scientists to increase public understanding by providing factual information on these and other hazards which result from our advanced scientific technology.

Lytt I. Gardner, Barry Commoner, Arthur R. Tamplin, Edward Weiss, Marvin L. Rallison, Robert A. Conrad, Oliver Johnson, Martin Sonenberg, Herman T. Blumenthal, and Yook C. Ng.

Secrecy, Privacy, and Public Information (28–29 Dec.)

Arranged by Margaret Mead (American Museum of Natural History).

The first two sessions will focus on some of the complex relationships exemplified by the following questions: Is secrecy in any guise compatible with the education of students and with the practice and function of science in our society? What legal and ethical problems arise, and what actions should be considered to safeguard the individual's rights of privacy in a democracy, particularly when human beings are the subjects of research?

The third session will deal with the scientist's responsibility to bring scientific information relevant to social fields to the attention of the public. Case histories of severe air and water pollution in two American cities will be presented as illustrations of the current environmental crisis, and of interaction between scientists' information groups and the local community.

Detlev W. Bronk, Philip E. Mosley, Robert L. Sproull, Margaret Mead, Oscar Ruebhausen, Peter Rossi, Rene Dubos, Barry Commoner, David Wilson, George Berg, and C. C. Gordon.

Weather Modification in Arid Lands (30 Dec.)

Arranged by Joel E. Fletcher (Utah State University, Logan).

Man has dreamed of controlling his environment for hundreds of years. Great strides have been made through the creation of air conditioning, heating, and housing but it remained for Vincent J. Shaefer and his associates to prove that man could influence the weather. That July day in 1946 when they spread dry-ice on a cold box cloud and observed snow falling to the bottom will remain memorable in the annals of progress.

The great possibilities of weather modification almost immediately occurred to people working in arid lands. Companies offering rain for sale mushroomed. It seems inevitable to us now that a charlatan or two would be involved with anything that appealed to the popular fancy so well and offered opportunities for financial gain. The publicity of these few mixed with the reliable information from the preponderance of the industry resulted in public concepts based on confusion and even misinformation. Such a state of public knowledge has resulted in proposed state laws which prohibited cloud seeding because it caused droughts on the one hand and repetition because it caused floods on the other hand.

It is the purpose of the symposium on "Weather Modification in Arid Lands" to acquaint scientists in other fields and through them the general public with a true picture of the facts and state of development of the science of weather modification as applied to arid lands.

Joel E. Fletcher, Vincent J. Schaefer, Roscoe R. Braham, Jr., Eugene L. Peck, Lyle D. Calvin, Charles F. Cooper, Emery N. Castle, J. B. Stevens, Robert B. Ellert, Archie M. Kahan, and Werner A. Baum.

AAAS GENERAL SYMPOSIA

Michael Faraday—Natural Philosopher (26, 29 Dec.)

Arranged by Raymond J. Seeger (National Science Foundation).

August 25, 1967, marked the 100th anniversary of the death of Michael Faraday. Despite his lack of formal education, this amazing man made many significant contributions to the intellectual history of mankind in the 19th century. The present symposium regards him from the vantage points of different professions today: a historian of science, a physical chemist, a theoretical physicist, an engineer, and a teacher of physics. In addition, the symposium will have a lecture demonstration, utilizing some of the original Faraday equipment, by Ronald King of the Royal Institution of London, where Faraday devoted his life to understanding physical phenomena. Faraday materials are being arranged for a public exhibition in the Abbey Rockefeller Hall of Rockefeller University.

William W. Havens, Jr., L. Pearce Williams, Ralph E. Gibson, Richard M. Bozorth, Nathaniel Frank, Ernest Weber, Raymond J. Seeger, and Ronald King.

Is Defense against Ballistic Missiles Possible? (26–27 Dec.)

Arranged by Leonard S. Rodberg (University of Maryland).

The nature and potential effectiveness of currently proposed antiballistic missile systems will be discussed.

The desirability of a defense against ballistic missiles will be discussed. Its impact on strategic stability and the nuclear arms race, upon U.S. foreign relations, and upon future world security will be analyzed.

Richard L. Garwin, Hans A. Bethe, Daniel Fink, Freeman

Dyson, Marvin Kalkstein, Philip M. Farley, Donald G. Brennan, George Rathjens, Adam Yarmolinsky, and Glenn Kent.

Crime, Science, and Technology (27–29 Dec.)

Arranged by Joseph F. Coates (Institute for Defense Analyses) and James Osterburg (Visiting Professor, School of Criminology, University of California).

Topics: Forensics and Criminalistics; New Perspectives in Law Enforcement; Some New Technology in Law Enforcement; Riots and Urban Mass Violence I; Riots and Urban Mass Violence II; and Panel Discussion on the Expanding Role of Science and Technology in Law Enforcement and Criminal Justice.

Within the next decade, the systematic application of science and technology may well become the dominant theme in law enforcement and the administration of criminal justice. This symposium calls attention to some trends and opportunities for developments in this field and highlights some of the limitations in the expanding involvement of science and technology in criminal justice.

Scientific crime detection is one of the oldest and best established applications of science to law enforcement. But this field is not stagnant. The first session will review the present state-of-the-art from a number of points of view and highlight the dominant themes now unfolding.

Three new perspectives in the system of criminal justice will be considered in the second session. Local control of law enforcement as a major, if not necessary, feature in the preservation of democratic order in the United States is a widely and steadfastly held belief. Comparative studies may shed significant light on the feasibility, advantages, and risks in alternate organizations and approaches. Contemporary economic techniques have been sparsely applied to law enforcement, in part, for want of adequate measures, i.e., quantifiable criteria of success and failure. Progress is being made, measures are being developed, so that the methods of economists may become as powerful tools in law enforcement as they are in the civilian and military sectors. The more immediate problems of allocating limited resources at the disposal of any police force and some attempts at the rational solution of this problem will be discussed.

Communication and identification are perennial, major concerns of the police. Voiceprints and voice individuality are typical of new areas in technology applied to law enforcement, while the combination of identification and communication techniques is exemplified in the novel development of the New York State Intelligence and Identification System.

The prospect for controlling narcotics addiction through science will be discussed in terms of recent legislation.

Non-lethal weapons and other technological developments offer promise in moderating violence in law enforcement.

Games, including various forms of playacting and role-taking are emerging as a potentially major technique for rehabilitation, crime prevention, personnel selection, and training.

The past summers of violence have evoked practical and theoretical interest in rioting and urban mass violence. A cross section of investigators will present, from their personal and professional perspectives, what is known or could be made known on the origin, development, proliferation, prevention, and extinguishment of urban mass violence.

A distinguished panel, representing complementary perspectives of law enforcement, criminal justice, and science will discuss the opportunities and risks inherent in the expanding role of science and technology in law enforcement and criminal justice.

James Osterburg, Ralph Turner, Paul L. Kirk, Walter C. McCrone, Michael Bayard, Cyril Wecht, Charles Petty, and Alexander Joseph.

Joseph F. Coates, Raymond Galvin, Gordon Misner, Richard B. Hoffman, Robert Riggs, and W. Michael Mahoney.

Cecil Frost, Charles Kingston, Paul Veillette, Charles Robinson, Daniel Glaser, Regina Herzlinger, and Robert Rea.

Louis Masotti, Allen Grimshaw, John Spiegel, and Maier Tuchler.

Elliott Rudwick, James Laue, Joseph Lohman, and Thomas Tomlinson.

James Scheuer, Alfred Blumstein, Sanford Garelik, John Pemberton, and Daniel H. Watts.

Marine Science (27–28 Dec.)

Arranged by Arthur E. Maxwell (Woods Hole Oceanographic Institution) and Edward Wenk, Jr. (National Council on Marine Resources and Engineering Development).

Topics: Marine Science Affairs—Policies and Concepts; National Programs—A Look Toward the Future; Frontiers of Marine Science; and Food from the Sea.

The symposium on Marine Science will present a current picture of the diverse activities taking place in this rapidly growing area of science. The first session will concern itself with some of the policies and concepts being discussed within the federal government. Representatives of several of the agencies having major programs in this field will discuss areas to which particular attention is being given, each of which is of prime importance in the national oceanographic program now being formulated.

The next session will look at some programs that are developing on a national basis. Education, engineering, prediction, and deep-sea drilling promise to have a significant impact on the future of marine science in this country.

There will be a session devoted to two research programs that have captured the imagination of many marine scientists: ocean variability and the hypothesis of sea floor spreading. Most of the historical work in oceanography has been directed toward the determination of what one might call an average picture of the ocean. We have now reached a stage where our present knowledge and technology allow us to look into the deviations from this average condition, and results of this work are proving to be extremely interesting. The sea floor spreading hypothesis is based on the results of many different observations that have been made on the mid-ocean rises and ridges. As is often the case, these results are open to different interpretations, and cases both for and against sea floor spreading will be presented.

The last session concerns the possibility of using the living resources of the sea to provide protein-rich food for the undernourished areas of the world. Federal programs that are being initiated in this area will be discussed along with potentialities and limitations of this resource.

Edward Wenk, Jr., Robert Frosch, Stanley Cain, Robert White, and Herman Pollack.

I. E. Wallen, Robert Abel, John Craven, Eugene E. Aubert, and Charles Drake.

Hugh McLellan, Nicolas P. Fofonoff, John Isaacs, Frederick Vine, and J. Lamar Worzel.

H. Burr Steinbach, Milner Schafer, G. K. Parman, John Ryther, and Donald Snyder.

Man and Transportation (27–30 Dec.)

Arranged by Paul Rosenberg (Paul Rosenberg Associates, Pelham, N.Y.; *Chairman*, Section M—Engineering), Newman A. Hall (Commission on Engineering Education, Washington, D.C.; Secretary, Section M—Engineering), and Walter G. Berl (Applied Physics Laboratory, Johns Hopkins University).

Topics: Opening Addresses; Traffic Flow and Congestion; Ground Transportation: Possibilities and Probabilities for Future Development; Future Modes of Air Transportation; Promising Urban Transportation Technology; Interaction of the Physical and Social Sciences in Transport Planning; Health and Transportation; and Automotive and Air Safety.

The problems of modern transportation are more than the engineering problems of designing and constructing automobiles, highways, aircraft, airports, and ships. Transportation involves problems of sociology, economics, ecology, population distribution, and health. In the conviction that many scientific disciplines can make significant contributions to these problems, the Engineering Section (M) of the AAAS has arranged a series of eight interdisciplinary symposia on "Man and Transportation."

The symposia will cover the subjects of: traffic flow and congestion on the highways, in the cities, and in the air; future modes of ground and air transportation; relations of transportation to ecology, urban development, and health; and automobile and air safety. These symposia will be directed primarily to the interests of the multidisciplinary audience which distinguishes an AAAS meeting, and secondarily to transportation specialists. For example, some of the papers discuss: air pollution from automobiles; psychology of automobile accidents; agriculture and transportation; statistics and mathematics of traffic flow; electric- and nuclear-powered automobiles; and the SST.

Claiborne Pell, Constantinos A. Doxiades, and Colin Buchanan.

Roger H. Gilman, Denos G. Gazis, Martin A. Warskow, R. M. Thomas, and Henry A. Barnes.

Siegfried M. Breuning, Richard H. Shackson, Aaron J. Gellman, Victor Wouk, and William W. Seifert.

Raymond L. Bisplinghoff, Arnold F. Kossar, John Stack, H. G. Edler, and Stephen G. Saltzman.

Sumner Myers, Morton I. Weinberg, Kay L. Neilson, William H. Avery, Maurice Sulkin, and John D. Garcia.

Robert P. Whorf, Edwin T. Haefele, Marvin Manheim, and Donald P. McKinnon.

W. G. Berl, E. S. Starkman, J. K. Patterson, Peter A. Franken, and Peter V. Siegel.

Jerome Lederer, Robert Brenner, Ross A. McFarland, and John P. Stapp.

Do Life Processes Transcend Physics and Chemistry? (30 Dec.)

An informal discussion between Gerald Holton, Michael Polanyi, John R. Platt, Ernest Nagel, and Barry Commoner will be held.

MATHEMATICS (A)

Computer-Aided Research (28 Dec.)

Arranged by Wallace Givens (Argonne National Laboratory).

The digital computer has, in two decades, become a familiar tool to many working scientists. Imaginative and extensive use of the varied capabilities of a computer system as an integral part of theoretical research is the unifying theme of this Symposium.

Cyrus Levinthal will use computer-generated films to show the structure of small molecules as well as of proteins. He will describe his employment of time-sharing techniques in order to provide opportunity for observation and modification of structures as an essential part of this research.

Don L. Bunker will report on his studies of the rates and dynamics of chemical reactions using Monte Carlo techniques to accumulate information on randomly selected reaction events. Computer results will be compared with the outcome of molecular beam experiments as well as, in other cases, with predictions of theory. Both high arithmetic speed and large memory capacity are required, with some trade-off of one for the other possible.

Part of the original impetus for the development of the modern digital computer came from the need to calculate at Los Alamos certain time-dependent fluid flows. The solution by difference-approximation methods of partial differential equations has continued to make heavy demands on the most powerful machines. Numerical experiments in fluid dynamics with output direct from the computer on film will be reported by C. W. Hirt.

Wallace Givens, Cyrus Levinthal, Don L. Bunker, and C. W. Hirt.

Second Annual Symposium on Mathematical Questions in Biology (27 Dec.)

Arranged by the Joint Committee on Mathematics in the Life Sciences.

Murray Gerstenhaber (University of Pennsylvania), *Chairman*; Hans J. Bremermann (University of California, Berkeley); and Alston S. Householder (Oak Ridge National Laboratory)

The use of appropriate parts of mathematics in studies of ecological equations, mating behavior in animals, and neural networks illustrates the broad applicability of the subject in the biological sciences. Thus, Robert H. MacArthur employs graphical analysis, William Bossert uses stability concepts, and J. D. Cowan finds differential equations, Hamiltonian mechanics, and Gibbsian statistical mechanics appropriate.

Murray Gerstenhaber, Robert H. MacArthur, William Bossert, and J. D. Cowan.

Research Topics in Computer Science (27 Dec.)

Arranged by A. J. Perlis (Carnegie-Mellon University, Pittsburgh).

The three papers of this symposium treat some of the more important phenomena surrounding computers. Each, while specific, can be thought of as exemplary of problem, point of view, and technique.

Every use of the computer requires translation into a symbolic representation which is adequate, that is, sufficient for the solution of the problem, and mechanical, and capable of being correctly manipulated entirely within the computer by resident programs. When the problems have a classical mathematical flavor, the choice of representation is so familiar that it need not be studied. When the problems are related to problem-solving itself, the computer representation of data and tools becomes crucial and worthy of deep study. The first paper deals with this phenomenon.

While each computer program is specific, the concept of a program and a task can be abstracted to study important properties common to all programs. Thus each program requires the resource of storage and utilizes time. It is important to determine lower bounds on the time and storage required by certain classes of programs and, conversely, to study the properties of programs which have such lower bounds. The second paper considers this aspect of computer science.

The computer with its programs is a part of the apparatus of scientific research. As our understanding of symbolic modeling deepens, it is natural to expect the computer to become increasingly imbedded in the research process and more dedicated to automatic response to the demands of the user discipline. Nowhere is this more apparent than in the studies where the refining of bulk data is necessary to reveal the "precious" result. High-energy physics relies on such extraction processes for which the computer is crucial. The third paper treats the artistic imbedding of the computer in the process of high-energy physics research.

Finally, the chairman will summarize and relate these three aspects to each other, since each uses phenomena studied by the other two, and to the other phenomena which now occupy the attention of computer scientists.

Saul Gorn, Allen Newell, Juris Hartmanis, and William Miller.

PHYSICS (B)

New Useful Developments Derived from Recent Pure Research in Physics (29 Dec.)

Arranged by W. W. Havens, Jr. (Columbia University).

The new devices and technologies resulting from pure research in physics often come as a surprise to the scientists investigating the phenomena. Unfortunately, the benefits society ultimately realizes are not and cannot be predicted when the research is begun. The motivation behind the physicist doing basic research is obtaining a better understanding of the phenomenon he is investigating. He would like to be able to exactly predict the results of an experiment on the basis of some reasonable theory which assumes no more than the fundamental laws of physics. On the forefront of research, the current theories are either incapable of predicting the experimental results or allow for so many possible results that the true answer may only be obtained by controlled experimentation.

There are many examples, of discoveries which directly affect our day-to-day lives. A long interrelated series of theoretical and experimental trials designed to more fully understand the behavior of solids resulted in the invention of the transistor. Our electrical power and communications systems have been substantially improved by discoveries resulting from research in plasma physics. In one of the most recent examples, the study of the structure of molecules and the mechanism which binds them in solids resulted in the invention of the Maser and the Laser.

The speakers at the symposium on "New and Useful Developments Resulting from Pure Research in Physics" will show how research designed to study a specific phenomenon can produce useful and unexpected results. The four speakers are well acquainted with their respective specialties, which are nuclear physics, solid state physics, plasma physics, and atomic and molecular physics. Each speaker will give illustrations of how the curiosity of physicists resulted in new and useful developments in the past and in what areas such developments might occur in the future.

Polykarp Kusch, W. W. Havens, Jr., John Marshall, Rolf Landauer, and Charles H. Townes.

Exobiology: the Search for Extraterrestrial Life and Its Biological and Sociological Implications (30 Dec.)

Arranged by Martin M. Freundlich (Airborne Instruments Laboratory, Deer Park, N.Y.).

The panel will discuss the physical environment of the planets of the solar system with reference to their habitability by indigenous organisms and give a critique of ground-based attempts to detect extraterrestrial life with particular attention to the planet Mars. The speakers will discuss the integrated experiments that must be performed in order to determine whether life exists on any of the planets. Life detection packages that can serve as automated laboratories to perform metabolic experiments will be described. The problems of preventing contamination of extraterrestrial bodies and their impact on space programs will be discussed.

The electromagnetic processes that are of importance in the search for intelligent extraterrestrial life will be reviewed. The possibility of exploiting the 1420 Mhz line of atomic hydrogen and the four lines of OH at approximately 1700 Mhz for interstellar communication will be scrutinized. The present status of techniques and observations in this field will be summarized and possible future refinements will be reviewed. Methods of distinguishing information from intelligent beings from signals of natural origin will be discussed. The panel will speculate on the forms that life may have taken outside of our planet. Our present concepts on unicellar development will be applied to this problem. Assuming that extraterrestrial life does indeed exist, a variety of philosophical, sociological, and biological implications arise. To what extent is our society prepared for these problems?

Bernard Wagner, Carl Sagan, Richard S. Young, Gilbert Levin, Everett M. Hafner, Henry D. Isenberg, and Wolf Vishniac.

The Role of the Tropics in the General Circulation of the Atmosphere (29 Dec.)

Arranged by Henry M. E. van de Boogaard and Edward D. Zipser (National Center for Atmospheric Research, Boulder, Colorado).

Postwar developments in meteorology have depended in large part on the electronic computer. Computer studies have led to better physical understanding of temperate-latitude atmospheric circulations and to dynamic modeling which has made numerical weather prediction possible for these latitudes.

Until now meteorological research in the tropics has not benefitted a great deal from these developments, largely because of the lack of sufficient observations to diagnose the far more complex structure of the tropical atmosphere.

The tropics constitute a great heat engine which is partly responsible for driving the global atmosphere. Much of the solar heat received by the tropical ocean and land surfaces is released to the lower layers of the atmosphere by contact, evaporation and radiation. This heat is then further transported to the higher layers of the tropical atmosphere by means of cumulus cloud convection, and also by radiation. In turn, this accumulated energy is gradually transported poleward and transformed into kinetic energy, experienced in the form of wind or air currents.

Highly organized and intense tropical cumulus cloud development sometimes leads to development of tropical storms and hurricanes. These in essence are safety valves which provide the tropical atmosphere with another method of releasing its accumulated energy.

The locations of these regions of organized cumulus convection are essential data for tropical weather analysis. The recent synchronous ATS-1 (Applications Technology Satellite) satellite with its cloud camera has shown the way for ultimate instantaneous global cloud observations.

New technology such as the ATS-1 has encouraged scientists to have another look at the tropics. Future research programs, like the recently completed Line Islands Experiment, will provide a much more complete understanding of the behavior of the tropical atmosphere.

Louis J. Battan, Henry M. E. van de Boogaard, Edward D. Zipser, Robert H. Simpson, Joanne Simpson, Tetsuja Fujita, and Dorothy L. Bradbury.

CHEMISTRY (C)

Present State of the Art (27 Dec.)

Arranged by H. F. Mark (Polytechnic Institute of Brooklyn) and S. M. Atlas (Bronx Community College).

James E. McEvoy, *Catalysis: Present State of the Art.*

David Harker, *X-ray Crystallography as a Chemical Discipline.*

Sir Robert Robinson, *Recollections of Sixty Years of Organic Chemical Research.*

H. F. Mark, *Synthesis and Uses of Organic Polymers.*

Chemistry and Urban Problems (29 Dec.)

Arranged by H. F. Mark (Polytechnic Institute of Brooklyn) and S. M. Atlas (Bronx Community College).

J. M. Campbell, *Transportation.*

F. D. Rosi, *Communications.*

Fred Leonard, *Rehabilitation and Biomedicine.*

Self-Assembly of Matter (29 Dec.)

Arranged by Sidney W. Fox (University of Miami).

The program on Self-Assembly of Matter is concerned with the ways in which matter, especially biological matter, tends to organize itself structurally. Some of the most striking examples of this tendency are found at the level of protein molecules and of models of primitive cells. Are such tendencies discernible at more fundamental chemical and physical levels?

Sidney W. Fox, Victor Weisskopf, William N. Lipscomb, Lester J. Reed, and Angus Wood.

ASTRONOMY (D)

Plasma Astrophysics (27 Dec.)

Arranged by Russell Kulsrud (Plasma Physics Laboratory, Princeton University).

The subject of plasma astrophysics comprises those areas of astrophysics in which a thorough knowledge of plasma effects is needed for understanding and interpretation. Such areas are the mechanism for cosmic and solar radio emission; the origin and behavior of cosmic rays, and the effect they play on structure of the galaxy; the influence of the supernovae and H-II regions on the latter; solar activity and the resulting solar wind with its terrestrial interaction producing storms; and many other areas of astrophysics. In recent years, there has been a growing appreciation of the fundamental importance of the newer developments in plasma physics in understanding these phenomena and a new subject of plasma astrophysics is growing up and attracting both astronomers and plasma physicists. It seems appropriate at this time to have a symposium in which experts in a variety of subjects in this field review these subjects. For this reason, the symposium consists of a number of somewhat unrelated topics to illustrate the broad scope of the subject.

Bruno Coppi, A. J. Dessler, Derek Tidmann, Russell Kulsrud, Barry Lasker, and Eugene Parker.

Structure and Evolution of our Universe (28 Dec.)

Arranged by Hong-Yee Chiu (Goddard Institute for Space Studies and State University of New York at Stony Brook).

In this symposium, the current status of cosmology will be reviewed by experts in this field. Chiu will review cosmological theories as originally formulated by Friedman, with emphasis on observational properties of the Universe. Thorne will discuss some new ideas in cosmological theories, including anisotropic models. Wilkinson will discuss radio observations of the Universe, including some new results obtained recently on the 3°K black body radiation. Kristian will summarize astronomical observations dealing with the gross structure of the Universe.

Hong-Yee Chiu, Kip S. Thorne, David T. Wilkinson, and Jerome Kristian.

Lloyd V. Berkner Memorial Symposium on Evolution of the Earth's Atmosphere (27 Dec.)

Arranged by S. I. Rasool (Goddard Institute for Space Studies, New York City).

Both biochemical arguments and geological evidence strongly suggest that the atmosphere of the earth has undergone major evolutionary changes during its long history. There is convincing evidence that the present atmosphere and hydrosphere arose largely from the earth's interior by volcanic emanations. But the sequence of events which led to present-day composition of N_2 and O_2 has yet to be established. What is the history of volatiles now present at the surface of the earth? Has the carbon, nitrogen, oxygen, and hydrogen always been in the form of CO_2, N_2, H_2O, and H_2, or did carbon and nitrogen combine with hydrogen early in the earth's history to form CH_4 and NH_3? Under what atmospheric conditions did life originate on earth and how did the appearance of life change the atmosphere?

Despite disagreement over the composition of the primitive atmosphere, it is almost certain that it was devoid of free oxygen. The late Lloyd V. Berkner and L. C. Marshall have presented detailed calculations indicating that free oxygen was limited to about 0.1 percent of the present atmospheric level during the entire prebiological history and accumulated slowly to the present amount since the start of photosynthesis. Difficulties arise, however, when one attempts to construct an evolutionary model of the atmosphere which would be consistent from the prebiological period to the present. Some of these important questions will be discussed in the symposium.

Harrison Brown, P. Cloud, S. I. Rasool, W. E. McGovern, S. W. Fox, L. C. Marshall, and H. D. Holland.

GEOLOGY AND GEOGRAPHY (E)

Earth Sciences in Secondary Schools (27 Dec.)

Arranged by G. Gordon Connally (Lafayette College and SUNY, College at New Paltz).

John H. Moss, Kurt E. Lowe, Roger W. Ming, Irving L. Horowitz, Whitman Cross II, Harold C. Fry, Jr., Archie W. Pollock, David L. Kendall, G. Gordon Connally, Anastasia Van Burkalow, Samuel N. Namowitz, John F. Thompson, Richard P. Boekenkamp, Joseph J. Fratamico, and Kenneth F. Bick.

Geography and Policy Research (30 Dec.)

Arranged by Gordon E. Reckord (Division of Earth Sciences, National Research Council).

Saul B. Cohen, Gordon E. Reckord, Edward M. Risley, Arch C. Gerlach, Wolfram U. Drewes, Victor Roterus, and Lewis M. Alexander.

Cave Geology; Ecology of Cave Animals; and Cave Geography and Exploration (29–30 Dec.)

Arranged by William B. White (Pennsylvania State University).

William B. White, Victor R. Baker, George H. Deike, John M. Rutherford, Jr., G. E. Eddy, D. B. Williamson. Thomas L. Poulson, Ronald A. Brandon, Stewart Peck, Thomas Jegla David Culver, and Robert Mitchell.

John R. Holsinger, Roger Barody, and Douglas Medville.

ZOOLOGICAL SCIENCES (F)

Sharing as a Genecological Process (30 Dec.)

Arranged by Pierre Dansereau (New York Botanical Garden, Bronx) and H. G. Baker (University of California, Berkeley).

Interactions between organisms in biotic communities have more often been investigated in terms of deleterious consequences than advantageous ones. There is a growing body of evidence, however, that positive interactions do occur. Very little attention has been paid to the evolutionary processes which bring about the adjustment of taxonomically distinct organisms so that they share rather than compete for natural resources. What we are concerned with is the opposite of the character-displacement. The symposium may very well examine what evidence exists for sharing in nature and the genecological processes which increase its efficiency.

H. G. Baker, Daniel Janzen, Lincoln Brower, and Pierre Dansereau.

Environmental Input and Endocrine Activity (27 Dec.)

Arranged by A. van Tienhoven (Cornell University).

All the phenomena which are observed in the animal kingdom are the result of interactions between the inherited characteristics of the animal and the environment. It is the purpose of this symposium to consider a small part of these phenomena, that is, the effects of the environment, and the manner in which the environment is able to affect the function of the endocrine system of animals.

The endocrine system was selected because it is one of the coordinating systems and many interactions with the other coordinating system, that is, the nervous system, have been studied.

By giving consideration to separate inputs, that is, light, touch, smell, a deeper understanding can be obtained concerning some of the mechanisms by which endocrine phenomena are affected. The similarities, differences, and the adaptive signficance of these phenomena will receive particular attention, as is evident from the fact that vertebrates and invertebrates are to be discussed.

A. van Tienhoven, H. Karten, S. J. Berry, W. M. Hamner, P. Licht, D. Aiken, D. S. Lehrman, B. Scharrer, C. A. Barraclough, F. Engleman, F. H. Bronson, T. Eisner, B. Brockway, and W. Loher.

Control Mechanisms in Morphogenesis (29 Dec.)

Arranged by Malcolm S. Steinberg (Princeton University).

As Johannes Holtfreter retires from teaching and turns his scholarly efforts entirely to research, his colleagues honor him through this symposium.

Jane M. Oppenheimer of Bryn Mawr College will review how our understanding of "Cells, Organizers, and Or-organization" has evolved during the past 50 years, over which Holtfreter's important contributions have been spread.

J. T. Bonner of Princeton University will discuss the evidence demonstrating chemotaxis in the cellular slime molds. His presentation will include recent evidence from his laboratory concerning the chemical identity and action of "acrasin," the chemotactic agent which signals the individual, free-living amoebae to aggregate and to differentiate and organize into a multicellular organism.

Malcom S. Steinberg, also of Princeton University, will present new experiments from his laboratory which are an extension of earlier experiments by Holtfreter. The findings indicate that the same physical principles which operate to control the self-assembly of macromolecular subunits into higher cell or viral structures also operate to guide major steps in the organization of the vertebrate body during embryonic development.

Viktor Hamburger, Jane M. Oppenheimer, J. T. Bonner, Theo M. Konijn, Malcolm S. Steinberg, and J. Lawrence Kelland.

Refresher Course: Principles of Ecology for Bio-Environmental Engineers (27 Dec.)

Arranged by Rezneat M. Darnell (Marquette University) and Theodore A. Olson (University of Minnesota).

The community of ecologists is becoming progressively concerned over the impact of civilization upon natural ecosystems. Increasing population pressure, together with expanding technology, are posing threats whose directions and magnitudes must be assessed, not only on the local, but on the worldwide scale. Few ecologists, however, are in positions to retard the effects of environmental modification which are becoming so apparent to all.

The community of environmental engineers is itself the agent which plans and executes many environmental modifications, which provides for the wastes of civilization, and which carries out programs for the assessment of tolerance levels for environmental disturbance. Increased communication between the ecologist and the environmental engineer is essential to the optimal long-term management of our limited environmental resources.

The present refresher course is an attempt to strengthen this dialogue. Principles of community and ecosystem-ecology will be presented in some detail and their engineering implications discussed. The community under stress will be examined from both ecological and engineering standpoints.

George L. Clarke, Robert G. Wetzel, David E. Reichle, Thomas D. Brock, and Frank B. Golley.

Eugene P. Odum, George M. Woodwell, Robert H. Whittaker, Richard S. Englebrecht, Willis E. Pequegnat, Stanley I. Auerbach, and Frederick E. Smith.

Alfred F. Bartsch, Howard T. Odum, Gordon M. Fair, John E. Cantlon, and Conrad P. Straub.

Animal Communication (28 Dec.)

Arranged by Neal A. Weber (Swarthmore College).

Animal communication may take auditory, visual, tactile, biochemical or some combination of forms, both between members of a species or between unrelated species. The organism receives information from the external environment, a signal is made, and the animal perceives it, responding appropriately.

The advent of refined instrumentation and more critical approaches have markedly increased our knowledge of animal communication. The biochemistry of the signals, their origins and methods of transmittal, the receptors, the neural mechanisms are all being investigated intensively in both vertebrates and invertebrates.

Neal A. Weber, Robert Capranica, William F. Martin, W. John Smith, R. Allen, Beatrice T. Gardner, Vincent G. Dethier Thomas Eisner, and Edward O. Wilson.

Terrestrial Adaptations in Crustacea (27–29 Dec.)

Dedicated to the memory of Warren J. Gross, a leading investigator in the field of crustacean terrestrial adaptations.

Arranged by Dorothy E. Bliss and Linda Habas Mantel (American Museum of Natural History, New York City).

The Transition from Water to Land in Three Major Groups.

Adaptations Concerned with Osmoregulation and Water Balance.

Adaptations Concerned with Temperature, Respiration, and Circulation.

Adaptations of Metabolism.

Adaptations of Water Conservation and Behavior.

Adaptations of Sensory Perception and Behavior.

In the past 5 years there has been a marked rise in interest in the adaptive characteristics of crustaceans that have invaded the intertidal zone and the land above the

Vice-Presidential Addresses

Mathematics—A. M. Gleason: "Symmetry, the Scientist's Friend," 30 Dec.

Physics—W. W. Havens: "Nuclear Physics Research as a Source of Technology," 29 Dec.

Chemistry—H. F. Mark: "Are There Limits to Polymer Research?" 27 Dec.

Geology and Geography—Joe Webb Peoples: "Geology in State Governments," 27 Dec.

Zoological Sciences—C. S. Pittendrigh: "Time and Life," 29 Dec.

Botanical Sciences—W. C. Steere: "The Evolutionary Position of the Bryophyta," 29 Dec.

Anthropology—Alexander Spoehr: "Anthropology Today," 27 Dec.

Psychology—L. J. Postman: "Mechanisms of Interference in Forgetting," 30 Dec.

Social and Economic Sciences—David B. Truman: "The Social Sciences: Maturity, Relevance, and the Problem of Training," 29 Dec.

History and Philosophy of Science—P. J. Caws: "Structure, Statistics, and the Logic of Discovery," 30 Dec.

Dentistry—L. R. Cahn: "Global Oral Pathology," 28 Dec.

Pharmaceutical Sciences—Curtis Waldon: "Pharmacy and the Developing Federal Programs," 29 Dec.

Industrial Science—Ellis A. Johnson: "Ethical Dilemmas in the Applications of Operations Research toward the Organizational Behavior of Very Large Systems," 28 Dec.

Education—Herbert A. Smith, "Fallout from a Decade of Criticism in Science Education," 27 Dec.

Information and Communication—P. V. Parkins: "Confessions of a Communications Non-Conformist," 29 Dec.

Statistics—G. E. P. Box: "Science and Statistics," 29 Dec.

tides. Considerable research on these animals is now under way. This symposium will bring together for the first time almost all of the investigators currently active in the field, including several from abroad.

Varying degrees of terrestriality have been achieved by three major groups of crustaceans. In the first session of the symposium, speakers will describe the progress made by these three groups.

With the groundwork for the symposium presented, the remaining sessions of the symposium will then consider in more detail various aspects of the physiology, ecology, and behavior of terrestrial crustaceans. The papers will deal mainly with isopods and decapods, on which most experimental research has been and is being done.

A feature of each session will be a general discussion at its conclusion.

F. John Vernberg, E. B. Edney, Desmond E. Hurley, Dorothy E. Bliss, E. L. Bousfield, and G. W. Wharton.

Frederick A. Kalber, John D. Costlow, Jr., C. G. Bookhout, Paul P. Rudy, D. Eugene Copeland, Linda Habas Mantel, and Betty J. Wall.

W. B. Vernberg, Don Curtis Miller, James R. Redmond, Leonard Stutman, Marilyn Dolliver, John Mark Dean, John M. Augenfeld, and Oscar H. Paris.

Dorothy M. Skinner, Wolfgang Wieser, Roy Hartenstein, Charles A. Gifford, John D. O'Connor, Lawrence I. Gilbert, and Edward J. de Villez.

E. B. Edney, Michael R. Warburg, K. Ranga Rao, Franklin H. Barnwell, William Herrnkind, E. B. Edney, and Milton Nathanson.

Helen Ghiradella, James Cronshaw, James Case, Howard O. Wright, Michael Salmon, Samuel Atsaides, Hermann Schöne, June F. Harrigan, Brian A. Hazlett, and Howard S. Hodgson.

Web-Building Spiders (29–30 Dec.)

Arranged by Peter N. Witt (North Carolina Department of Mental Health, Raleigh).

Spider Silk and Spinning.

Central Nervous System Anatomy and Function: The Vibration Receptor.

Poisons, Traps, Prey-Catching Behavior.

Webs and Web-Building.

The geometric orb web which certain species of spiders build every morning has been investigated as a record of the animal's behavior. Complexity as well as uniformity of shape, species specificity and changing of the pattern with age, disturbances of geometry through bodily injury or through changes in body chemistry by drugs, have offered a special opportunity to analyze changes in behavior. The symposium constitutes the first meeting of scientists with diverse backgrounds whose work has contributed to the understanding of web-building. Silk synthesis, thread extrusion, and their regulation are first discussed from the biophysical, chemical, and anatomical angle. The central nervous system of spiders, its structure as well as function, is explored as an organ in which incoming signals from various receptors are processed, and where the leg movements are regulated for positioning of the thread. Webs are only a special form of traps, and other prey-catching tools of spiders, including their poisons, form the topic of a third session. In the final session, the time sequence of orb construction, its plasticity as well as rigidity, and the mathematical and computer approach to the elucidation of web geometry are explored. The discussion should lead to better understanding of spiders and to the formulation of general rules of body-behavior interaction in animals.

Peter N. Witt, David B. Peakall, R. M. Langer, W. B. Eberhard, V. L. Friedrich, Ronald Wilson, A. Shulov, and Gershon Levi.

Charles F. Reed, K. Sasira Babu, Charles Walcott, and Louis Leguelte.

Hans M. Peters, John McCrone, Wolfgang Buecherl, Michael Robinson, Harro Buchili, Jonathan Reiskind, and Bertrand Krafft.

William Eberhard and Samuel Bays.

Functional Morphology of the Vertebrate Heart (28 Dec.)

One of the most important functions of the vertebrate circulatory system, and hence of the heart, is the distribution of oxygenated blood to all parts of the body. Thus any changes in the respiratory apparatus must be reflected in the circulatory system. In most fishes gills form the main respiratory surface, and the circulation is arranged as a single circuit with the blood passing from the heart to the gills to the body to the heart. However, in lungfish and tetrapods, lungs largely or entirely replace the gills and a new arrangement must be developed. In birds and mammals a complete two-circuit system—heart to lungs to heart to body to heart—is achieved, but in lungfish, amphibians, and reptiles various "compromises" are found. In this symposium the various problems in delivering oxygenated blood to all parts of the body and in keeping it separated from the non-oxygenated blood and the ways in which different vertebrates have met them will be discussed.

Thomas S. Parsons, David Randall, David Hanson, Kjell Johansen, Fred N. White, and Ursula Rowlatt.

Radiation and Behavior (29 Dec.)

Arranged by Howard Vogel, Jr. (University of Tennessee).

Donald J. Kimeldorf, James C. Smith, Gary S. Shaber, Robert L. Brent, James A. Rumsey, Gail Newingham, John R. Tester, D. B. Siniff, Orrin J. Rongstad, Ernest Furchgott, and Sylvan J. Kaplan.

Primary Productivity and Mineral Cycling in Natural Ecosystems (27 Dec.)

Arranged by Harold E. Young (University of Maine).

There is a growing awareness by mankind that the most critical problems facing the world are population growth, 2 percent per year, and rapid deterioration of man's environment. The solutions to these problems and their corollaries challenge the efforts of scientists and nonscientists alike. To solve these problems, research must first be conducted by scientists within a number of separate disciplines. The results must then be integrated into a series of action programs with little time before such programs must go into effect.

The environment is of concern to many scientific disciplines, particularly ecologists. Ecologists are currently obtaining basic information on primary productivity and mineral cycling of natural ecosystems. This information will be the basis for producing more food and fiber to meet the requirements of the rapidly increasing world population and to prevent further damage to natural ecosystems as well as the rehabilitation of ecosystems that have deteriorated.

Internationally known scientists will present general principles and specific information on primary productivity and mineral cycling in natural ecosystems. If these scientists, by their accomplishments, can encourage others to add to the limited pool of knowledge in this area, then a significant step forward will have been made in the solution of these major world problems: overpopulation and environment deterioration.

Harold E. Young, Afanasii I. Marchenko, Peter J. Rennie, Taisitiroo Satoo, Howard T. Odum, Bostwick H. Ketchum, Jerry S. Olson, Rudolph F. Scheltema, J. D. Ovington, F. H. Bormann, G. M. Woodwell, D. W. Cole, S. P. Gessel, S. F. Dice, R. H. Whittaker, and H. A. I. Madgewick.

A Coastal Marine Ecosytem: Diversified Ecological Approaches to Barnstable Harbor, Massachusetts (29 Dec.)

Arranged by David C. Grant and Roger H. Green (Marine Biological Laboratory).

This symposium has been arranged to draw together the existing ecological research on a single ecosystem, to synthesize the information within the context of modern ecological theory, and to point out any gaps in the present knowledge of a relatively well-known system. Barnstable Harbor is particularly appropriate because of the extensive studies carried out in the past several years by many persons utilizing diverse approaches. The symposium will consist of two half-day sessions of half-hour papers synthesizing the participant's individual research in Barnstable Harbor with any later or current marine ecological work. In addition to comments on the individual presentations, there will be a general round-table discussion and summary at the conclusion of the symposium.

David C. Grant, Alfred C. Redfield, J. Dungan Smith, Donald C. Rhoads, John D. Palmer, Charlotte P. Mangum, Charles E. Jenner, Rudolph F. Scheltema, Roger H. Green, Katherine D. Hobson, Eric L. Mills, and Howard L. Sanders.

Allelopathy Among the Higher Plants (30 Dec.)

Arranged by Pierre Dansereau (New York Botanical Garden, Bronx) and John Cantlon (Michigan State University).

The mechanism of evolution in vegetation differs from that in species in detail only. The selective pressures in each include antagonisms between organisms which may determine survival of specific genomes as well as interspecific associations. Allelopathy is a factor frequently responsible for such antagonisms and capable of controlling germination, ecesis, invasion, dominance, exclusion, and ultimate vegetational composition. The toxic products involved in allelopathy are controlled by habitat factors, both as to the kinds and quantities of toxins produced by plants and their persistence and effectiveness in the environment. Thus associations of plants may derive not only from coincidence of soil and climatic requirements but also from tolerance of one another's exudates which in turn are somewhat controlled by soil and climatic qualities.

John Cantlon, Cornelius Muller, H. B. Tukey, F. W. Woods, and Helmut Leith.

Adaptive Radiation in Aquatic Animals (28 Dec.)

Arranged by Arthur H. Clarke, Jr. (National Museum of Canada) and Alan H. Cheetham (U.S. National Museum).

Many aquatic animal groups have increased in diversity during Paleocene to Recent time by exploiting ecologic or biogeographic opportunities through acquisition of advantageous morphologic, physiologic, or behavioral features. Adaptive radiation, grounded in Cenozoic or earlier evolutionary events, is less well known in aquatic animals than in some terrestrial groups. Participants in the symposium will discuss neontologic and paleontologic views of adaptive radiation and will present evidence for rates of radiation and the functional bases of adaptation. Those groups of Recent invertebrates and vertebrates having a fossil record and occurring in a wide variety of freshwater and marine habitats will be emphasized.

Arthur H. Clarke, Jr., Eugene G. Munrow, Alfred S. Romer, Richard Cifelli, Alan H. Cheetham, John W. Wells, David Nicol, J. Wyatt Durham, G. Arthur Cooper, Richard H. Benson, E. L. Bousfield, Richard Lund, Alan Keast, Max K. Hecht, and Frank Whitmore, Jr.

Techniques for Comparative Studies of Protein Structure (29 Dec.)

Arranged by Charles G. Sibley (Yale University).

This symposium will concern the application of the techniques of protein chemistry, specifically structural techniques, to the study of systematic problems. Techniques which permit one to determine the sequence of amino acids in a polypeptide chain or which provide an index to part or all of the sequence will be discussed.

Charles G. Sibley, Richard A. Laursen, Russell F. Doolittle, and E. Margoliash.

Zoologists' Library and Book Lounge

The Zoologists' Library and Book Lounge will be open throughout the meetings as a lounge and informal meeting place. All zoologists are invited to visit this room and to examine the special exhibits arranged there. The Lounge again will feature the extensive collection of recent books and monographs on zoological subjects.

Books in the collection include works on all aspects of animal science: general zoology and biology texts, reference books, natural histories, works on principles and philosophical aspects of zoology, popular books and guides, periodicals, and monographs on specific groups of animals. The collection includes most of the books on animals currently in print in the English language.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

PROGRAM OF THE 134TH ANNUAL MEETING

NEW YORK CITY 26-31 DECEMBER 1967

			DECEMBER 26 A.M.	DECEMBER 26 P.M.	DECEMBER 27 A.M.	DECEMBER 27 P.M.	DECEMBER 28 A.M.	DECEMBER 28 P.M.	DECEMBER 29 A.M.	DECEMBER 29 P.M.	DECEMBER 30 A.M.	DECEMBER 30 P.M.
AAAS INVITED LECTURES				FRONTIERS OF SCIENCE I G.W. WILLIAMS (8:30)		FRONTIERS OF SCIENCE II K. LONSDALE (4:30)		FRONTIERS OF SCIENCE III R. REVELLE & PANEL (2:00)	GENERAL LECTURE H. KAHN (9:00)	GENERAL LECTURE H. KAHN PANEL (2:00)		NATIONAL GEOGRAPHIC (8:30) SOCIETY: FILM B. WASHBURN
						DISTINGUISHED LECTURE A. SPILHAUS (8:30)		SARTON MEMORIAL LECTURE C.S. SMITH (4:30)		RESA ANNUAL ADDRESS A. WOLMAN & PANEL (2:00)		
								ADDRESS RETIRING PRESIDENT A.S. ROMER (8:30)		GENERAL LECTURE B.F. SKINNER (4:15)		
										SIGMA XI - PHI BETA KAPPA J.A. WHEELER (8:30)		
AAAS COMMITTEE SYMPOSIA					← IODINE-131 FALLOUT	→	← SECRECY, PRIVACY AND PUBLIC INFORMATION	→	→		← WEATHER MODIFICATION IN ARID LANDS	→
AAAS GENERAL SYMPOSIA AND DISCUSSIONS				BALLISTIC MISSILE DEFENSE	← CRIME, SCIENCE AND TECHNOLOGY	→	→	→	→	→		
					← MARINE SCIENCE	→	→	→				LIFE PHYSICS AND CHEMISTRY
					← MAN AND TRANSPORTATION	→	→	→	→	→	→	→
				MICHAEL FARADAY						MICHAEL FARADAY		
MATHEMATICS	SECTION A	A					COMPUTER AIDED RESEARCH			A.M. GLEASON, V.P. (4:00)		
	AM. MATH. SOCIETY	A1			MATHEMATICAL BIOLOGY							
	ASSOC. COMPUT. MACHINERY	A2				COMPUTER SCIENCE						
PHYSICS	SECTION B	B							W W HAVENS, V.P & USEFUL DEVELOPMENTS			
	AM. ASTRONAUTICAL SOC.	B1									← EXOBIOLOGY	→
	AM. METEOROL. SOC.	B2								TROPICS IN GENERAL CIRCULATION OF ATMOSPHERE		
CHEMISTRY	SECTION C	C			H F. MARK, V.P AND STATE OF THE ART				SELF ASSEMBLY OF MATTER	URBAN PROBLEMS PANEL		
	AM. ASSOCIATION CLINICAL CHEMISTS	C1			CONTRIBUTED PAPERS	IMMUNOGLOBULINS						
ASTRONOMY	SECTION D	D			EARTH'S ATMOSPHERE	PLASMA ASTROPHYSICS	STRUCTURE OF UNIVERSE					
GEOLOGY	SECTION E	E			← EARTH SCIENCES IN SECONDARY SCHOOLS	J.W. PEOPLES, V.P. (4:45) →						
	ASSOC. OF AMERICAN GEOGRAPHERS	E1									← REPORT	→
	NATL. SPELEOLOGICAL SOC.	E2							CAVE GEOLOGY	ECOLOGY OF CAVE ANIMALS (1:30)	CAVE GEOGRAPHY	
	PALEONTOLOGICAL SOCIETY	E3					← ADAPTIVE RADIATION IN AQUATIC ANIMALS	→				
ZOOLOGICAL SCIENCES	SECTION F	F						C.S. PITTENDRIGH				
	AMERICAN SOC. NATURALISTS	F1						PRESIDENTIAL ADDRESS				SHARING
	AMERICAN SOC. ZOOLOGISTS	F2				PAST PRESIDENT'S SYMPOSIUM	ANATOMY OF VERTEBRATE HEARTS		← WEB BUILDING SPIDERS	→	→	→
					← C.P. MISCELLANEOUS	C.P. INVERT. ZOOL. (7:00) →	← ANIMAL COMMUNICATION	→	C.P. MISCELLANEOUS	C.P. INVERTEBRATE ZOOLOGY (7:00)	← CONTRIBUTED PAPERS	→
					← C.P. DEVELOPMENTAL BIOLOGY	→	→	→		← C.P. DEVELOPMENTAL BIOLOGY	→	→
					← C.P. COMPARATIVE PHYSIOLOGY	→	→	→	→	→	→	→
						COMPARATIVE PHYSIOLOGY (7:30)			MORPHOGENESIS		INTERSTITIAL FAUNA	
					← TERRESTRIAL ADAPTATIONS IN CRUSTACEA	→	→	→	→	→		
					← INPUT AND ENDOCRINE ACTIVITY (1:30)	→			← C.P. VERTEBRATE MORPHOLOGY	→		
					← PRINCIPLES OF ECOLOGY (2:00 & 8:00)	→	← C.P. COMPARATIVE ENDOCRINOLOGY	→	→	→	→	→
	ANIMAL BEHAVIOR SOCIETY	F3			← CONTRIBUTED PAPERS	→	→	→	→	→	→	→
								OPEN DISCUSSION (9:00)	RADIATION BEHAVIOR	OPEN DISCUSSION (8:00)		
	COMM. EXPERIMENTAL STUDY POPULATION	F4					DISCUSSION					
	ECOLOGICAL SOCIETY	F5			← PRODUCTIVITY AND MINERAL CYCLING C.P. PLANT ECOLOGY (8:00)	→	C.P. PLANT ECOLOGY C.P. ECOLOGY (8:00)		← COASTAL MARINE ECOSYSTEM	C.P. ECOLOGY →	ALLELOPATHY	
	HERPETOLOGISTS' LEAGUE	F6					← CONTRIBUTED PAPERS	→	→			
	SOC. SYSTEMATIC ZOOLOGISTS	F7			← CONTRIBUTED PAPERS	→	← ADAPTIVE RADIATION IN AQUATIC ANIMALS	→	PROTEIN STRUCTURE	CONTRIBUTED PAPERS		
BOTANICAL SCIENCES	SECTION G TORREY BOTANICAL CLUB	G							W.C. STEERE, V.P. 1:30 AND MORPHOGENESIS			

ANTHROPOLOGY	SECTION H	H				A. SPOEHR, V.P. (4:30) CONTRIBUTED PAPERS						
					← INDIANS, ANTHROPOLOGISTS AND POVERTY →		OBSIDIAN STUDIES		← ENTREPRENEURSHIP IN CROSS-SOCIETAL PERSPECTIVE →			
PSYCHOLOGY	SECTION I	I							DISTURBED CHILDREN	ATTITUDE CHANGE (1:30)	L.J. POSTMAN, V.P. & TRANSFER, INTERFERENCE, FORGETTING	QUANTITATIVE METHODOLOGY (2:30)
	AM. PSYCHOANALYTIC ASSOC	I1			← DEPRIVATION IN EARLY CHILDHOOD →							
	AM. SPEECH HEARING ASSOC	I2									SPEECH PATHOLOGY	
SOCIAL AND ECONOMIC SCIENCES	SECTION K	K				D. TRUMAN, V.P. (4:30)	POLITICAL DECISION MAKING		BIRTH CONTROL RESEARCH			
						INSTRUMENTS OF POLICY (1:30)			WORKSHOP			
	AM. SOC. CRIMINOLOGY	K1					← JUVENILE COURT PROJECT →					
	AM. SOCIOL. ASSOCIATION	K2										SOCIAL SCIENCES AS PUBLIC POLICY
	METRIC. ASSOCIATION	K3									← INVITED PAPERS →	
	NATL. INST. SOCIAL BEHAVIORAL SCIENCE	K4						CONTRIBUTED PAPERS (1:30)				
	POPULATION ASSOCIATION	K5									← CONTRIBUTED PAPERS →	
	SOC. SCIENTIFIC STUDY OF RELIGION	K6			RELIGION AND ANTI-SEMITISM							
HISTORY AND PHILOSOPHY OF SCIENCE	SECTION L	L			PROBLEM OF STATISTICAL EXPLANATION	COMPARATIVE METHODOLOGY	STATISTICAL EXPLANATION IN PHYSICS				STATISTICAL EXPLANATION IN SOCIAL SCIENCES	P.J. CAWS, V.P. (12:00)
	SOC. GENERAL SYSTEMS RESEARCH	L1	EDUCATION IN THE SEVENTIES	← ECOLOGY SOCIETY AND FUTURE →		COMP. METHODOLOGY		CONTRIBUTED PAPERS (2:30)	COMPARATIVE ADMINISTRATION SYSTEMS	GENERALISTS IN INDUSTRY	← METROPOLITAN AND REGIONAL PLANNING →	
ENGINEERING	SECTION M	M			← MAN AND TRANSPORTATION →							
MEDICAL SCIENCES	SECTION N	N							← MOLECULAR APPROACHES TO LEARNING AND MEMORY →		DELIVERY OF PERSONAL HEALTH SERVICES	
	AM. ASSOCIATION OF BIOANALYSTS	N1		INVITED PAPERS								
	AM. PSYCHIATRIC ASSOCIATION	N2					← PSYCHOCHEMICAL RESEARCH STRATEGIES IN MAN →					
DENTISTRY	SECTION Nd	Nd					← ADHESION IN BIOLOGICAL SYSTEMS → L. R. CAHN (8:30) GLOBAL ORAL PATHOLOGY					
PHARMACEUTICAL SCIENCES	SECTION Np	Np							← C.P. HOSPITAL PHARMACY →		C.P. PHARMACEUTICALS	ABSORPTION AND DISTRIBUTION (2:00)
										C. WALDON, V.P. (1:00) PHARMACY IN FED. PROGRAMS		J.L. GODDARD (1:00)
AGRICULTURE	SECTION O	O			← EDUCATION FOR THE CRISES IN FOOD AND NATURAL RESOURCES →							
INDUSTRIAL SCIENCES	SECTION P	P					SYSTEMS ANALYSES OF THE CITY	E.A. JOHNSON, V.P (12:00) OPERATIONS RESEARCH				
EDUCATION	SECTION Q	Q		INTERNATIONAL SCIENCE EDUCATION	H.A. SMITH, V.P. BENCHMARKS FOR SCIENCE EDUCATION	GROUP ACHIEVEMENT IN EDUCATION	RELATIONSHIP OF BASIC & APPLIED SCIENCE		TOWARD AN INTEGRATED MATHEMATICS			
	ALPHA EPSILON DELTA	Q1					CHANGING PATTERNS IN MEDICAL EDUCATION					
	AM. NATURE STUDY SOCIETY	Q2			C.P. ORIENTATION TO N.Y.		OPEN SPACE	LENSES ON NATURE (9:30)		RESOURCES AND YOUTH		
	AM. PHYSIOL. SOCIETY	Q3										PHYSIOLOGY IN COLLEGE
	C.U.E.B.S.	Q							UNDERGRADUATE EDUCATION IN BIOLOGY			
	NATL. COUNCIL OF TEACHERS OF MATH.	Q5								EDUCATION IN MATH. SCIENCE		
	NATL. SCIENCE TEACHERS ASSOC.	Q6			COLLEGE SCIENCE TEACHING		ELEMENTARY SCIENCE TEACHING			SECONDARY SCHOOL SCIENCE		
	JOINT SCIENCE TEACHING SOC.	Q4				HUMAN ECOLOGY			EDUCATION FOR URBAN ENVIRONMENT			
	SCIENCE COURSES FOR BACCALAUREATE EDUCATION	Q7		INTEGRATED COURSE IN SCIENCE								
INFORMATION AND COMMUNICATION	SECTION T	T		PROCESSING OF PUBLICATIONS		ROLE OF MUSEUMS IN COMMUNICATIONS			GENESIS OF INFORMATION SYSTEMS	H. BENTLEY GLASS (12:30) P.V. PARKINS, V.P. (4:30)		
STATISTICS	SECTION U	U								G.E.P. BOX, V.P. (4:30)		
	BIOMETRIC SOCIETY	U1			← NUMBERS IN INSECT POPULATION →		KIDNEY TRANSPLANTS					
GENERAL SCIENCES	ACADEMY CONFERENCE	X1			AAAS-ACADEMY RELATIONSHIPS	YOUTH ACTIVITIES V.E. ANDERSON (6:00)	← AMERICAN JUNIOR ACADEMY →		← JUNIOR SCIENTIST ASSEMBLY →			
AAAS FILM THEATER					FOREIGN I	FOREIGN II	UNITED STATES	TRANSPORTATION	MARINE SCIENCE	MUMFORD ON THE CITY	75 YEARS OF FILM	

BOTANICAL SCIENCES (G)

Aspects of Morphogenesis 1967 (29 Dec.)

Arranged by William J. Crotty (New York University).

This symposium is the last in a series organized to celebrate the centennial of the Torrey Botanical Club and to commemorate the memory of John Torrey, a leading American botanist of the nineteenth century.

John Torrey was active in the formative years of many American scientific societies, including the forerunner of the present New York Academy of Sciences, and was listed among the "first fifty" incorporators of the National Academy of Sciences. It has been said that he found the meetings of the American Association for the Advancement of Science particularly congenial and he served as its president in 1855.

This symposium should serve to emphasize by means of rather specific contributions just how rapid the progress has been in the development of theoretical concepts and investigative techniques in the botanical sciences since the time of Torrey. The subject matter embraces problems of phylogeny, development, causal morphology and physiology. It comes as something of a shock to realize that many of the theoretical bases which the symposium speakers here take for granted were not even clearly formulated much less accepted when John Torrey's basic work in American systematic botany was fairly well completed.

Warren H. Wagner, William C. Steere, William J. Crotty, Dominic Basile, Edwin B. Matzke, Ulrich Naf, Myron C. Ledbetter, and Alberto Mancinelli.

ANTHROPOLOGY (H)

Anthropologists and Others (27 Dec.)

Arranged by Carol K. Rachlin and Alice Marriott (Southwestern Research Association, Oklahoma City).

The purpose of this symposium is to obtain some insight into the contributions of anthropology to applied fields (other than teaching) which can benefit from use of its data. The contemporary society of the United States offers many diverse opportunities to anthropologists. The acceptance of anthropologists in many of these fields has been less than the acceptance from scholars in other disciplines.

The fields of social work, religion, government, art, and literature will be represented on the program. All these fields can use anthropology and its students, yet few anthropologists are employed in them. Popovi Da, artist, San Ildefonso Pueblo, and Alice Marriott, writer and anthropologist, offer an instance where anthropology, literature, and art have come together.

The participants of this symposium will discuss the positive and negative aspects of anthropology in relation to their respective areas of endeavors. Problems of communication between anthropologists and others will be considered and solutions sought.

Carol K. Rachlin, Iola Taylor, Peter J. Powell, James Officer, Popovi Da, Alice Marriott, and Gene Weltfish.

Obsidian Studies in Archeology (28 Dec.)

Arranged by Joseph W. Michels (The Pennsylvania State University).

Obsidian is a lithic material with very desirable fracturing qualities which were recognized and exploited by prehistoric man for the production of tools, weapons, and ornaments in all parts of the world where obsidian outcroppings are to be found. Considerable attention is currently being focused on the archeological recovery of obsidian artifacts, and on the reexamination of previously excavated collections of obsidian artifacts, in response to the development of several new analytic approaches to the cultural interpretation of worked obsidian. The discovery of a technique by which each obsidian artifact may be accurately dated, quickly and inexpensively, has resulted in obsidian becoming a valuable resource in solving problems of site chronology. In addition, obsidian dating has proved to be a highly versatile tool for general archeological analysis by permitting the investigator to regard time as a known variable in the study of various aspects of an archeological site, and in the reconstruction of community activity. Application of radioactive trace element analysis to the problem of identifying quarry sources for worked obsidian is contributing valuable information on inter-community contact in general, and on trade networks in particular. When trace element analysis and hydration rim-dating are applied jointly to the study of obsidian collections, the collections become a significant source of culture historical information. The current interest in stone-flaking technology among archeologists has also contributed to interest in worked obsidian. Because of its glass-like composition, obsidian provides possibilities for observation of the scar phenomena resulting from stoneworking activities not usually observable in flint or other chipped-stone materials. This observational clarity is contributing to the development of formal procedures for investigating percussion-flaking technology. The symposium highlights the growing application of the physical sciences to the study of archeology.

Clifford Evans, Irving Friedman, James B. Griffin, Gary A. Wright, William J. Mayer-Oakes, Joseph W. Michels, and Elizabeth K. Ralph.

Entrepreneurship in Cross-Societal Perspective (29–30 Dec.)

Arranged by Richard P. Schaedel (University of Texas).

Africa and Afro-American Parallels.

Latin America: Urban and Rural Aspects of Entrepreneurship.

Asia: Local and Trans-local Entrepreneurship.

Entrepreneurship for What?—Market vs. Antimarket Mentality.

The symposium is designed to bring into focus the concept of non-Western entrepreneurship and how it has functioned in economies of nonliterate peoples and so-called "underdeveloped" areas.

Substantive papers are to be presented from three major world areas: Latin America, Africa, and Asia. The purpose of the symposium is to relate the contributions of these papers to the current approaches in economic anthropological and economic theory. It is expected that certain participants will concentrate on theory, others on data, and still others on case histories supporting or refuting hypotheses that have been advanced to date in economics and anthropology regarding the contexts and limitations of entrepreneurship, for example, entrepreneurship is meaningful only in terms of West European capitalism. Non-Western economic behavior and practices require other concepts; entrepreneurship is said to be nonexistent or to be performed by marginal "brokers" in nonliterate peasant subcultures because of indigenous or "pre-industrial" value systems or the operation of the principle of limited good. That type of entrepreneurship develops very sophisticated forms in non- and semi-literate lower class segments of society, in contrast to its weak elaboration among the elite, and reflects the assimilative character of "transitional" society.

The symposium is structured in such a way as to permit as much exchange among participants on cross-cultural cases as the occasion may warrant. It will be divided into three sessions, each of which will focus on a specific area. The fourth will have to do mainly with terminological problems, theory, the implications of entrepreneurship in the public domain, and the role of entrepreneurship in policy for accelerating socio-economic change.

John Middleton, Richard P. Schaedel, John Harris, Charles Frank, Marvin Miracle, and Gloria Marshall.

Manning Nash, Anthony Leeds, Tony Bonaparte, Calvin P. Blair, and Victor Goldkind.

Richard Lambert, Walter Neale, Arafin Siregar, and George Weightman.

Edward LeClair, George Dalton, Everett W. Hagan, Stefan Robock, and Warren Dean.

PSYCHOLOGY (I)

Transfer, Interference, and Forgetting (30 Dec.)

Arranged by Leo J. Postman (University of California, Berkeley).

The purpose of this symposium is to discuss current theoretical and experimental approaches to the analysis of transfer and interference in verbal learning. Since interference theory includes a widely applied interpretation of the forgetting process, the papers will be addressed to problems of both acquisition and of retention. A variety of theoretical positions and experimental programs will be represented.

Tulving's work centers on the role of subjective organization, that is, the structure imposed by the learner on the materials to be recalled. Ceraso's studies emphasize the sources of interference which come into play during tests of recall. Greeno's experiments are carried out within the framework of a mathematical model of the associative process. Martin's investigations are designed to specify the role of stimulus factors in transfer, as exemplified by the discrimination and recognition of stimuli in successive tasks. Keppel is concerned with the application of the principles of the two-factor theory of interference which attributes retention loss to the unlearning of old associations during the acquisition of new ones and the competition between available responses at the time of recall. Richardson is engaged in a systematic analysis of the component mechanisms of positive transfer, with special emphasis on the role of mediation. Postman's address will be directed at an evaluation of the present status of two-factor theory, and in particular current interpretations of the process of unlearning.

Murray Glanzer, Endel Tulving, Edwin Martin, James Greeno, John Ceraso, Geoffrey Keppel, Jack Richardson, and Leo J. Postman.

The Emotionally Disturbed Child in the Public School

Arranged by Dale B. Harris (Pennsylvania State University).

The problems of exceptional children have become particularly acute with the rapid expansion of the child population in the 1940's following a decade of depression in which attention was given to economy and to subsistence needs of people rather than to educational and welfare needs of special groups. Consequently, in the 50's, we found ourselves completely unprepared to handle the populations of children with special needs. A number of crash programs of education and welfare have been adopted. Many of these have been established at the federal level as a device for urging states to undertake their rightful responsibilities.

The emotionally disturbed child has recently become the object of such action. This category of children, long known to psychiatry and clinical psychology, poses several special problems when aids are devised for it through the agency of the public school. First, there is the problem of criteria for selection for special attention. In the second place, there exists no body of literature pertaining to special facilities, programs, and curricula for the education of these groups within the context of the educational institution. Such modes of "re-education" as exist have been developed principally within the psychiatrist's purview and the special facilities of the mental hygiene clinic. In the third place, because schools have been slow to pick up their responsibilities to this group, a wide variety of privately sponsored attempts have arisen to reeducate these children. Thus, the problem of certifying such agencies in the public interest exists as a significant one at the present time.

James Tomkins, Gabriel Simches, Shirley Cohen, Dale B. Harris, Wilbert W. Lewis, J. David Colfax, and Irving L. Allen.

Attitude Change: Recent Developments in Experimental Research

Arranged by Irving L. Janis (Yale University).

In the first talk, a series of recent experiments which were designed to test several explanatory hypotheses that might account for the conflicting results from prior experiments in forced compliance will be discussed. In these experiments, people are induced to play a role or to write essays in which they take a stand that goes counter to their own position. The new series of experiments specified the conditions under which the amount of monetary incentive will be positively or negatively related to the amount of attitude change.

The second talk will deal with a series of experiments that were stimulated by the discovery of an anomalous sequence effect: it was repeatedly found that in face-to-face discussions, a person will end up having less esteem for a stranger if the stranger had shown signs of liking the person from the start than if he had shown signs of disliking him at first and then signs of liking him. Subsequent experiments indicated that under the latter conditions the stranger was more effective in persuading the subject to change his beliefs or judgments. Some studies to be reported attempt to determine the extent to which the anomalous phenomena can be explained by drive reduction, increased self-esteem and other mediating processes.

Individual differences in responsiveness to persuasive communications will be examined in the third talk from the standpoint of three psychological processes: (i) attention to the communication, (ii) comprehension of the message, and (iii) yielding tendencies that make for acceptance of the message.

The final talk will attempt to call attention to new approaches in experimental social psychology that may help to solve some basic problems in the field of attitude change. In this context, the implications of the three preceding talks will be highlighted and several other new lines of research cited.

Irving L. Janis, Barry Collins, Elliot Aronson, and William McGuire.

Quantitative Approaches to Classification in the Social Sciences (30 Dec.)

Arranged by Bert F. Green, Jr. (Carnegie-Mellon University, Pittsburgh).

The problem of discerning meaningful classes within populations is common to all the behavioral and social sciences. Standard quantitative methods of classification will be examined critically, and new computer-based techniques will be examined and discussed.

Bert F. Green, Jr., James M. Beshers, Neil W. Henry, Stephen C. Johnson, A. Kimball Romney, and Warren S. Torgerson.

Psychoanalytic Studies in Child Development: Biological and Social Deprivation in Early Childhood (27 Dec.)

Arranged by Albert J. Solnit (Child Study Center, Yale University).

Through the study of deviations evoked by social and biological deprivation, psychoanalysts refine their theoretical propositions and formulate new hypotheses. The investigation of "accidents" of nature and of society are compelling because of the human needs involved and because certain early psychological functions may be most clearly illuminated under such conditions. In this panel, four investigations reveal the range and continuum of such psychoanalytic studies in child development.

Albert J. Solnit, Sally Provence, Justin D. Call, Selma Fraiberg, Charles A. Malone and Reginald S. Lourie.

Speech Pathology: Some Principles Underlying Therapeutic Practices (30 Dec.)

Arranged by Arthur S. House (Purdue University).

Areas of study in which processes fundamental to human speech and language behavior are delineated. The processes—linguistic theory, language acquisition, respiratory physiology—are critical components in descriptions of speech language behavior, and as such should support the activities of speech pathologists that are aimed at the amelioration of disorders of speech and language. The areas will be presented in some detail and they will be discussed with an emphasis on determining the degree to which therapeutic practices are dependent upon underlying principles.

D. C. Spriestersbach, Paula Menyuk, Ronald S. Tikofsky, Harris Winitz, Edgar R. Garrett, James C. Hardy, and J. Douglas Noll.

SOCIAL AND ECONOMIC SCIENCES (K)

Science and Technology as Instruments of Policy (27 Dec.)

Arranged by Sanford A. Lakoff (State University of New York, Stony Brook).

Systems analysis is a tool to assist in making large scale decisions within a complex social setting. It has recently been embedded in a decision process called the Planning, Programming and Budgeting System (PPBS) for the non-military agencies of the federal government and for some state and local governments. The principal antecedents of both systems analysis and PPBS are in the design and operation of our military forces. The need for systems analysis in military applications arose from the displacement of directly relevant experience by the revolutionary post-World War II developments in military technology, by the accompanying increase in the importance, complexity, and cost of military equipment, and especially by the need to extend the planning horizon farther into the future.

Systems analysis was incorporated into an integrated planning, programming and budgeting process for the Defense Department under Secretary MacNamara in 1961. That process laid heavy emphasis on the explicit statement of alternatives and systematic comparisons among the costs and effectiveness of the alternatives as a basis for making choices among them. This basis has not replaced judgment in the process, but has strengthened and informed it. It has not replaced debate and bargaining in the process, but has focussed it and enabled it to converge on useful, rather than arbitrary, compromises.

There are important differences, as well as some similarities, in the reasons for applying systems analysis and the PPBS to the non-military agencies. Our society is undergoing important changes in both its goals and technology. Their effect has been largely to increase the importance and scale of collective decisions. This increase has created vitally important problems for government. First, our society still prefers individual choice wherever it leads to viable results. Second, unlike the competitive sectors of the private enterprise economy, government activities are not automatically subject to a selective process or discipline ensuring their efficiency. Third, public activities powerfully affect, for good or evil, the private sectors of our economy. It is the aim of PPBS to devise yardsticks to aid judgment about the goals and efficiency of government programs.

Sanford A. Lakoff, Fred S. Hoffman, Amitai Etzioni, Edward Friedland, Bruce L. R. Smith, and Albert Wohlstetter.

Science, Technology, and Political Decision Making (28 Dec.)

Arranged by Charles V. Kidd (Federal Council for Science and Technology, Washington, D.C.).

No problem of science policy has generated more theoretical issues than that of how to determine rationally how much ought to be invested in science and in technology, and how this investment ought to be divided among fields of science and among efforts to solve important problems. An equally difficult set of issues arises in the practical area: If one knew what to do, what structures and processes are best designed to secure effective action? Recent reductions and increases in the budgets of federal agencies accentuate the practical significance of the problems of choice, which involve a complex of technical, economic, social and political issues. The symposium will provide an opportunity to discuss the competition for resources among activities designed to reach economic, social and cultural goals, and the processes through which the competition is expressed.

Charles V. Kidd, Emmanuel Mesthene, Herbert Roback, Richard Nelson, and Christopher Wright.

Workshop on Science and Public Policy (29 Dec.)

Arranged by Eugene B. Skolnikoff (M.I.T.).

This session will be a general discussion, primarily among those concerned with developing university teaching and research in the area of science and public policy. A final detailed agenda will await further discussions at the meetings.

Research in Birth Control and Changing Sex Behavior (29 Dec.)

Arranged by Ailon Shiloh (University of Pittsburgh).

The purpose of this symposium is to present original research data concerning relationships between birth control and changing sex behavior. The symposium will highlight different theoretical and methodological approaches to the problem. Two senior authorities in this area of research will evaluate and discuss the papers and their implications. Audience questions and comments have been scheduled following each presented paper and the discussants.

Ailon Shiloh, Paul H. Gebhard, Ira L. Reiss, Frederick J. Ziegler, Mary Calderone, and Charles F. Westoff.

The Juvenile Court Project: Problems, Progress, and Prospects (28 Dec.)

Arranged by Donal E. J. MacNamara (John Jay College of Criminal Justice, City University of New York).

Short papers will be presented as the basis for evaluation and discussion by members of the project staff.

John Martin, Jacob Chwast, Stephen Schafer, John H. Noble, Vittorio Bonomo, James J. Sullivan, Edward Sagarin, and Canio Zarrilli.

Social Science as Public Policy (30 Dec.)

Arranged by Raymond W. Mack (Northwestern University and Russell Sage Foundation).

Four papers will address the question of what impact social science research has on policy. We shall look not only at the deliberate and intended application of social science findings in reaching policy decisions, but also at the unintended consequences of social science analysis and the dissemination of results on the data themselves and on the formation and implementation of public policy.

Participants will discuss the uses of social science in societal self-analysis and decision-making, some social consequences of research on education and on racial relations, and the reconstruction of social realities in developing areas.

Raymond W. Mack, Amitai Etzioni, Walter L. Wallace, Melvin M. Tumin, and Wendell Bell.

Invited Papers: Metric Association (30 Dec.)

Arranged by Douglas V. Frost (Dartmouth Medical School).

Fred J. Helgren, James F. Anderson, Frank L. Sheldon, Frank Y. Speight, and Joseph J. Urbancek.

Douglas V. Frost, John N. Howard, A. V. Astin and A. G. McNish, John Kincaid, Claiborne Pell, and Louis F. Sokol.

Population Trends (30 Dec.)

Arranged by Joseph A. Cavanaugh (Agency for International Development) and Dudley Kirk (Stanford University).

Parker Mauldin, Paul C. Glick, Stephanie Ventura, Norman B. Ryder, Raymond H. Porvin, Charles Westoff, Joseph A. Cavanaugh, R. T. Ravenholt, Moye Freymann, Robert G. Potter, Ronald Freedman, and Ansley Coale.

Religion and Anti-Semitism (27 Dec.)

Arranged by Marshall Sklare (Yeshiva University)

Speaker: Charles Y. Glock; Panel Discussion: Bernard Spilka, M. P. Strommen, J. J. Vaneko, and J. E. Dittes.

HISTORY AND PHILOSOPHY OF SCIENCE (L)

The Problem of Statistical Explanation (27 Dec.)

The scientific explanation of phenomena by their subscription under general laws is simple if the laws are universal, i.e. if the phenomena covered by them exhibit a uniform pattern. Unfortunately this very rarely happens; more often laws are statistical, i.e. the phenomena exhibit alternative patterns in more or less definite proportions, whether this means an occasional exception or a more nearly equal partition between cases. This raises a number of important philosophical issues, among them the following: (i) are there any genuinely universal laws, and if so are they to be regarded as limiting cases of statistical laws or as different in kind? (ii) is the inductive relation between the law and the evidence on which it rests similar in the two cases, or are statistical laws to be established according to different principles, in particular perhaps according to a different interpretation of the concept of probability? (iii) does the explanation provided by statistical laws follow the pattern set by (ideal) universal laws, and make a similar contribution to our understanding of the world, or does it need to be regarded in quite a different (possibly more modest and pragmatic) light?

Arnold Koslow, Isaac Levi, Richard C. Jeffrey, and Wesley Salmon.

Comparative Methodology of the Physical and Social Sciences (27 Dec.)

One of the goals of general systems theory has been to identify common patterns in the structures and methods of different sciences. An obvious respect in which the physical and social sciences have resorted to common methods is in their use of statistical techniques. But it is not so obvious whether this represents more than a superficial similarity. Some of the questions which need to be raised and answered, therefore, include (i) whether in this (or in any other) respect the physical and social sciences exhibit a genuine methodological unity, (ii) whether the fact that in thermodynamics and particle physics the individual events covered by statistical laws cannot in general be observed individually, while in most social science situations the corresponding events in general can be, constitutes a radical difference between the two cases, and (iii) whether, and if so in what particular ways, statistical (or any other) techniques require special adaptation in the contexts of the different sciences (whether for example levels of significance taken as establishing causal relations in the social sciences might be considered inadequate for the same purpose in the physical sciences).

Richard Rudner, Sidney Morgenbesser, and William Sacksteder.

Statistical Explanation in Physics—the Copenhagen Interpretation (28 Dec.)

The chief philosophical puzzle posed by microphysics continues to be the theoretical status of the probabilistic or statistical measures which constitute its empirical foundation at the present time. The standard (Copenhagen) approach to the problem interprets these as measures of classical or "neo-classical" variables (mass, time, length, charge, spin) invoking the correspondence principle to bridge the gap between classical and quantum conditions, and considers the foundation so provided to be fundamental in principle. Various attempts, for example those involving "hidden variables," have been made to approach the problem in new ways, which would describe the physical state of affairs in non-classical terms. Apart from the difficult problem as to the nature of physical reality involved in this confrontation, it gives rise to an interesting question about statistical explanation, namely whether phenomena (as distinct from underlying states) which can be described *only* in statistical terms can nevertheless be explained in non-statistical ones, or whether in principle they require statistical explanation.

Albert E. Blumberg, Richard Schlegel, Arthur Komar, and Joseph Sneed.

Statistical Explanation in the Social Sciences (30 Dec.)

The social sciences, dealing as they do with populations whose members are individuals of a very high degree of complexity, must embody their results almost without exception in statistical laws, so that (unlike the physical sciences) their paradigm of explanation is statistical. They have in consequence been the source of numerous methodological innovations, some of which have acquired the status of theories in their own right (game theory, communication theory, etc.). Also scientific explanation itself is a phenomenon properly dealt with by the social sciences, to an analysis of which information theory, for example, is particularly relevant. Under the title of the symposium, therefore, two problems can be distinguished: (i) what forms do explanations in the social sciences in fact take (since they are virtually all statistical)? (ii) what light do the techniques of the social sciences throw on the nature of statistical explanation in whatever scientific context?

Stephen Spielman, Joseph Hanna, Roger Rosenkrantz, and Paul Diesing.

The Role of Systems Analysis in the Educational System of the Seventies (26 Dec.)

This session will feature the role of systems analysis in meeting educational challenges posed by the emerging technological and informational trends. It will explore ways to simplify, vitalize, and promote the systems approach to education. Emphasis will be placed on efforts to develop, utilize and finance curricula for all age groups in the educational programs of schools, colleges, business firms, and governmental agencies.

Jere W. Clark, Kenneth E. Boulding, Milton C. Marney, Bert J. Decker, and Carl E. Gregory.

Ecology, Society, and the Future (26–27 Dec.)

There are specific problems associated with human pressure on the natural environment. While each of these problems lies within the field of competence of a particular expert, their recommendations for the solution of a specific problem may conflict with the possibility of solving some other problems in the professional domain of other experts. In this sense, the simultaneous solutions to the spectrum of problems arising out of human population growth requires a systems approach in the richest meaning of the term.

Lawrence B. Slobodkin, Ruth Patrick, Kenneth E. F. Watt, John Wolfe, Phillip Ritterbush, and George White.

Comparative Administration and Management Systems (29 Dec.)

Recently, in the search for a "unified theory of management," "systems theory" and "general systems theory" have sparked new hope that at least a language suitable to explore the possibility may have been found. At this time, a new spirit of urgency is manifest. The toils of large-scale organizations embrace modern man ever more tightly and confront him with increasingly difficult and vexing problems. Modern technology has supplied cybernetically oriented computerized management information systems for more effectively coping with the new problems. A major quest has become: How can we, with respect to any organizational problem, sufficiently take into account the "systems within systems within systems" reality?

Richard F. Ericson, Chadwick J. Haberstroh, Bertram M. Gross, Herman Berkman, W. H. McWinney, C. G. Lundberg, C. R. Dechert, and Raghu Nath.

Are Generalists Born or Educated—If Educated, for What? (29 Dec.)

Should there be undergraduate education in general systems to train people to be generalists? Can generalists be trained at junior levels? If so, what can they do with this training in industry? Considerable controversy exists. While many young persons and some academicians feel that general systems theory can and should be taught, many senior professional people question the validity and desirability of such training unless persons are also given a very strong and fundamental training in a specific discipline as well. Employment prospects will be discussed concerning these younger persons primarily interested in starting as generalists compared to those who will start in a specific direction.

Herbert Halbrecht, Elmer Doughtry, Walter Hahn, M. Mesorivic, and Milton D. Rubin.

General Systems and Urban Planning (30 Dec.)

Recent developments in systems analysis, decision-making tools, and computer technology have challenged traditional methods of urban planning and problem solving. This session is designed to appeal to both the analyst and the public administrator and to provide the opportunity for real dialogue between the two. The morning session will attempt a critical evaluation of what systems analysis can and cannot do in urban planning. Discussion will continue over lunch as participants join interest groups for round-table sharing of experiences and concerns. The afternoon session presents a review of systems analysis and new approaches in selected fields.

Albert H. Baugher, Harold W. Adams, William H. Mitchel, William L. Garrison, Charles P. Livermore, George Akahoshi, Martin Murphy, Robert N. Grosse, Stewart D. Marquis, Allen Feldt, and David F. Parker.

MEDICAL SCIENCES (N)

Molecular Approaches to Learning and Memory (29–30 Dec.)

Arranged by William L. Byrne (Duke University).

The availability of a variety of experimental techniques which can manipulate memory consolidation, enhancement as well as inhibition, have made it possible to propose definitive stages in memory storage. The nature of these stages in molecular terms is suggested by these techniques and by anatomical, chemical, and metabolic changes which are correlated with learning. Mechanistic proposals for learning focus on the apparent "prewired" nature of the nervous system and synaptic modification as a consequence of macromolecular synthesis. The synthetic capacity of synaptosomes can be evaluated, and the metathoracic ganglion of the cockroach is an experimental system for the study of nerve regeneration, a model for the differentiation of the nervous system.

The major emphasis of the second session will be an attempt to describe and evaluate the new controversial field of behavioral modification by injection of brain-derived materials, so-called "memory transfer." This evaluation will include a progress report on efforts to develop and test the reproducibility of specific procedures from several laboratories. The chemical nature of the active material(s) and a spectrum of psychological approaches will be described in individual presentations.

William L. Byrne, James McGaugh, Murray Jarvik, Samuel Barondes, Bernard W. Agranoff, John Zemp, Edward Bennett, Stanley Appel, Melvin J. Cohen, Robert McCleary, William Corning, Ejnar Fjerdingstad, George Ungar, Stanislav Reinis, and Frank Rosenblatt.

David Samuel, James V. McConnell, Harold Salive, Tsuyoshi Shigehisa, James A. Dyal, Arnold Golub, Otto Wolthuis, William B. Rucker, Ward C. Halstead, David Krech, Edward L. Bennett, Peter Ragan, and Walter B. Essman.

Some Current Issues in Psychochemical Research Strategies in Man (28–29 Dec.)

Arranged by Arnold J. Mandell (UCLA Center for the Health Sciences, Los Angeles).

After several decades of the use of various approaches to chemical studies of body fluids in psychological states in man in which research styles varied and "discoveries" have come and gone, it was thought that a conference devoted to stategy was both appropriate and timely. Has the failure to find very many significant and meaningful relationships been solely a function of the technical barrier of an inaccessible human brain, or has there been in addition some lack of clear thinking in the development of research approaches in this most difficult area?

A number of leading investigators who are proponents and users of various methodologies have agreed to come together to discuss the thinking behind their diverse approaches. Their data will constitute foci with which to elucidate the logic of their research strategies. It is hoped that the conference material will present explanations for past trends and perhaps generate new ones in research in this area.

Milton M. Cohen, W. Keith Selvey, Arthur Sawitsky, Arthur Siegelman, A. Friedhoff, A. J. Mandell, B. LaDu, G. Weber, M. Masuda, S. Eiduson, A. Yuwiler, G. Winokur, S. Kety, L. Sokoloff, D. X. Freedman, W. Dement, R. Kado and W. Ross Adey.

L. L. Judd, J. Durell, L. A. Gottschalk, J. Schildkraut, W. Bunney, E. Sacher, J. Mendelson, and M. Lipton.

Public Authority and Voluntary Initiative in the Delivery of Personal Health Services (30 Dec.)

Arranged by Gerard Piel (Publisher, *Scientific American*).

Public funds now underwrite the public undertaking that needed medical care shall not be denied to any person because he, individually, cannot pay the costs. The "consumers, arrangers, providers, and payers" in each community must now seek the rational organization of health services necessary to make optimum care available and accessible to all.

Gerard Piel, Lester Breslow, Lewis Thomas, and Kerr White.

DENTISTRY (Nd)

Adhesion in Biological Systems (28–29 Dec.)

Arranged by Richard S. Manly (Tufts University School of Dentistry).

Strong cohesive and adhesive bonds between cells are probably required for survival of land animals. These are properties needed in the fibers in a tendon and in the attachment between tendons and bones. Some marine organisms, such as barnacles, show abilities to form strong adhesive bonds. These bonds can be formed promptly under water to such inert surfaces as Teflon.

If the mechanism of biological adhesion could be applied by practitioners of the healing arts, there would be several benefits. Adhesives are being developed to fasten tissues together, and to bond tissues to organic and inorganic substances. Such properties are valuable to surgeons as substitutes for sutures, and to dentists for restoration of oral hard-tissue lesions.

The topic, "Adhesion in Biological Systems," was chosen to seek an interdisciplinary program that might cause sharing of knowledge about adhesion that is known only within unrelated disciplines. Certain scientists in physics, chemistry, zoology, botany, engineering, medical science, pharmacy, and dentistry, have special knowledge regarding adhesion, and others in these fields have an interest and a need to extend their understanding of mechanisms of adhesion. The emphasis on adhesion in biological systems may cause the scientists and engineers who have studied adhesion so thoroughly in nonbiological systems to become interested in the mechanism by which biological adhesion is so successful in the presence of moisture.

Three phases are involved in the cementation of one solid to another. The symposium begins with systems where all three phases are of biological origin, such as adhesion among cells in vivo and continues through the two biological phases, involving cementation of living tissues. Next follows systems where only one phase is of biological origin, such as in restorations to be cemented to teeth, or in adhesive bandages. The program also places emphasis on adhesion that takes place and remains effective in the presence of moisture. This again focuses attention on the mechanisms for adhesion which have meaning for the biological and clinical applications of adhesion.

There have been excellent symposia on the theory and action of adhesives commonly used for bonding surfaces of paper, wood, or metal. This program has scarcely any overlap with such symposia because of our emphasis on adhesion in the presence of moisture. This program is more concerned with the theories of adhesion, especially as they apply to biological systems, than with the nature of adhesives themselves. This avoids chance of the overlap with some excellent reviews that have been prepared on the more narrow field of adhesive dental restorations.

Barnet M. Levy, Lester R. Cahn, Leonard Weiss, A. Cecil Taylor, Robert Baier, Elaine Shafrin, W. Zisman, Sholom Perlman, Nathan F. Cardarelli, Charles E. Lane, and C. W. Cooper.

Peter M. Margetis, Fred Leonard, Surindar N. Bhaskar, Teruo Matsumoto, Ralph W. Phillips, Gilman N. Cyr, Ralph Heiser, James Chen, Henry L. Lee, John D. Galligan, and Anthony M. Schwartz.

PHARMACEUTICAL SCIENCES (Np)

Absorption, Distribution, Metabolism, and Excretion of Therapeutics (30 Dec.)

Lee H. MacDonald, William F. Bousquet, H. Patrick Fletcher, and John G. Wagner.

Section Np Distinguished Lecture (30 Dec.)

James L. Goddard, *Safety and Efficacy in Our Environment.*

AGRICULTURE (O)

Education for the Crises in Food and Natural Resources (27–29 Dec.)

Arranged by Richard E. Geyer (Commission on Education in Agriculture, National Research Council).

The Challenges Ahead.

Directions for Undergraduate and Graduate Programs in Agriculture and Natural Resources.

Education and Worldwide Agricultural Productivity.

Education and the Natural Resource Renewal, Use, and Preservation.

Improving Interinstitutional and Interdisciplinary Relationships.

The Future Role and Character of Technician Education Programs.

The crises in world food supply and in natural resource conservation continue to unfold. Whether major catastrophes can be averted may depend in large part on the education of future scientists, as well as the education of the technologists and technicians whose endeavors complement and supplement the scientists' efforts. Major long-range issues in higher education in agriculture and natural resources will be explored.

Russell E. Larson, George L. Mehren, Charles E. Palm, Thomas Ware, and Stephen C. Smith.

Richard H. Bohning, Franklin E. Eldridge, F. N. Andrews, Robert W. Hougas, and Keith McFarland.

N. C. Brady, Charles M. Hardin, Ralph W. Cummings, Leonard D. Baver, and Erven J. Long.

R. Keith Arnold, Carl H. Stoltenberg, Louis F. Twardzik, George Sprugel, and Norman A. Berg.

T. C. Byerly, E. J. Kersting, Nash N. Winstead, A. F. Isbell, Lester V. Manderscheid, and J. T. Clayton.

A. R. Hilst, Fred W. Manley, David H. Huntington, Seeber C. Tarbell, Melvin E. Jenkins, and H. Brooks James.

INDUSTRIAL SCIENCE (P)

Systems Analysis of the City (28 Dec.)

Arranged by Burton V. Dean (Case-Western Reserve University).

Operations research and systems analysis procedures have expanded their realms of applicability in the past decade from the earlier defense and industrial problems. The latest developments lie in applications to problems of local government.

This session reports on four important aspects of some of these problems. The first paper relates to the familiar problems of urban traffic systems. The second paper reports on a student project where instructional values were obtained from requiring students to design a completely new town in Boston harbor and to estimate the fiscal and engineering feasibility of its construction. The interesting keyword was "flexibility," in that it was a required ingredient of the plan. The third paper develops a management information system designed better to serve the city administrator's decision needs. Finally, the fourth paper addresses the crucial question of the role of the behavioral sciences in indicating preferred solutions to city problems—problems in which the human factor is so dominant.

W. Edward Cushen, Leslie C. Edie, Siegfried M. Breuning, David B. Hertz, Carter Bales, and Rosedith Sitgreaves.

Applications of Operations Research to Very Big Systems (28 Dec.)

Arranged by Ellis A. Johnson (American University, Washington, D.C.).

This session concerns itself with the many complex problems associated with the growing difficulties of nurturing new areas of operations research involving the organizational behavior of very large systems.

In systems involving the creative roles of many large future-applied aspects of the social sciences, there is greater need for development and use of many large hybrid systems. Deliberate creativity is required but multiple goals and objectives tend to be unpopular as well as difficult. This session seeks ways of solving the problem.

Ellis A. Johnson, W. L. Whitson, Russell L. Ackoff, and Joseph Becker.

EDUCATION (Q)

International Science Education (26 Dec.)

Arranged by Arthur Livermore (AAAS).

Dr. James DeRose, a consultant to the Science Teaching Center of the University of the Philippines, will report on the activities of the center in developing new science programs for elementary and secondary schools. Dr. Laurence E. Strong, formerly director of the UNESCO Pilot Project for Chemistry Teaching in Asia, will discuss the program that is being developed at Chulalonkorn University in Bangkok. Dr. Arthur Roe, Head of the Office of International Science Activities of NSF, will report on the summer institutes that have been held for the past four years in India. A view of international science education as seen from the vantage point of the Division of Science Teaching of the Department for the Advancement of Science of UNESCO will be given by Dr. Albert V. Baez. Dr. Baez has recently retired as Director of the Division of Science Teaching, a post which he held for 6 years.

Benchmarks for Science Education (27 Dec.)

Arranged by F. B. Dutton (Michigan State University).

F. B. Dutton, J. Darrell Barnard, Lee S. Shulman and H. A. Smith.

Measuring Group Achievement in Education (27 Dec.)

Arranged by Jack Merwin (Exploratory Committee on Assessing the Progress of Education, Minneapolis).

Achievement tests are developed to obtain reliable differences in levels of achievement of individuals. Summaries of scores for individuals from these tests have been, and likely will continue to be, one approach to measuring group achievement in education.

In recent years there has been recognition of the need to broaden our approach to group measurement. Three notable projects aimed at developing new procedures for measuring group achievement, one nationwide and two statewide, will be presented and discussed.

Lloyd N. Morrisett, Ralph W. Tyler, Jefferson Eastman, Paul Campbell, and J. Myron Atkin.

Relationship Between Basic and Applied Sciences Implication for Research and Development in Education (28 Dec.)

Arranged by J. Myron Atkin (University of Illinois, Urbana).

Mission-oriented agencies in education have the responsibility of improving school practices as rapidly as possible. At the same time, all those concerned with improvement of education must assure the existence of a scholarly and research base for innovations in the future. It is difficult to determine with certainty which research will have the most profound effect on practice.

There may be similarities between this broad problem and the basic/applied relationship in science, and the possible comparability will be examined in the symposium. Interrelations among federal agencies, universities, professional associations, regional laboratories, and industry as they affect research policy will also be discussed.

The recent availability of relatively large-scale funds for educational research and development activities requires examination of basic assumptions related to the most effective use of the public investment in education.

J. Myron Atkin, R. Louis Bright, and Richard Dershimer.

Toward an Integrated Mathematics-Science Curriculum in the Public Schools (29 Dec.)

Arranged by H. P. Bradley (Educational Development Center, Newton, Mass.).

The symposium will be a report of a conference held in Boston from 21 August to 8 September 1967, to discuss the interface between science and mathematics as taught in our schools and to propose changes which might lead to a better coordinated syllabus.

Andrew M. Gleason, Earle Lomon, A. S. Flexer, and Edward Begle.

Undergraduate Education in Biology (29 Dec.)

This symposium will consider the dual education responsibilities of biology departments: courses and curricula for biology majors, and courses and programs for nonscience students.

The morning session will be devoted to a consideration of curricula for majors and a discussion of attempts to narrow the gap between what is happening in the research laboratories and what is taught to undergraduate students. Curriculums that do not reflect the state of the discipline are grossly unfair to the student in terms of his being forced to expend much time and effort to make up deficiencies at a later date, and to the field of biology in terms of being deprived of a steady flow of adequately prepared teachers and researchers.

The afternoon session will consider the role of biology in the general education of students, chiefly those who at present are exposed to few (if any) science courses. In an age when science (and biology) has such a decided impact on everyday affairs, we can no longer afford a scientifically naive electorate.

Henry Koffler, Martin W. Schein, Clifford Grobstein, Jay Barton II, Donald S. Farner, Thomas S. Hall, Jeffrey J. W. Baker, and Carl P. Swanson.

Changing Patterns in Medical Education (29 Dec.)

Arranged by Maurice L. Moore (7 Brookside Circle, Bronxville, N.Y.).

The Alpha Epsilon Delta Symposium will present a program outlining the Changing Patterns in Medical Education anticipated in the next decade. The philosophical and pedagogical objectives of the medical curriculum in coping with the current medical knowledge explosion will be discussed with emphasis on the place of the curriculum in the overall training of the physician and the need of the curriculum to develop study and learning habits that will enable the student to continue his medical education throughout his professional life. The results of the current studies on the learning problems of medical students will be analyzed and evaluated. Representatives of three medical schools—one still in the developmental stage; another just getting under way; and the third a well established school—will review the innovations and changes under development in their curricula. An informal panel discussion will follow with the speakers answering questions from the audience. The symposium will be summarized with a critical appraisal of "Tomorrow's Medical School Applicant."

All persons interested in medical and premedical education and the preparation of students for a career in the health professions are invited and urged to attend this program.

Ralph D. Ascah, Edmund D. Pellegrino, Joseph S. Gonnella, Thomas R. Forbes, Richard J. Cross, George James, and George A. Perera.

Man and the Urban Society (27 Dec.)

Arranged by William B. Staff (University of Michigan).

Orientation to the New York City Environment.

Preservation and Utilization of Open Space.

Lenses on Nature.

Urban Environmental Resource Problems and Youth.

H. Seymour Fowler, Christopher Schuberth, Sam Yeaton, Emanuel Tobier, and Ron M. Linton.

Douglas E. Wade, Charles E. Little, William Roach, Hugh Davis, and George Pratt.

Verne N. Rockcastle.

Phyllis S. Busch, Edward A. Ames, Spencer W. Havlick, Martha Munzer, and Diana MacArthur.

The Role of Physiology in the Undergraduate Curriculum (30 Dec.)

Arranged by Grover C. Stephens (University of California, Irvine).

Developments in the field of physiology have been of overwhelming importance, both theoretical and practical, in shaping the development of biology in this century. The pace of these developments is such as to force continuing attention to the new way in which physiological information is coordinated with other topics to which students of biology should be exposed. Interesting and pressing matters of concern are raised by such facts as the tremendous proliferation of information in the various branches of physiology, a significant overlap of interests with such areas as biochemistry and biophysics and ultrastructure, and the increasing emphasis on quantitative approaches to biological problems at all levels of organization.

Grover C. Stephens, Donald S. Farner, H. Marguerite Webb, John A. Johnson, and William K. Stephenson.

Colloquium on Education in the Mathematical Sciences (29 Dec.)

Arranged by Marcia E. Weiser (Association of Teachers of Mathematics of New York City), Julius H. Hlavaty (Conference Board of the Mathematical Sciences), and George S. Cunningham (National Council of Teachers of Mathematics).

Roxee Joly, Carl B. Allendoerfer, Julius H. Hlavaty, Stanley J. Bezuszka, S.J., and Burt Kaufman.

College Science Teaching (27 Dec.)

Morris H. Shamos, Martin W. Schein, John Butler, and Walter Matulis.

Elementary Science Teaching (28 Dec.)

Harold E. Tannenbaum, Dean Ivey, Richard T. Codispoti, and Joseph Lipson.

Secondary School Science and a Liberal Education (29 Dec.)

Richard M. Harbeck, Robert Morgan, John Butler, and Albert F. Eiss.

Human Ecology and the Problem of Environmental Pollution (27 Dec.)

Robert W. Boenig, LaMont C. Cole, Ben Davidson, and Austin N. Heller.

Problem of Education in the Urban Environment (29 Dec.)

N. Sylvester King, Joseph C. Paige, Lawrence Hopp, and Robert Rosenthal.

An Integrated Course in Science Is Feasible (26 Dec.)

Arranged by V. L. Parsegian (Rensselaer Polytechnic Institute).

An Introduction to Natural Science (which includes multidisciplinary, historical, philosophical features, and social implications of science) seems to have been achieved in the new course being developed and tried through support of the Charles F. Kettering Foundation. The course is for college students preparing for such fields as law, business, political science, art, teaching, theology, psychology, sociology, and anthropology.

V. L. Parsegian, Alan S. Meltzer, Paul R. Shilling, Abraham S. Luchins, and K. Scott Kinerson.

INFORMATION AND COMMUNICATIONS (T)

The Role of Museums in Modern Communications (27 Dec.)

Arranged by Ileen E. Stewart (National Institutes of Health).

Museums are moving into an era of diversification and automation. Their role in the nation and the community is changing rapidly as they attempt to serve many kinds of people in many new ways. Long a reservoir of priceless materials, their storehouse is now being shared in new and interesting ways with both laymen and scientists. Museums are gradually assuming a more dynamic role in the structure of higher education. Their importance as an adjunct to elementary education is increasing as they develop new ways to reach a larger percentage of the school children of the nation. In order to efficiently catalog, store and distribute the vast quantities of new materials that reach them daily, museums are employing the computer. This symposium will attempt to describe the changes that are taking place in the country's major museums and the hoped-for effects that these changes will have on public usage and education as well as on scientific advances.

Sidney R. Galler, James A. Oliver, H. Radclyffe Roberts, Herbert Friedman, and Donald F. Squires.

The Genesis of Information Systems: Hindsight and Foresight (29 Dec.)

Arranged by Ileen E. Stewart (National Institutes of Health).

Why and how do information services start? What pressures and what needs create the impetus and provide the resources to initiate new systems? How are needs incorporated into design? How are changing needs discovered and reflected in the system? Why have some services succeeded and others failed? These are the kinds of questions that this symposium will attempt to answer. Speakers will represent or discuss a variety of existing information services, one defunct service and two in the early stages of planning and/or implementation.

Richard L. Kenyon, Meyer Kessler, Joseph Caponio, Karl F. Heumann, Norman E. Cottrell, and Joseph Becker.

Roles in the Processing of Scientific and Technical Publications (26 Dec.)

Arranged by Ethaline H. Cortelyou (National Institutes of Health).

Ethaline H. Cortelyou, Samuel Katzoff, L. Dillwyn Eckhard, Mary Schaefer, Mary Killilea, and George S. Haskins.

Section T Luncheon Address (29 Dec.)

H. Bentley Glass, *"Pugwash" Interest in Communications.*

STATISTICS (U)

Estimating the Numbers in Insect Populations (27 Dec.)

Arranged by E. C. Pielou (Canada Department of Agriculture, Ottawa).

As the world's population grows the struggle between

Participating AAAS Committees, Sections, and Affiliated Societies

Committees: AAAS Committee on Arid Lands, AAAS Committee on Science in the Promotion of Human Welfare.

Sections: Mathematics, Physics, Chemistry, Astronomy, Geology and Geography, Zoological Sciences, Botanical Sciences, Anthropology, Psychology, Social and Economic Sciences, History and Philosophy of Science, Engineering, Medical Sciences, Dentistry, Pharmaceutical Sciences, Agriculture, Industrial Science, Education, Information and Communication, and Statistics.

Affiliated societies: Academy Conference, Alpha Epsilon Delta, American Association of Bioanalysts, American Association of Clinical Chemists, American Astronautical Society, American Educational Research Association, American Mathematical Society, American Meteorological Society, American Nature Study Society, American Physiological Society, American Psychiatric Association, American Psychoanalytic Association, American Society of Criminology, American Society of Naturalists, American Society of Zoologists, American Sociological Association, American Speech and Hearing Association, Animal Behavior Society, Association for Computing Machinery, Association of American Geographers, Biometric Society, Central Association of Science and Mathematics Teachers, Commission on Education in Agriculture and Natural Resources, Commission on Undergraduate Education in the Biological Sciences, Committee for the Experimental Study of Populations, Ecological Society of America, Herpetologists' League, Metric Association, National Association for Research in Science Teaching, National Association of Biology Teachers, National Council of Teachers of Mathematics, National Geographic Society, National Institute of Social and Behavioral Sciences, National Science Teachers Association, National Speleological Society, Paleontological Society, Phi Beta Kappa, Population Association of America, Science Courses for Baccalaureate Education, Scientific Research Society of America (RESA), Scientists' Institute for Public Information, Sigma Delta Epsilon, Society for General Systems Research, Society for Industrial and Applied Mathematics, Society for the Scientific Study of Religion, Society of Systematic Zoology, Society of Technical Writers and Publishers, The Society of the Sigma Xi, and Torrey Botanical Club.

men and pest insects for the available food and forest resources is becoming more intense, and more expensive. The success, or lack of it, of attempts at pest control cannot be judged unless one can estimate the number of pests in a given area. Only when these estimates can be made is it possible to judge how population sizes fluctuate, both naturally and as a result of human intervention. Many species of insect are involved; they vary widely in density; in the sort of environment they are found in; in motility; in their behavior at the different stages of their life histories; in the degree to which they are controlled by natural agencies; and in the damage they cause. Any particular population therefore presents its own peculiar problems. Taking the particular circumstances into account, the field worker has to devise a sampling scheme that is statistically sound, that gives the required precision, and that he can afford on his budget. There is thus great need for a thorough union of practical and theoretical knowledge.

E. C. Pielou, J. F. Wear, C. A. Miller, D. O. Greenbank, J. U. McGuire, Jr., L. P. Lefkovitch, F. B. Knight, D. M. Lee, R. C. Chapman, and G. M. Furnival.

Testing Compatibility for Kidney Transplants (28 Dec.)

Arranged by Max A. Woodbury (Duke University Medical Center).

Fritz H. Bach, S. J. Kilpatrick, Benjamin Barnes, and Max A. Woodbury.

GENERAL SCIENCE (X)

Academy Conference (27–28 Dec.)

AAAS–Academy Relationships (27 Dec.)
Youth Activities of the Academies (27 Dec.).
American Junior Academy of Science (28 Dec.).
Twenty-first Annual Junior Scientists' Assembly (28 Dec.).

AAAS SCIENCE FILM THEATRE

Arranged by Marlyn Lippard (AAAS Staff).
Note: Young people under sixteen are admitted to the Theatre only if accompanied by a registered adult.

Foreign Films I (27 Dec.)

Winter Guests (Les Studios Cinematographiques "Al. Sahia," Bucharest, Roumania).

The Nuclear Challenge (International Atomic Energy Agency, Vienna, with Kráthý Film, Prague, Czechoslovakia).

The Beautiful Land—The Geological Evolution of Japan (Tokyo Cinema Company, Inc.).

The 4th State of Matter (Comitato Nazionale per l'Energia Nucleare, Rome, Italy).

Catching of Fish by Poisoning the Water (Institut für den Wissenschaftlichen Film, Göttingen, West Germany).

The Metamorphosis of the Lepidoptera (Montello Film, Rome, Italy).

A New Realty (Statens Filmcentral and Laterna Films, Denmark, and Organization for Economic Cooperation and Development).

Foreign Films II (27 Dec.)

Crystallographers in Conference (Commonwealth Scientific and Industrial Research Organization, Australia).

Living Jewels (M. Guillon, France).

Low Reynolds Number Flow (National Committee for Fluid Mechanics Films and Educational Services Inc.).

In Pursuit of Cancer Cells (Tokyo Cinema Incorporated, Japan).

A Light in Nature (Petroleum Institute for the Royal Society, London).

Serpents of the China Sea (Laboratoire des Instituts Pasteur hors Metropole, Saigon).

United States Films (28 Dec.)

Legacy of Gemini (National Aeronautics and Space Administration).

Brookhaven Spectrum (Atomic Energy Commission's Brookhaven National Laboratory).

Secret of the White Cell (Prism Productions, Inc.).

Symmetry (Sturgis-Grant Productions).

LSD: Insight or Insanity? (Max Miller).

The Growing Edge (Empire Photosound Incorporated).

People and Particles: A Documentary Film of Physics Laboratory (Harvard Project Physics).

Introduction by Gerald Holton (Professor of Physics, Harvard University).

Films on Transportation (28 Dec.)

A Trip from Chicago (CBS News, Inc.).

Autos, Autos Everywhere (CBS News, Inc.).

Safety First-Second-Third (General Motors Corporation).

Dawn of an Industry (Derek Stuart for the British Petroleum Co., Ltd.).

United Aircraft Turbo-Train: A New Dimension in Rail Passenger Travel (United Aircraft Corporate Systems Center).

Horsepower and Hydrocarbons (State of California Motor Vehicle Pollution Control Board).

Noise: The New Pollutant (National Educational Television).

Films on Marine Science (29 Dec.)

The Earth Beneath the Sea (Lamont Geological Observatory of Columbia University).

Flying at the Bottom of the Sea (National Educational Television).

History, Layer by Layer (Lamont Geological Observatory of Columbia University).

Oceanography at Work (Willard Bascom).

Conquering the Sea (CBS News, Inc.).

A Fish-Eye View of Alligator Reef (National Geographic Society).

Illustrated Lecture by Walter A. Starck II (Institute of Marine Sciences, University of Miami).

Lewis Mumford On The City (29 Dec.)

The City, Heaven and Hell; The City, Cars or People; The City and Its Region; The Heart of the City; The City as Man's Home, and *The City and the Future.*
(National Film Board of Canada).

Seventy-Five Years of Scientific Films: 1890–1965 (30 Dec.)

A collection of unique historical films, some more than 70 years old, has been gathered from many countries for this special program illustrating the development of the scientific film.

Introductory remarks by Peter Morris (National Science Film Library, Canadian Film Institute).

Documents Filmés (Marey-Bull), France, 1891–1924.

Pond Life (Section), Britain, 1903.

Neu-Guinea (In Memoriam Dr. Rudolph Poch), Austria, 1904–1906.

Les Rayons Invisibles de Roentgen, France, 1912.

La Circulation du Sang, France, 1912.

Crystals: Their Making, Habits, and Beauty, U.S.A., 1914.

Battle of the Ants, Britain, 1922.

The Praying Mantis, Britain, 1927.

Einstein's Theory of Relativity, U.S.A., 1923.

The Cultivation of Living Tissue (Extract), Britain, 1923–1933.

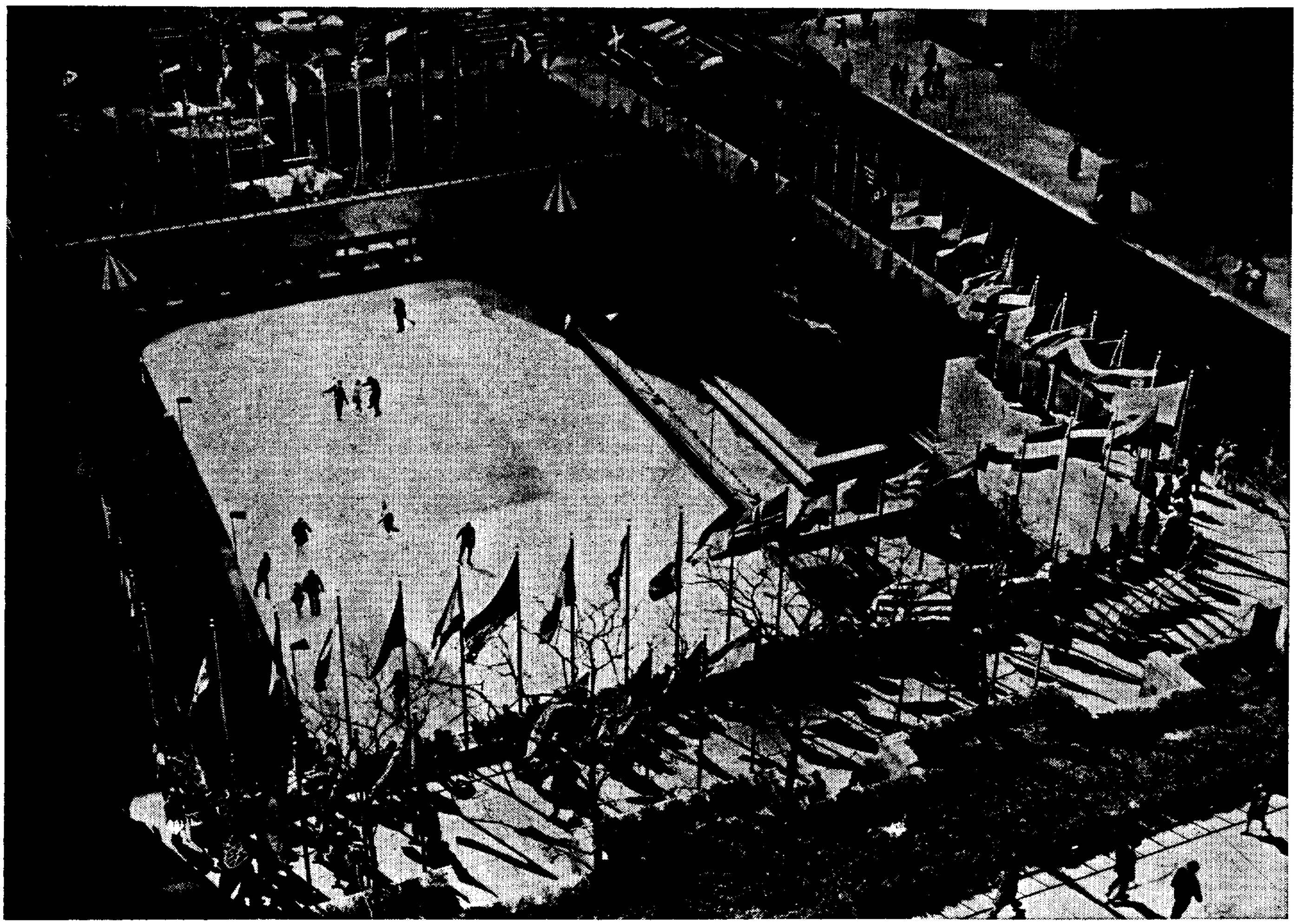
L'Hippocampe, France, 1934.

In the Sands of Central Asia, U.S.S.R., 1942.

Embryonic Development—The Chick (Extract), Canada, 1953.

Cancer Cells (Extract), Japan, 1959.

Inflorescence, Czechoslovakia, 1966.



Ice skating at Rockefeller Center, midtown Manhattan. [Impact Photos, New York City]

See Science, *22 September 1967, for details about registration and hotel reservations for the AAAS Annual Meeting. Additional reports on events or symposia taking place during the AAAS Annual Meeting appear in the following issues of* Science: *22 September, "Evolution of the Earth's Atmosphere"; 29 September, "Terrestrial Adaptation in Crustacea"; 6 October, "Behavioral Research—New York Zoological Park"; 13 October, "Weather Modification"; 20 October, "Hazards of Iodine-131 Fallout in Utah"; 27 October, "New York Botanical Garden—Research and Education"; 3 November, "New York Aquarium and Osborn Laboratories of Marine Sciences"; 10 November, "Psychoanalytic Studies in Child Development" and "Adhesion in Biological Systems"; 17 November, "Lamont Geological Observatory" and "Marine Science"; 24 November, "Crime, Science, and Technology," "Molecular Approaches to Learning and Memory," and "Man and Transportation"; and 1 December, "Haskins Laboratories," "Web-Building Spiders," and "AAAS General and Sectional Symposia." Additional coverage about the meeting will appear in* Science, *15 December ("Boyce Thompson Institute," "AAAS Section Programs," and "Psychochemical Research Strategies in Man").*

Meetings

Geology along the North Atlantic: Gander Conference

Geologic relations on opposite sides of the North Atlantic Ocean do not prove the theory of continental drift but most of them support the hypothesis. This was the informal conclusion at an international conference held 24–31 August 1967, at Gander, Newfoundland. More than 50 papers were presented to 114 participants, of whom 40 came from the United States, 31 from Great Britain, 30 from Canada, and 13 from other countries. Several field trips were made before, during, and after the formal programs.

The papers fell into two main categories. Many were informative or discursive, describing the details of geologic relations and rocks in Great Britain, the maritime provinces of Canada, northeastern United States, Greenland, and the islands of the North Atlantic. Other papers were advocative or argumentative, noting pertinent comparisons or contrasts within or between the several geographic regions, or pressing for specific interpretations of structure or geologic history. Still others dealt with such particular processes as faunal relations, oceanographic and geophysical findings, and geotectonic matters. A large volume of detailed data was laid before the conference, in part summarizing known information and in part suggesting new lines of research for additional study.

The program commenced with several papers on the PreCambrian of Scotland, Ireland, Newfoundland, and New England, with emphasis on the radiometric age, structure, and metamorphism of such rocks as the Lewisian, Torridonian, Grenville, and early Dalradian series. This discussion was followed by similar regional analyses of the Cambrian and Ordovician rocks around the North Atlantic, with special emphasis on their similarities, geologic and faunal histories, magnetism, and tectonic structures. Differences were discussed between the so-called Atlantic and Pacific provinces of Newfoundland and Britain. Intercontinental correlations of Cambro-Ordovician rocks and graptolites were suggested.

Other sessions dealt with Silurian, Devonian, and Carboniferous systems of the North Atlantic region; transcurrent and other faulting, including the thrust sheets of western Newfoundland; the relation of specific formations, such as the Old Red Sandstone and various other conglomerates, to general tectonic history and to particular structures; Arctic lands; geophysical and oceanographic relations; and the synthesis of all of these details into a composite pattern.

The subject of continental drift was a common thread running through most of the papers. Evidence bearing upon drift fell into five types: (i) paleogeographic evidence based on intercontinental similarities during a single time span; (ii) structural comparisons of historical events during extended time periods; (iii) the physical congruence of Atlantic coasts or the jigsaw types of continental fit; (iv) specialized interpretations such as polar wandering, magnetic reversals, seismic and sea-floor data; and (v) faunal and radiometric similarities. In general it was agreed that the Canadian Maritime Provinces and the British Isles are remarkably alike in many geologic respects, with differences being less prominent than their similarities. At the same time there was some sentiment that Newfoundland is more like Ireland than Labrador or the American mainland, while Ireland resembles Newfoundland more than it does Scotland. There was no strong anti-drift sentiment, although some items supporting drift were questioned and many speakers took no stand pro or con.

The suggestion was made that the term "continental drift" no longer represents the whole of the tectonic process involved, and that a better term might sharpen the further study of these matters. It was also suggested that geologists on both sides of the Atlantic should standardize or integrate their use of such broad terms as Taconic, Caledonian, Appalachian, and others, so that all schools of geology would have a common understanding of the time and geographic significance of these terms. A portion of the last session was devoted to such a synthesis and some of its inherent problems were discussed without producing any interregional agreement.

A number of unresolved problems emerged in the course of the conference, such as the precise age of the Dalradian rocks of Ireland and northern Britain; the cause of certain anomalous radiometric dates, whether related to subsequent cooling or produced by the overprinting of subsequent events; the whereabouts of the American Grenville rocks in the British Isles; the nature of the crust under Newfoundland; the proper integration of American Taconic deformation with European Caledonian events; and the possible consanguinity of the Old Red Sandstone with the American Catskill formation. Other matters inviting more study were the great rifts described in eastern Greenland and the general dissimilarity of its geologic history with that of the rest of the North Atlantic province; the possibility of residual scars on the ocean floor resulting from the former stand of vagrant continental blocks; some revision of the reputed age dates of various Atlantic islands; and a suggested correlation of the extinction of certain foraminiferal genera with epochs of magnetic reversals.

One speaker discussed the need to analyze the types of evidence for continental drift, suggesting that a linear variable which could be identified on one side of the Atlantic and continued on the other might be more impressive and convincing than mere physical resemblances which could arise from a common history without requiring actual proximity.

The field trip to New World Island, 40 miles north of Gander, was attended by most participants who examined Ordovician and Silurian sedimentary and volcanic rocks that were strongly folded, variously intruded, thrust faulted, and subsequently broken by steeply dipping faults many of which showed transcurrent movement. One of the latter is the Lukes Arm fault which can be suspected of being a trans-Atlantic continuation of one of the

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analogous transcurrent faults of the Scottish Highlands.

The conference was arranged by Marshall Kay (Columbia University) with support from the National Science Foundation and the participation of the Geological Society of Canada.

The proceedings of the Gander Conference including both papers and their discussion will be published in a symposium volume shortly to be issued by the American Association of Petroleum Geologists.

HERBERT P. WOODWARD
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Calendar of Events

National Meetings

December

28–30. Archaeological Inst. of America, Boston, Mass. (C. Grandjouan, Archaeological Inst. of America, 100 Washington Sq. East, New York 10003)

28–30. **Econometric** Soc., annual mtg., Washington, D.C. (Administrative Assistant, The Society, Box 1264, Yale Station, New Haven, Conn.)

29. **Scientific Research** Society of America, New York, N.Y. (D. B. Prentice, 155 Whitney Ave., New Haven, Conn.)

January

4–6. **Human Factors in Automotive Engineering** Design, Ann Arbor, Mich. (Society of Automotive Engineers, Continuing Education Program, 485 Lexington Ave., New York 10017)

7–12. American **Chemical** Soc., New Orleans, La. (Meetings Manager, 1155 16th St., NW, Washington, D.C. 20036)

8–9. National Specialists Symposium on **Orbital Resonance**, Redondo Beach, Calif. (G. S. Gedeon, Systems Group, TRW, Inc., One Space Park, Redondo Beach 90278)

8–12. Automotive **Engineering** Congress and Exposition, Detroit, Mich. (W. I. Marble, Soc. of Automotive Engineers, Meetings Div., 485 Lexington Ave., New York 10017)

9–11. **Chemical Marketing**, Hopatcong, N.J. (Saul Gordon Associates Center for Professional Advancement, P.O. Box 66, Hopatcong 07843)

10–13. National Soc. of **Professional Engineers**, winter mtg., Washington, D.C. (P. H. Robbins, NSPE, 2029 K Street NW, Washington, D.C. 20006)

14–18. Society for **Cryo-Ophthalmologists**, Miami Beach, Fla. (J. G. Bellows, Executive Secretary, 30 N. Michigan Ave., Chicago, Ill. 60602)

15–16. **Medical Library** Board, Washington, D.C. (Medical Library Assoc., Inc., 919 N. Michigan Avenue, Chicago, Ill.)

15–17. **Noise Measurement and Control**, Hopatcong, N.J. (Saul Gordon Associates Center for Professional Advancement, P.O. Box 66, Hopatcong 07843)

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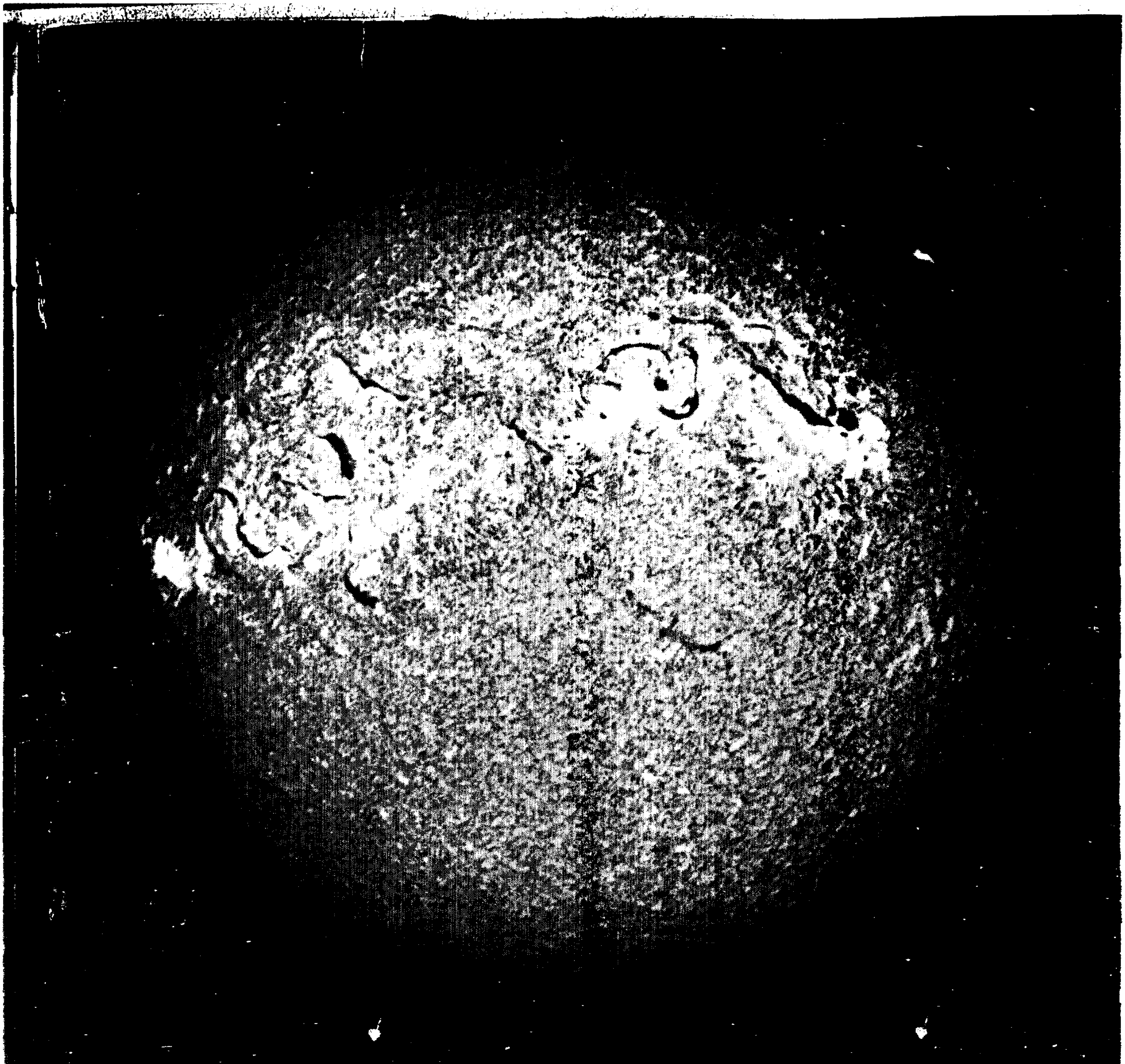

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NATURALLY OCCURRING ALPHA-ACTIVITY OF DRINKING WATERS

By R. C. TURNER, J. M. RADLEY and PROF. W. V. MAYNEORD

Physics Department, Institute of Cancer Research : Royal Cancer Hospital, London, S.W.3

THE present article represents a continuation of investigations into the nature and levels of naturally occurring α-activity in man and his environment. We have demonstrated the great variations of α-activity to be found as between different human foods[1]. Following the observations on foods it was natural to study the radioactivity of drinking waters supplied to the population of Great Britain.

Several investigators[2-8] have reported measurements of the radium-226 content of potable waters in other countries, but very few data have been published during recent years on the activity of waters in Britain. Following the observations of J. J. Thomson[9] early in this century on Cambridge water, there was considerable interest in this subject, but much of the earlier work leaves doubt as to whether the observed values applied to radium-226 or also included gaseous products such as radon-222, known to exist in certain waters at considerably higher levels of activity than its parent. In the present experiments we have measured the radium-226 content of 71 drinking waters available in Britain, and in addition we report the values for radon-222 and radium-224 (thorium *X*) when present.

In most instances the water samples have been made available to us by the co-operation of the local water undertakings at the request of the Ministry of Housing and Local Government

Experimental Procedure

The water samples were selected from several points of view, including the size of population supplied and the nature of the associated geological formations. The specimens were chosen with the view of assessing the total daily intake of natural radioactivity throughout Britain from its water supplies.

Preliminary experiments indicated that. if polythene containers were used for the collection and transport of the samples, it was unnecessary to add either carrier or acid agent to the water at the time of sampling. No residual α-activity could be detected on the walls of such containers even after they had housed specimens of relatively high activity for several days.

A litre of each specimen of water to be measured was evaporated to dryness in a 'Vitreosil' beaker and the α-activity of the residue measured, using the α-ray counting technique previously described[10]. In a few cases where the mineral content of the water was very low, 20 mgm. of barium chloride having known low α-activity was added to the water before evaporation in order to provide adequate residue.

Measurements were made on each specimen of residue immediately after evaporation and at intervals of a few days during the following 30 days, by which time the radon-222 and its α-emitting daughters polonium-218 (radium *A*) and polonium-214 (radium *C'*) would have reached equilibrium with the radium-226 present. After 30 days no further change of α-activity of the residue could be detected in any of the specimens. Assessment of the amount of radon-222 above the level required for equilibrium with the radium-226 present in each water was effected by observations on a liquid sample 2–3 mm. deep, sealed in contact with a zinc–cadmium sulphide phosphor of area 93 cm.^{2}. Adsorption by zinc sulphide crystals of the daughter products of radon-222 present in solution had been previously reported by Rosholt[11], who used the method to obtain quantitative yields of lead-218 (radium *B*) and polonium-214 (radium *C'*).

It has been observed by us that, when water containing dissolved radon at a level of activity many times higher than its content of radium-226 is assembled in such an arrangement, the α-counting-rate increases for the first hour after sealing the sample and thereafter decreases with the half-life of radon-222 (3·8 days), until the activity has fallen to the level represented by the content of radium-226 and other long-lived activity. If at any intermediate stage the water is removed and the activity of the phosphor itself observed, the counting-rate decreases rapidly during the first 10 min. or so, corresponding to decay of polonium-218 (radium *A*), and thereafter falls with a half-life of approximately 40 min. compatible with the decay of lead-214 (radium *B*) and bismuth-214 (radium *C*). It is thought that the solid decay products of the dissolved radon are deposited on the surface of the zinc sulphide crystals and the α-particles emitted by polonium-218 (radium *A*) and polonium-214 (radium *C'*) are assumed counted with 2π efficiency. So long as the water itself is present, the observed activity is maintained with the half-life characteristic of radon, although the radon α-particles themselves may contribute little to the counting-rate since their range in the medium is only 1 or 2 per cent of the depth of the water layer.

Fig. 1 shows the characteristic pattern of decay of α-activity observed in a water sample containing radon greatly in excess of the amount required for equilibrium with its radium-226 content. Each estimate of radon content has been corrected for decay between the time of collection of the sample and the actual measurement.

In a number of the more active water residues, fast pairs of α-particles were observed, indicating the presence of at least the shorter-lived members of the thorium series[10]. This conclusion was borne out by the subsequent variation of the thorium series activity with time, since it decreased rapidly during the first 20 days or so following evaporation, after which the thorium activity remained constant at a relatively low level. The presence of radium-224 (thorium *X*) in American potable waters has already been reported by Stehney[2], who found the levels of radium-224 in freshly sampled waters comparable with those observed for radium-226. Due to the short half-life of radium-224 (3·64 days) and of its α-emitting daughter members of the thorium series, this α-activity decreases to very low values in the 2–3 weeks subsequent to sampling. There is little doubt that the decreasing thorium series activity observed

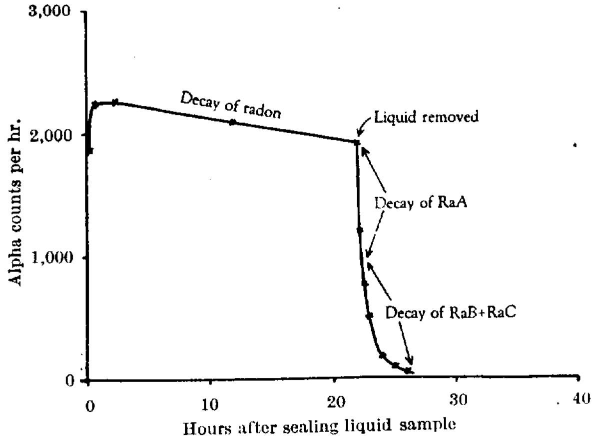

Fig. 1

in a number of our specimens is due to the presence of radium-224 and its daughters in the freshly sampled waters. In the absence of long-lived members of the thorium series, such as thorium-228 (radiothorium-228), at comparable levels of activity, the initial thorium series activity of these waters is regarded as due to radium-224 and its daughters. These values are given in Table 3 corrected for decay of activity since time of sampling.

In a number of the waters having very low activity it has not been possible to determine either the level of radium-224 or of the long-lived members of the thorium series.

In a few specimens having intermediate values of long-lived α-activity, the presence of thorium-228 and its daughters has been observed but at levels representing small fractions of the total long-lived α-activities given in Table 1.

Results

The values of long-lived α-activity together with the activities due to excess radon-222 and its daughters are given in Table 1 for various categories of water.

In a number of instances waters from more than one source have been measured for a given town, and these are listed separately. Ground-waters have been divided into two groups comprising those derived from boreholes in chalk and those from boreholes in other geological strata. Surface waters include sources such as springs, rivers, lakes and reservoirs.

Column 4 of Table 1 gives the content of solid matter observed (in parts per million), and column 5 the long-lived α-activity of this residue 30 days after evaporation of the liquid specimen.

Table 2 indicates the range of values and mean long-lived α-activity for the different categories of water and their residues.

In Table 3 the total α-activity of a number of the more active samples is broken down into its three main components.

Discussion

It will be seen from Tables 1 and 2 that the highest values of long-lived α-activity are found in the group of spa waters, which possess high contents of mineral matter having specific activities greater than those

Table 1

Origin	Long-lived α-activity (μμc./litre at 30 days)	Excess radon and daughters (μμc./litre at time of sampling)	Solid matter observed (parts per million)	α-Activity of residue (μμc./gm. at 30 days)
Spas				
* Vichy Celestin	48·5	—	3,150	15·4
Juventus	45·5	—	1,250	36·4
* Vichy Catalan	43·3	—	1,700	25·5
Bath	37·0	1,000–2,000	2,540	14·7
Llandrindod	26·2	200–300	3,320	7·9
Leamington	16·7	200–300	10,200	1·7
Buxton	4·5	1,500–2,000	210	21·5
* Vittel	2·2	—	675	3·3
* Perrier	1·8	—	370	4·8
Cornish waters				
St. Ives 1	9·40	9,000–10,000	163	57·6
Helston 3	4·10	600	170	24·1
Helston 2	2·20	100–200	125	17·6
Helston 1	1·41	1,000–2,000	83	17·0
Penzance 2	1·24	700–800	54	23·0
Penzance 1	1·02	100–200	70	14·6
St. Ives 2	1·00	9,000–10,000	42	23·8
Penzance 3	0·90	500–600	133	6·8
Camborne 1	0·59	4,000–5,000	83	7·1
Camborne 2	0·46	4,000–5,000	5	92·0
Ground-waters (not chalk strata)				
Bristol 1	2·90	300–400	1,230	2·4
Wolverhampton	2·28	—	273	8·4
Bristol 2	1·75	600–700	300	5·8
Leamington	1·60	100–200	420	3·8
Spalding	1·34	100–200	360	3·7
Hartlepools	1·00	100–200	380	2·6
Ashford (Kent) 2	0·58	~ 10	210	2·8
Cirencester	0·38	—	290	1·3
South Staffs 1	0·37	—	133	2·8
Ground-waters (chalk strata)				
London 1	1·22	—	380	3·2
Uxbridge	0·65	—	216	3·0
Canterbury	0·30	—	234	1·3
Sutton (Surrey)	0·27	10–20	100	2·7
Ashford (Kent) 1	0·26	—	200	1·3
Portsmouth	0·23	—	209	1·1
Colne Valley	0·22	100–200	360	0·6
Amersham	0·22	—	217	1·0
Barnet	0·19	100–200	200	1·0
Farnham Common	0·11	—	125	0·9
Brighton	0·11	—	188	0·6
Surface waters				
Bristol 3	0·81	100–200	370	2·2
Glamorgan 1	0·62	300–400	240	2·6
Bristol 4	0·52	50–100	158	3·3
London 3	0·47	—	380	1·2
London 2	0·41	—	284	1·5
Bath	0·33	10–20	244	1·4
Belfast	0·38	—	30	13·1
Paignton	0·30	—	25	12·0
Blaenau Festiniog	0·20	—	—	—
Skipton	0·20	< 1	80	2·5
Aberdeen	0·14	—	42	3·3
Manchester 1	0·12	—	54	2·2
Charminster	0·11	—	96	1·2
Dundee	0·11	< 1	33	3·3
Torquay	0·11	< 1	55	2·0
Edinburgh	0·10	< 1	33	3·0
Aberystwyth	0·10	—	—	—
Glasgow	0·09	—	—	—
Glamorgan 2	0·09	—	33	2·7
Sheffield	0·09	—	54	1·7
South Staffs 2	0·08	—	208	0·4
Hamilton	0·08	< 1	38	2·1
Birmingham	0·07	—	33	2·1
Manchester 2	0·05	—	29	1·7
Argyll	0·05	< 1	15	3·3
Elan Valley	0·04	—	5	8·0
Caernarvon	0·04	—	—	—
Manchester 3	0·04	—	21	1·9
Dolgelley	0·03	—	30	1·0
Bangor	0·03	—	—	—
Betws-y-Coed	0·03	—	—	—
Hazleton	0·02	—	—	—

* Bottled specimens as purchased

Table 2. LONG-LIVED α-ACTIVITIES IN DRINKING WATERS AND IN THEIR RESIDUES

Type of water	No. of samples	Activity of water in $\mu\mu$c./litre			Activity of residue in $\mu\mu$c./gm.		
		max.	min.	mean	max.	min.	mean
Spa	9	48·5	1·8	25·1	36·4	1·7	14·6
Cornish	10	9·4	0·46	2·2	92·0	6·8	28·4
Borehole (not chalk)	9	2·9	0·37	1·4	8·4	1·3	3·7
Borehole (in chalk)	11	1·2	0·11	0·34	3·2	0·6	1·5
Surface	32	0·8	0·02	0·18	13·1	0·4	3·2

Table 3. α-ACTIVITIES IN $\mu\mu$c./LITRE

Specimen		Short-lived α-activity due to radium-224 (Th X) and daughters at time of sampling	Long-lived α-activity after 30 days	α-Activity due to radon-222 and daughters at time of sampling
Llandrindod Spa		30·0	26·2	200–300
St. Ives	1	21·0	9·4	9,000–10,000
Bath Spa		7·7	37·0	1,000–2,000
Bristol	2	2·9	1·8	600–700
Helston	2	2·8	2·2	100–200
Helston	3	2·4	4·1	~ 600
St. Ives	2	0·7	1·0	9,000–10,000
Penzance	3	0·5	0·9	500–600
Camborne	1	0·3	0·6	4,000–5,000
Penzance	1	0·3	1·0	100–200
Camborne	2	0·2	0·5	4,000–5,000

found for surface waters or waters derived from boreholes.

The Cornish specimens, although having a mean level of activity lower than the spa waters by a factor of 12, are still approximately ten times higher in activity than the mean values of chalk borehole or surface waters. The mineral contents of the Cornish waters are relatively low; but the mineral matter has specific activities ranging up to 92 $\mu\mu$c./gm., doubtless associated with the known deposits of uranium and radium in parts of that county.

Next in descending order of long-lived α-activity come the drinking waters derived from boreholes in geological strata other than chalk. The mean activity of this group is only slightly lower than that found for the Cornish waters, and this would appear to be due to their higher mean contents of mineral matter, 400 parts per million compared with 90 for the Cornish samples.

Waters derived from boreholes in chalk have still lower activities with a mean level down by a factor of 4 below those derived from boreholes in other strata. It is interesting to note that the mean value found for the α-activities of their mineral residues (1·5 $\mu\mu$c./gm.) is very close to that reported previously by us[12] for the α-activity of chalk specimens.

The least-active group of waters observed by us are surface waters from rivers, lakes and reservoirs, even though a number are derived from areas of Pre-Cambrian or granitic rock formations. Their mean mineral content is 100 parts per million and their mean long-lived α-activity is lower by a factor of 12 than the Cornish waters.

There was, of course, the possibility that a substantial fraction of the observed long-lived α-activity was due to uranium-238. However, measurements of uranium contents of a number of waters in Great Britain have been reported by Smith and Chandler[13], who found values of less than 1 μgm. (0·34 $\mu\mu$c.) per litre in 124 out of a total of 162 specimens examined. Waters with values higher than this figure were, with one exception, not drinking waters. Our own observations on the growth of α-activity of the residues during the 30 days following evaporation leave little doubt that also in our series of waters the content of radium-226 is several times higher than the activity due to uranium-238.

Moreover, investigations of the uranium contents of North American river waters by Rona and Urry[14] show a ratio of radium-226 to uranium-238 of approximately 4 : 1. In another study of the activities of ground waters in the United States, Scott and Barker[15] also observed levels of radium-226 in excess of those due to uranium-238.

These results are borne out by the chemical estimations made by us of the uranium-238 contents of a number of our more active residues. These confirm the presence of uranium at levels of activity which represent only a small fraction of the total long-lived α-activity in each case. It is to be noted that even if the radium/uranium ratio is as low as 4 : 1, then the α-activity due to radium-226 and its daughters will still comprise 90 per cent of the total long-lived activity contributed by members of the uranium series.

In respect of the thorium series, Stehney[2] found no evidence of long-lived members such as thorium-228 in his studies of American potable waters, while Rona and Urry[14] assessed the ratio of thorium-230 (ionium-230) to uranium-238 in North American river waters as being a very small fraction of unity. The very low levels of long-lived α-activity due to the thorium series found by us in the present investigation agree with the findings of these observers.

In the absence, therefore, of either uranium-238 or thorium-228 at levels of activity comparable with those due to radium-226, the long-lived α-activities listed in Table 1 may be regarded as due to radium-226 and its α-emitting daughters, radon-222, polonium-218 and polonium-214, existing in radioactive equilibrium. The radium-226 content of any particular specimen is therefore taken as one quarter of the long-lived activity given in column 2 of Table 1. It will be seen, therefore, that the contents of radium-226 observed in this series of waters cover a range of 2,400–1, namely, from 0·005 $\mu\mu$c./litre to 12·1 $\mu\mu$c./litre.

If we exclude the spa waters and assume a daily intake of 2·5 litres per head of the population of Britain[16], then the daily intakes of radium-226 from water alone cover a range of almost 500–1, namely, from 0·013 $\mu\mu$c. to 5·9 $\mu\mu$c. In terms of long-lived α-activity the intakes from water range from 0·05 to approximately 24 $\mu\mu$c. per head per day.

So far we have considered only the long-lived α-activity due to the presence of radium-226 and its daughters. It will, however, be seen from Table 1 that a number of the waters possess relatively very high contents of radon-222 and its daughters at the time of sampling. This is especially the case in the Cornish specimens where the α-activities due to radon-222 and its daughters, polonium-218 and polonium-214, range up to 10,000 $\mu\mu$c./litre. On the basis of a daily intake of 2·5 litres the ingested α-activity can therefore be as high as 25,000 $\mu\mu$c. a day, that is, approximately 8,000 $\mu\mu$c. of radon and of each of its two short-lived α-emitting daughters. In any attempt to assess the possible significance of these materials we are faced with an almost complete lack of data concerning their metabolism in the human body. Meyer[17] in a classical series of experiments in the late 1920's came to the conclusion that radon ingested in drinking water had a 'mean life' of about 1 hr. in the body, being excreted principally by the lungs. On this assumption it is easy to calculate that during its stay in the body approximately 0·75 per cent, that is, 60 μμc. of radon and of each of its two α-emitting daughters, disintegrate completely. Since 1 μμc. of radon-222 comprises 1·78 × 10^4 atoms of radon, this implies the production of about 3 million α-particles and of a million or so atoms of lead-210 (radium *D*) in the body as the result of each day's intake of such water. In a future paper it is hoped to discuss certain aspects of the radiation dosimetry resulting from these findings.

It will be seen from Table 3 that a number of waters at the time of sampling also contain radium-224 (thorium *X*) and its three α-emitting daughters at levels of activity comparable with those of the long-lived activity due to radium-226 and its daughters. Since radium-224 is an isotope of radium-226 their fundamental chemistry would be identical, but the short mean life of radium-224 and its decay products may result in a very different distribution of absorbed energy.

Daily Intakes of Alpha-Activity

We now consider the mean daily intakes of α-activity per head of population resulting from drinking water. From information kindly supplied by the Ministry of Housing and Local Government we have estimated the number of consumers of each of the principal water supplies. Assuming a daily intake of 2·5 litres per head the mean daily intakes of α-activity from this source for various sections of the population are estimated in Table 4.

Table 4. Mean Daily Intake of α-Activity from Drinking Water μμc. per Head of Population

Group of population	Long-lived activity Ra-226 and daughters	+	Activity radon and daughters	+	Activity Ra-224 and daughters
Cornwall	4·5		8,300		~ 5·5
London area	1·0		20		very small
Whole of Britain	0·5		17		,, ,,
Scotland	0·25		2		,, ,,
Spa patients (1 litre per day)	21·1		~ 1,000		—

It will be seen that the mean daily intakes of long-lived α-activity for the four groups cover a range of 18 to 1, whereas from Table 1 it is clear that the range of individual intakes may exceed 400 to 1. For the mean daily intakes of radon plus daughters we have a range of 4,000 to 1 between the groups, with the range for individuals exceeding 10,000 to 1. The low mean value of long-lived α-activity in the Scottish waters illustrates, rather surprisingly, the low values which may be encountered in areas of granitic formations. For comparison, Table 4 also shows the approximate daily intake of α-activity resulting from the consumption of 1 litre per day of British spa water having an activity equal to the mean value observed by us for this type of water.

Maximum Permissible Levels of Natural Activity

The report of the International Commission on Radiological Protection[18] deliberately excludes 'natural background' from its scope. It is, however, recommended by the International Commission that, in considering the exposure of large populations in relation to somatic effects, the maximum permissible level be taken as one thirtieth of the continuous occupational value (168 hr./week) computed according to its basic rules. The value of maximum permissible concentration for soluble radium-226 in water suggested by the International Commission for continuous occupational exposure is 100 μμc./litre, so that the value for large populations would be 3·3 μμc./litre. This value is lower than our observed values for British spa waters and two Cornish waters. The activities of several other waters are more than 10 per cent of this estimate. A similar situation has been noted for some large populations in the United States[19].

However, direct observations by us[10] on human skeletons from Cornwall show that the radioactivity observed in them is many times less than would be expected on the basis of the assumptions made by the International Commission. The observed mean level of activity of the skeletons is a factor of at least a thousand below the lowest body burden known to have resulted in a tumour.

The apparent anomaly arises largely because the biological parameters which have been used in the calculations were based on observations on human subjects having large radium burdens acquired many years previously and who were therefore excreting the radioactive material at a very low rate.

In a previous article[20] we reported investigations of the levels of natural α-activity present in the daily diets of the population of Great Britain and came to the conclusion that the daily intakes of such activity could vary from a minimum of 4 or 5 μμc. to 400 or 500 μμc. or even more, depending on the particular choice of diet. It is evident that in places where the drinking water has a level of α-activity at the higher end of our observed range and the individual intake from food happens to be at the lower end of the range of dietary activity, then the daily intake of natural α-activity will be dominated by the contribution from water. In other locations where the drinking water is derived from surface sources having much lower activity, the contribution from food will be predominant, regardless of the choice of diet.

Whether the human body finds it easier to retain radium-226 and its daughters present in soluble form in drinking water than to retain the same elements, possibly in different chemical form, ingested in food, is not yet known. The relative contributions made by water and food to the real retention and utilization by the body of α-active substances and the factors which control retention in the two cases are the subject of present investigations.

Comparison with Fission Product Activity in Waters

Finally, perhaps we may consider these daily intakes of natural α-activity in water in relation to the published figures of the artificial β- and γ-activity due to the presence of strontium-90 and cæsium-137 in drinking water in Great Britain[21].

The pattern of distribution of these fission products is quite different from that of the natural α-activity, since they appear at their highest levels in surface waters. Ground waters have extremely low contents of fission products, but, as we have seen, high values of natural α-activity.

From the latest figures available (for the first half of 1959) we calculate the mean contents of strontium-90 and cæsium-137 in surface waters as 0·75 μμc./litre and 0·20 μμc./litre, respectively. The mean daily intakes of populations ingesting such drinking waters would therefore be 1·9 μμc. and 0·5 μμc. of the two nuclides, respectively.

For large populations the International Commission on Radiological Protection suggests 33 μμc./litre and 6,000 μμc./litre in water, respectively, for these materials as the maximum permissible concentrations. It will be seen that the observed values are very small in comparison to these permissible levels.

Note added in proof. Since these investigations were completed, we have had the opportunity of examining specimens of drinking waters supplied to Horrabridge, Devon. The radioactivity of these particular waters has been the subject of recent communications[22,23] concerning the incidence of cancer in the area. We find the long-lived natural activity of the Sampford Spiney supply to be 0·6 μμc./litre, and its content of radon + daughters 2,500–5,000 μμc./litre. It will be seen that these values are well within the range reported in Table 1 above for waters in south-west England.

Many of the water samples were obtained through the goodwill and co-operation of Mr. A. W. Kenny, of the Ministry of Housing and Local Government, who kindly approached on our behalf the chief engineers of numerous water undertakings, to all of whom we would like to express our sincere thanks.

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RaD, RaE, and Po in the Atmosphere

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At the time this research was undertaken, a survey of the literature revealed many references concerning the amounts of the short-lived RaB and ThB in the atmosphere, but no information on the quantities of the longer-lived RaD, RaE, and Po.‡ This dearth of information prompted us to install facilities at several naval bases in different parts of the world to collect natural radioactive products from the atmosphere for subsequent analysis at Washington, D. C.

These collections were made by either, or sometimes by both, of two methods. The first method used high-capacity air filter units with filter paper as the collecting medium. The second involved the collection of large volumes of rainwater (100–600 gal) and the concentration of the activity with aluminum hydroxide floc. As a result of the chemical methods used, the radioactivity from up to 1,000 gallons of rainwater or 10^6–10^7 ft^3 of air could be concentrated readily on 50–100 mg of carrier. Counting of the separated β-activity gave a reasonably accurate measurement of the concentration of the long-lived products in the atmosphere. Qualitative estimates of the Po alpha activity were made.

Rain-Water Collection

Rain was collected on 500–1,000-ft^2 surfaces made of aluminum sheeting and was conveyed by aluminum gutters and pipes to aluminum collecting tanks. For some of the collections made at the Naval Research Laboratory, automatic controls diverted portions of the rain into three different tanks so as to compare the activities collected during different parts of the rain.

In many of the collections more rain

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‡ Recently some information on the longer-lived activities in air has been reported (*1, 2*).

TABLE 1—Rainwater Collections Made at Washington, D. C.*

Date collected (1950)	Volume collected (gal)	Pb fraction: β-activity (dpm)	Pb fraction: α-activity (dpm)	Bi fraction: β-activity (dpm)	Bi fraction: α-activity (dpm)
Jan. 12–30	340	1,400	6	12,000	710
Mar. 31–Apr. 24	220	850	8	14,600	600
May 3–12	260	2,140	10	14,200	490

* Activity not corrected for decay, absorption, or backscattering.

TABLE 2—Distribution of RaE(Bi^{210}) Activity Among Rainwater Fractions Collected at Washington, D. C.

Date collected (1950)	Rainfall (in.)	Volume collected (gal)	Insoluble residue (gm)	β-activity (dpm)*	β-activity (dpm/gal): Tank A	Tank B	Tank C	Total collection
June 29		30	12.5	1,930	64			29
		60	2.9	1,740		29		
		150	1.4	3,200			21	
July 9		30	0.8	1,200	40			
		60	0.8	160		3		6
		225	2.4	450			2	
July 15–16		40	7.0	2,360	59			
	1.5	55	2.1	1,230		22		17
		300	0.9	3,080			10	
July 20		40	7.6	2,300	57			
	1.4	60	1.7	2,160		36		19
		300	1.7	3,240			11	
Aug. 19	4.8	40	25.0	1,700	43			
	(cont.)	60	3.6	1,080		18		13
		275	3.0	2,180			8	
Aug. 23	1.35	40	4.9	2,760	69			
	(2-hr	60	1.4	1,760		29		40
	rain)	275	2.0	10,640			39	
Sept. 11		40	5.3	250	6			
		115	3.0	790		7		9
		275	2.0	2,640			10	
Sept. 21		40	12.5	1,330	33			
	0.86	60	2.1	1,740		29		30
		275	2.1	8,250			30	
Oct. 8–9		40	7.6	1,280	32			
	0.54	60	3.5	950		16		12
		275	2.5	2,260			8	
Oct. 23		40	4.0	2,000	50			
	1.86	60	6.2	1,890		32		20
		275	3.0	3,400			12	
Nov. 20		40	5.3	2,220	56			
	0.55	60	13.7	1,640		27		22
		150	2.8	1,580			11	
				Average	46	22	15	20

* Activity of Bi_2O_3 fraction corrected to time of Pb-Bi separation.

fell than could be contained in the tanks and much was lost through overflow. The results are based on the water remaining in the tanks at the end of the collection period.

Floccing procedure. The rainwater in the tanks was stirred with a jet of compressed air and a solution of aluminum sulfate was added to make the final concentration about 0.2 gm $Al_2(SO_4)_3 \cdot 18\ H_2O$ per gallon of water. The pH was adjusted to 7.0 ± 0.1 with a sodium carbonate solution using LaMotte standards with bromthymol blue indicator. Stirring was continued for 45–60 min and the treated water allowed to settle undisturbed overnight. After settling, the clear supernate was removed by syphoning and the $Al(OH)_3$ floc transferred to glass bottles for further settling and concentrating. The floc from 1,000 gal of water could generally be concentrated to a volume of 2–5 gal.

This procedure has been checked by adding 50–100 mg of soluble lead and bismuth salts to 100 gal of water and then collecting them with aluminum hydroxide floc as described above. At the concentrations used ($0.6\text{–}1.1 \times 10^{-6}$ mole/liter), recoveries were about 70–90%, including all losses due to separation of the floc and chemical separation of the material.

Chemical procedure. The floc samples were boiled with hydrochloric acid (1:4) and filtered from any insoluble residue. In some cases this residue was further treated with nitric, sulfuric, and hydrofluoric acids and analyzed separately. This treatment was discontinued when insignificant quantities of RaD, RaE, and Po activities were found to be associated with this material.

Carriers equivalent to about 75 mg each of Bi_2O_3 and $PbSO_4$ were added to the solutions and equilibrated with the radioisotopes. Standard procedures for separating bismuth and lead were used. The separated materials were redissolved and reprecipitated to improve the radiochemical purity.* The time of separation was noted and the samples ignited, weighed, and mounted on plastic planchets for counting. The counting rates obtained by use of standard techniques were converted to decomposition rates by applying appropriate geometry corrections.

Results. Some of the data resulting from the analysis of a few rainwater samples collected at Washington, D. C., are shown in Table 1. The identity of the RaD (22-yr Pb^{210}) was established by following the rate of buildup of RaE (5-day Bi^{210}) in the lead fraction. The RaE contained in the bismuth fraction decayed with a 5-day half-life. Some α-activity due to Po^{210} was invariably found in the bismuth fractions. The separation of Po^{210} in carrier-free condition gave activities as high as 5,000 dpm from several collections; however, this procedure was not employed routinely since it gave only qualitative results.

A number of studies were made on the distribution of the RaD in different portions of the rain (Table 2). There seems to be no correlation between the concentration of activity in the sample and quantity of dirt, character of the rain, or time between rains. In general, however, the first portion of the rain contains the greatest amount of insoluble material and the highest concentration of activity.

Collections of RaD activity made at a number of different sites are compared in Table 3. Some variations are to be noted at each site though they are not as great as the differences between collections at different locations. Rainwater collections from inland sites such as Glenview, Ill., and Washington, D. C., exhibit the highest concentration

* At times when fission-product activity is present in the sample, further radiochemical purification of these fractions is required.

TABLE 3—Distribution of RaE in Rainwater at Various Locations

Location, date collected (1950)	*Rainfall (in.)*	*Volume collected (gal)*	*Insoluble residue (gm)*	*Carrier recovery (%)*	*β-activity of Bi_2O_3 fraction†*		
					dpm	*dpm/gal*	*dpm/gal (avg)*
Glenview, Ill.							
Jan.		265	*	89	6,600	25	
Jun. 2–3	1.6 (squall)	564	38.9	95	13,100	23	
Jun. 24–30	Flash showers	563		76	13,700	24	
Jul. 6–19	1.23 (showers)	563	6.6	22	5,640	10	21
Panama							
Mar. 7–14	0.48	170	0.1	102	470	2.8	
Mar. 16–Apr. 24		250	0.8	96	2,270	9	
May 18–27	15.96 (continuous)	500	0.3	87	600	1.2	
Jun. 28–Jul. 20	10.78 (continuous)	500	*	101	1,920	3.8	
Jul. 20–Aug. 14	16.17 (continuous)	500	0.5	96	1,210	2.4	
Nov. 24–Dec. 15	20.27 (continuous)	500	4.5	79	1,070	2.1	
Jan. 5–Feb. 6 (51)	1.75 (showers)	500	*	83	1,130	2.3	3
Hawaii							
Mar. 8–Apr. 7	showers	400	*	107	1,310	3.3	
May 2–Jun. 12	showers	350	0.2	100	720	2.1	
Aug. 13–Sep. 18	showers	400	5.0	89	4,890	12	
Sep. 18–Dec. 11	continuous	300	16.7	90	5,340	18	9
Philippine Islands							
May 4–25	showers	270	*	152	2,090	8	
Jul. 4–Aug. 2	continuous	270	*	108	2,070	8	
Aug. 2–30	cont. for 2 wk	270	*	143	2,280	8	
Oct. 3–25	showers	270	*	94	3,060	11	
Oct. 30–Nov. 30	showers	270	3.4	94	3,000	11	9
Samoa							
Apr. 1–30	daily	400	96.5	204	2,960	7.4	
May 1–31	daily	400	*	106	330	0.8	
Jun. 1–30	daily	400	*	90	290	0.7	
Jul. 1–31	daily	400	0.7	92	460	1.1	
Aug. 1–31	daily	400	0.4	97	170	0.4	
Sep. 1–30	daily	400	4.5	95	1,010	2.5	2
Kodiak, Alaska							
Jun. 6–19	2.3 (scattered)	400	4.8	90	2,620	6.5	
Jun. 19–Jul. 5	3.3 (scattered)	500	1.7	107	2,300	4.6	
Jul. 7–17	1.9 (scattered)	500	6.8	100	1,550	3.1	
Sep. 11–25	7.6 (continuous)	500	1.0	89	3,450	6.9	
Oct. 23–Nov. 6	0.4 (scattered)	500	5.5	89	6,350	12.7	
Dec. 5–27	2.1 (scattered)	500	4.0	101	2,590	5.2	6.5

* Residues dissolved completely by wet ashings and fusions.
† Corrected to time of Pb-Bi separation.

TABLE 4—Filter-Paper Collections Made at Washington, D. C.*

Date collected (1950)	Volume processed (ft^3)	Pb fraction		Bi fraction	
		β-activity (dpm)	α-activity (dpm)	β-activity (dpm)	α-activity (dpm)
Mar. 1–31	2×10^7	1,960	2	4,770	4
Mar. 21–31	5×10^6	960	4	2,040	112
Mar. 21–Apr. 24	2.5×10^7†	90	2	1,210	34
Mar. 31–Apr. 24	2×10^7	410	8	8,510	274
Apr. 3–15	1.5×10^7			5,610	128

* Activity not corrected for decay, absorption or backscattering.
† Filter used as backing for Mar. 21–31 and Mar. 31–Apr. 24 collections.

of activity; those on the coast (Panama) or on larger islands (Hawaii, Philippine Islands, Kodiak) show less activity, and the collection made on a relatively small land mass far removed from continental areas (Samoa) shows the least activity. All of the bismuth fractions that were checked showed some α-activity (Po^{210}).

Blower Collection

Air taken from outside was passed through a 400 in^2 filter paper (Army Chemical Corps Type 5) at about 2,000 ft^3/min and vented in such a manner that it was not drawn into the system again. At the end of the collection period the filter paper was removed and put into solution; the lead and bismuth were separated in the same manner as from the floc.

Chemical procedure. Filter-paper samples were dissolved by fuming with hot nitric-sulfuric acid mixtures to which a small quantity of hydrofluoric acid had been added. The remainder of the procedure was the same as for the rainwater samples.

Results. Results for the filter-paper collections (Table 4) were similar to those obtained with rain water. Only rough estimates of the volumes of air have been made since the quantity of dust picked up by the filter caused the flow-rate to decrease continuously.

As considerable time elapsed between the dates of collection at the various sites and analysis at Washington, D. C., the RaD-RaE equilibrium had been reestablished and RaE measurements were essentially the measurements of the RaD parent in the sample.

Conclusions

The presence of RaD and Po in the atmosphere suggests that a study of the ratio of these activities can lead to information relative to the lifetime of these materials in the atmosphere. It would be of interest to see how well such a determination would agree with the measured mean lifetime of about 15 days for RaD in the atmosphere as determined from comparisons of the short-lived radon decay products with RaD in the air (*1*). No attempt is made here to determine such a value since the Po determination was not made with sufficient accuracy.

The results suggest several generalizations:

1. High-capacity air filters and rainwater collections effectively provide large samples of airborne natural radioactive decay products.

2. The RaD activity collected by rain varies widely at different places and at different times at any given place. On the basis of present information, there seems to be no simple correlation of the quantity of activity collected with the character of the rain, the seasons, or the quantity of dirt present in the collection from rain.

3. The average RaD activity varied by a factor of 10 between island sites, e.g., Samoa, and inland locations, e.g., Washington, D. C.

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MEASUREMENTS OF RADON CONCENTRATION IN THE TROPOSPHERE UP TO 5,000 METERS

By

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SUMMARY

We measured the concentration of radon from sea level to 5,000 meters under different meteorological conditions. Assuming that the radon is in equilibrium with its daughters we can calculate the radon concentration from that of the daughter products.

The sampling is carried out by aircraft with two different techniques.

1. Stepwise sampling - The activity of the filter at the end of each sampling gives the radon concentration at the designated altitude.

2. Continuous sampling during climb and descent - A curve giving the activity of the filter as a function of altitude is analyzed with a computer.

In most cases the variations are most marked in the lower levels, the activity then falls off slowly with altitude. Results can be interpreted in terms of the meteorological conditions corresponding to the different samples.

I. INTRODUCTION

To our knowledge the first measurements of vertical distribution of radon in the troposphere were made in 1950 (1). The samples taken in Ohio showed a decrease in activity with altitude while the measurements made in California over the ocean showed an increase with altitude. The theoretical interpretation of these results indicated that in the second case the air originated in Asia and that the horizontal wind speed was greater at higher levels than near the surface. This explained the inverted concentration profile. Between 1956 and 1958 several series of measurements were made in the USSR by Kirichenko (2) who used the profiles obtained in certain cases to deduce the variation of the diffusion coefficient with altitude. In the United States Wilkening in 1952 (3) carried out several measurements above New Mexico, more recently this author has used radon to study the levels above the mountains (4). A theoretical study of the vertical distribution of radon in the troposphere has been made by Jacobi (5) and more recently by Bouville and Machta (6) who considered the time variations of the diffusion profile.

A knowledge of the vertical distribution of radioactivity in the troposphere is interesting for several reasons:

1. The natural radioactivity contributes to atmospheric ionization and therefore is of interest in atmospheric electricity.

2. Radon is the parent of long lived radionuclides (lead-210 and polonium-210) which are used as tracers for atmospheric physics (large scale air mass movements, washout, etc.). To interpret the variation in these nuclides and to study their diffusion it is necessary to know their source, that is the distribution of radon in the atmosphere.

3. Radon is an interesting tracer, in particular for the study of diffusion.

We have measured with aircraft the radon concentration to 5,000 meters under different meteorological conditions in the Southwest of France above Landes and Armagnac-Bigorre not far from the Atlantic Ocean. We assume that the radon is in equilibrium with its descendants and calculate its concentration from that of the daughter products. The apparatus has been designed so that it can be used with aircraft or with captive balloons.

II. PRINCIPLES OF THE METHOD OF RADON MEASUREMENT

Airborne aerosols are collected on a filter by a pump and the activity is measured during sampling.

With the aircraft we use two techniques. The first consists in sampling at a fixed altitude (sampling time is a function of the activity and of the desired precision). The filter which collects the radioactive daughter products is counted during the sampling and is changed at each altitude. The concentration is thus determined directly for each level and it is possible to cover a considerable range of altitudes in a few hours. In the second procedure we take the samples continuously during climb or descent of the aircraft without changing the filter, the activity being measured continuously. This method allows studying the activity at different altitudes in relatively short time but it is necessary to analyze the activity curve to obtain the variations of radon concentration.

In both cases we make simultaneous measurements at the surface.

With the captive balloons we place several samplers along the cable with one at the surface. The activities of the filters and the meteorological data are transmitted by telemetry.

III. DESCRIPTION OF THE EXPERIMENTAL EQUIPMENT

Sampling of atmospheric aerosols is carried out by drawing air through a fibre filter loaded with asbestos. The air is moved with a turbine having a 550 watt motor fed by the aircraft generator. There is a diaphragm flowmeter on the pump which allows constant regulation of the volume of air filtered. The air intake is a bent tube passing through one of the windows and facing forward.

The alpha activity of the atmospheric aerosols is measured by a scintillation counter made up of a ZnS scintillator 20 cm in diameter coupled to a 54 AVP photomultiplier by a plexiglass light guide. The shaped output pulses are fed to a portable scaler (Figure 1). In the captive balloons the turbines have 550 watt motors. The current is carried by the cables whose weight is 21 kg/km and whose core is a nylon thread having a 50 kg breaking strength. The voltage loss in the cables are compensated for at the surface by an autotransformer so that the supply to each motor is maintained at 220 volts. The electrical resistance of the cable is 500 ohms per km.

IV. FILTER ACTIVITY

A. Stepwise Measurements

The radon is assumed to be in equilibrium with its daughters. The radon concentration corresponding to a given level is calculated directly from the filter activity. Figure 2 shows the calculated variation of the total number of alpha particles emitted by the filter as a function of time during and after collection. The sensitivity of the apparatus is 5×10^{-13} curies/kg for a 20 minute sample of radon daughters.

B. Continuous Measurements

During climb or descent of the aircraft the radon concentration is not constant and it is no longer possible to determine the radon concentration directly from the filter activity. Our method allows determination of the concentration profile by assuming that radioactive equilibrium remains fixed in the air. The variation of the number of atoms of each daughter present on the filter is equal to:

$$\frac{d\,N_i(t)}{dt} = Q_i(t)\,q + \lambda_{i-1}\,N_{i-1}(t) - \lambda_i\,N_i(t)$$

where q is the air flow, N is the number of atoms of each type and λ is the decay constant for each daughter.

We assume that during the time interval from t_0 to t that the quantity of each element reaching the filter is constant and that the equilibrium remains established. After integration:

$$\begin{aligned} N_2(t) &= A_2\,N_2\,(t_0) + B_2\,Q_2(t) \\ N_3(t) &= A_3\,N_3\,(t_0) + B_3\,N_2(t_0) + C_3\,Q_2(t) \\ N_4(t) &= A_4\,N_4(t_0) + B_4\,N_3(t_0) + C_4\,N_2(t_0) + D_4\,Q_2(t) \end{aligned} \qquad (1)$$

where A, B, C, and D are the constant coefficients for the time interval determined from the initial equations.

The alpha activity of the filter during the time interval from t_0 to t is:

$$R_\alpha\,(t) = K\,\lambda_2\,N_2(t) + \lambda_4\,N_4(t)$$

where K is a coefficient allowing for the difference in detection efficiency for polonium-218 and polonium-214.

The radon concentration may thus be written:

$$Q_2(t) = \frac{1}{K\lambda_2 B_2 + \lambda_4 D_4}\quad R_\alpha(t) - K\lambda_2 A_2 N_2(t_0) + \lambda_4 A_4 N_4(t_0) + \lambda_4 B_4 N_3(t_0) + C_4 \lambda_4 N_2(t_0) \qquad (2$$

Knowing that at the start of sampling $t_0 = 0$, $N_2(0) = 0$, $N_3(0) = 0$, and $N_4(0) = 0$, the groups of equations (1) and (2) allow determination of the radon concentration from the alpha activity of the filter by means of a computer.

V. EXPERIMENTAL RESULTS

We present a certain number of radon profiles obtained during several sets of measurements. A meteorological study made with the help of daily measurements of the Weather Bureau plus measurements on board the aircraft (humidity, wind and temperature gradient) allow interpretation of the results.

A. Horizontal Flight

On May 9, 1966 we made a horizontal flight at 500 meters altitude between Mont-de-Marsan and Toulouse (150 km over a region cut with valleys and of the same geologic origin). The south of France is normally in a flow from the north-west, a cold circulation at high altitude maintains a strong unstable activity above France. The region surveyed was situated at the edge of the disturbance. There was partial cloud cover of low cumulus.

Curves 1 and 2 of Figure 3 show the variations in filter activity during the trip out and the return. Curve 3 shows the alpha activity of the filter for the case where the radon and daughter concentrations remain constant during sampling. The three curves are identical indicating a constant radon concentration during a flight. There were no significant variations due to uneven emanation from the soil.

B. Influence of an Emanation Discontinuity

On June 6, 1966 this same region was in a flow from west, south-west. Figure 4 shows the concentration profile at the beginning of afternoon at around 70 km from the coast. At 1500 meters the rapid decrease of radon concentration indicated a non-uniformity of emanation from the source plane. The emanation above the ocean is negligible. The air takes up radon passing across the earth and at 70 km from the coast the radon has only diffused up to 1500 meters. Above 2000 meters the measured radon is that which comes from the ocean. The radon concentration shows the presence of a mass of maritime air.

C. Combination of Two Air Masses of Different Origin

On October 6, 1966 there was a fog from the surface to 500 meters. The temperature gradient was slightly below adiabatic. Figure 5 shows a rapid decrease of radon with altitude.

At 1000 meters there was a temperature inversion. The air mass above 2000 meters was not of the same origin. It came from the north-west, that is to say from Great Britain. It contained more radon than that from the lower levels. At 500 meters altitude the wind speed was 10 meters per second south, south-east, while at 2000 meters the north, north-west wind was only 6 meters per second. On October 5th we were in the path of a disturbance from October 4th (passage of a cold front). The sky was covered with cumulus between 800 and 2000 meters. At the surface the wind was weak and from the north, north-east. At altitude above the cloud base the wind was from the south, south-west. Measured activity was greater above the clouds than at their base (Figure 6).

D. Case of a Maritime Air Mass

On December 6, 1966 we observed some exceptionaly weak activity (Figure 7). A cold front had passed during the day into the region where we were sampling. The wind at all levels was from the north, north-west but the air flow was from the west. The radon activity obtained at altitude showed that the air had stayed long enough above the ocean so that it contained only small amounts. Behind the cold front we made a horizontal flight at 800 meters and took samples from the coast to 150 km inland. The activity obtained was comparable to that measured above the ocean. At 100 km the surface radon had only diffused up to 800 meters.

VI. CONCLUSION

These measurements confirm the interest in radon as a tracer for atmospheric physics. The results shown cannot yet be extended to give a total quantitative interpretation.

We are continuing these studies so as to develop a qualitative interpretation. In particular the resolution of the Fick diffusion equation for a non-homogeneous emanation from the soil would allow using radon for the study of atmospheric diffusion in the troposphere.

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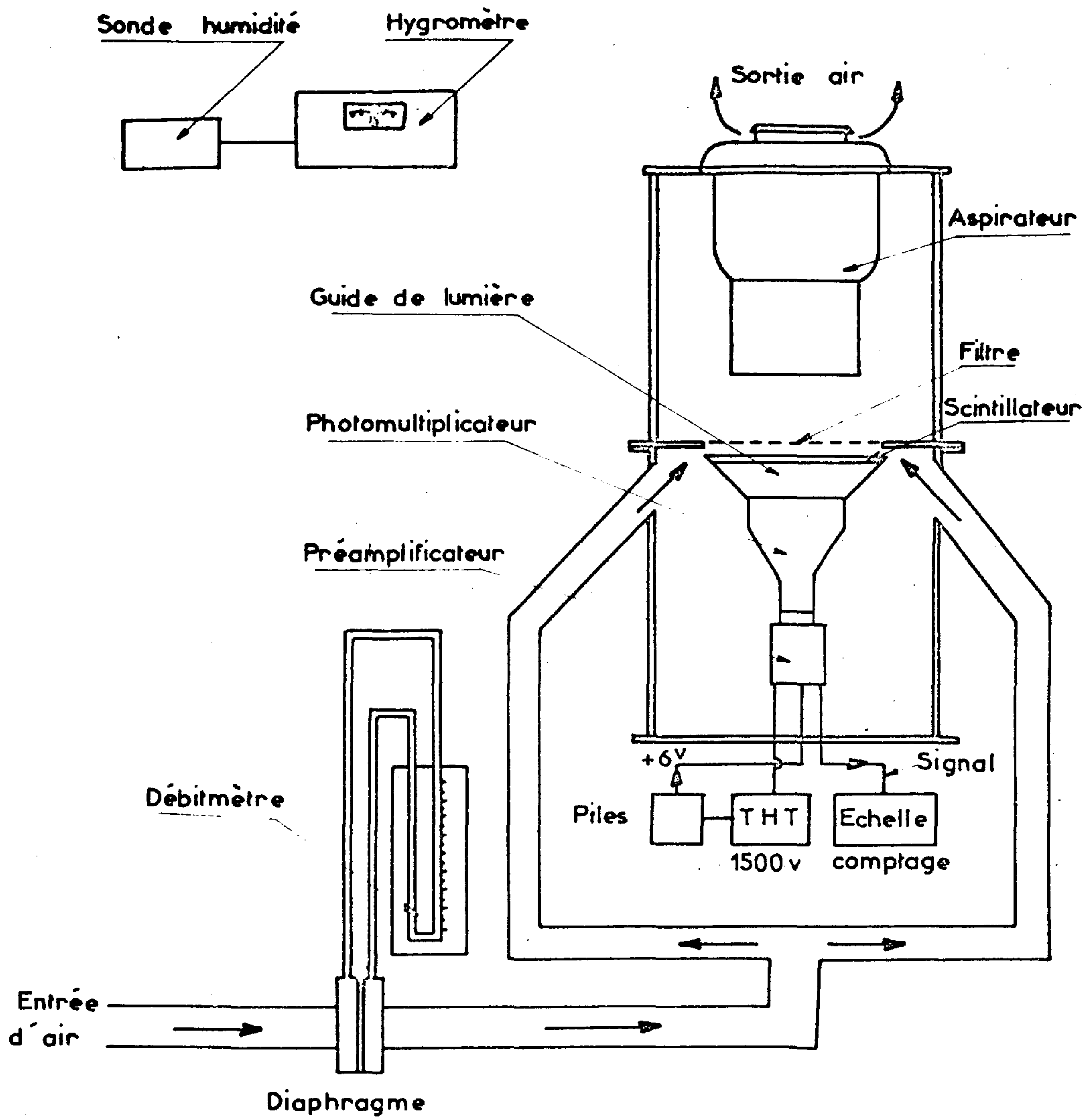
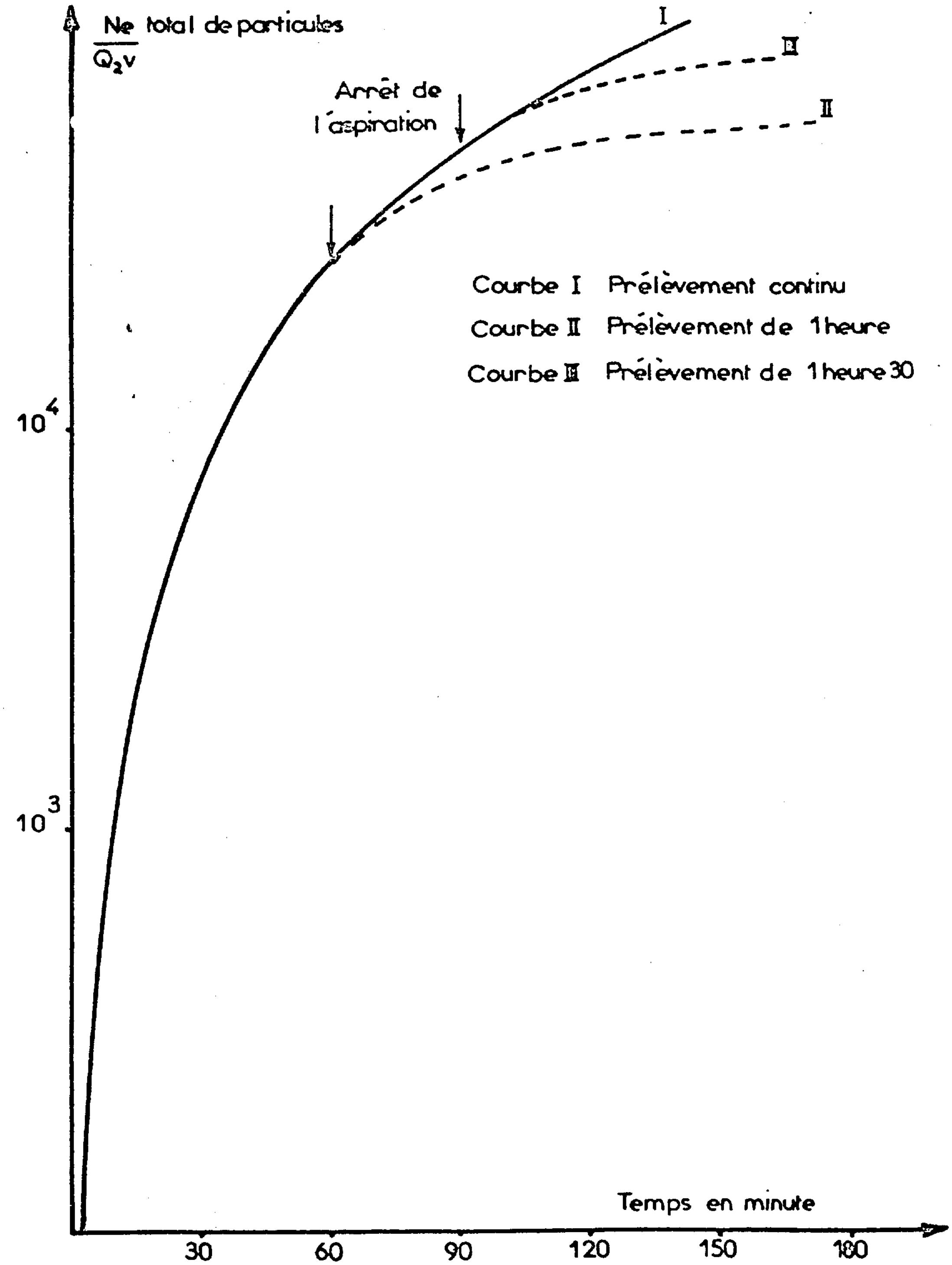
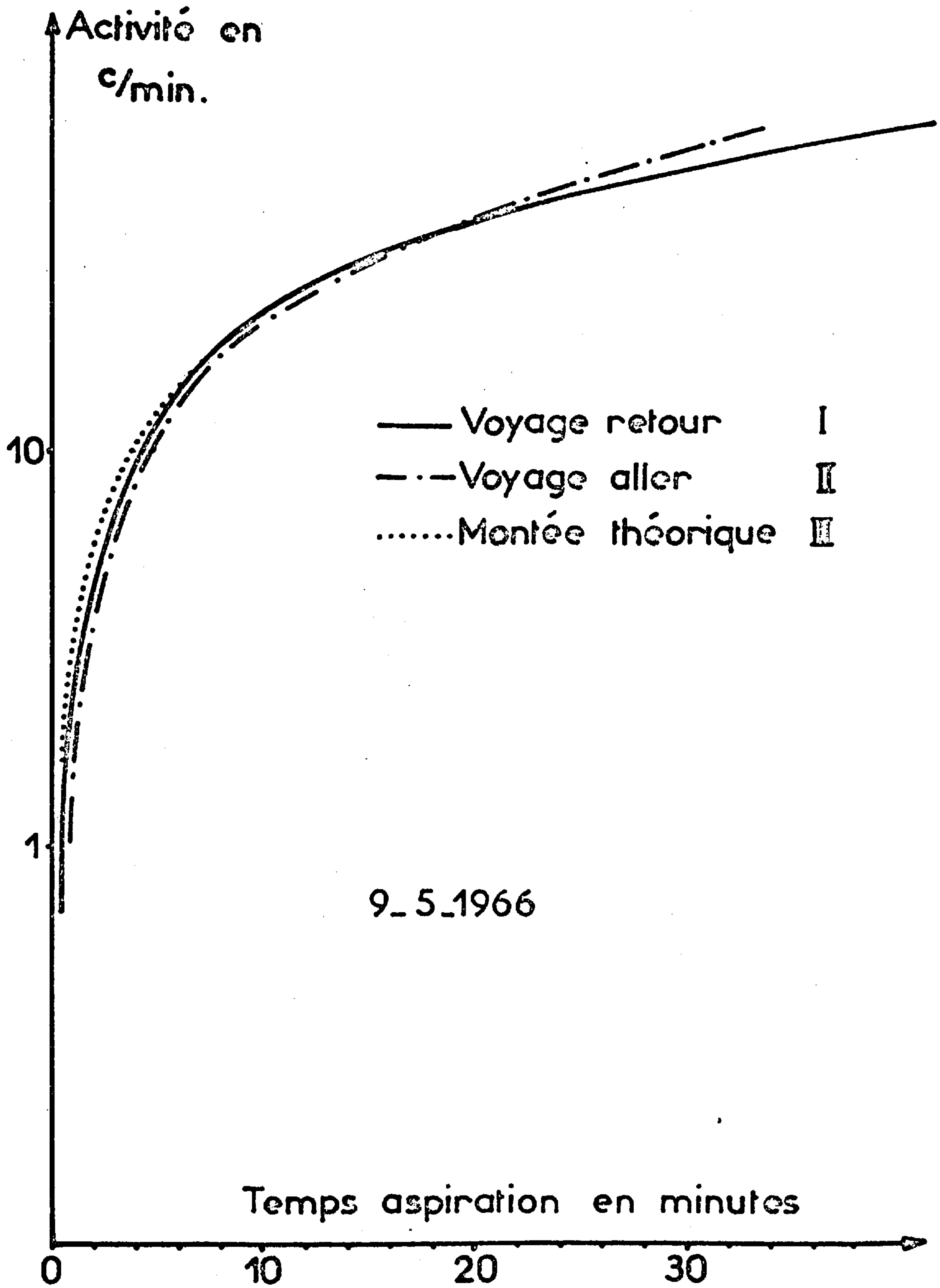


Fig. 1 – SCHEMA DE PRINCIPE DE L'INSTALLATION



Ne total de particules / Q_2v
Arrêt de l'aspiration
I
III
II
Courbe I Prélèvement continu
Courbe II Prélèvement de 1heure
Courbe III Prélèvement de 1heure 30
10^4
10^3
Temps en minute
30
60
90
120
150
180

Fig. 2


Activité en
c/min.
10
1
Voyage retour I
Voyage aller II
Montée théorique III
9_5_1966
Temps aspiration en minutes
0
10
20
30
Fig. 3

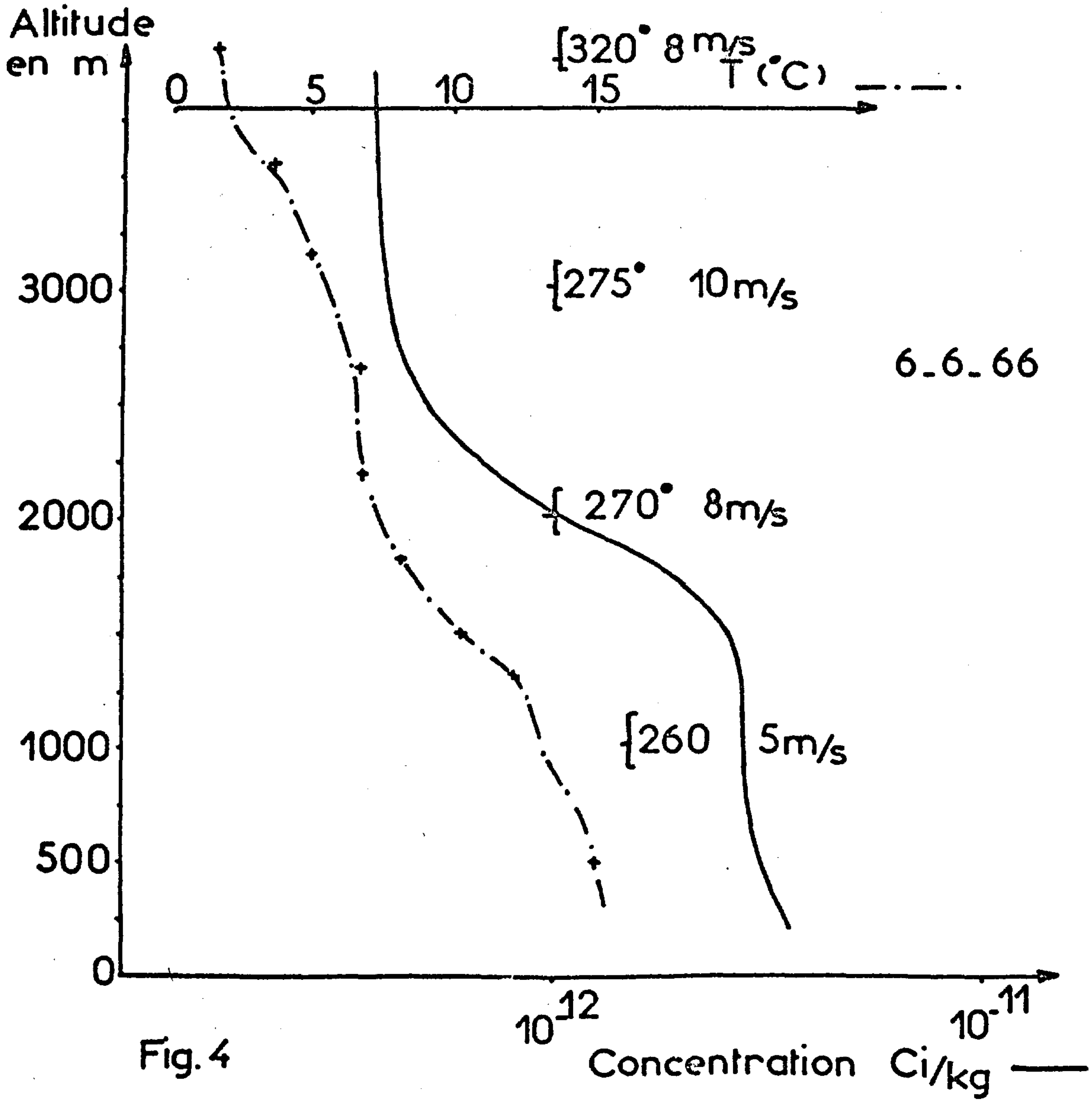
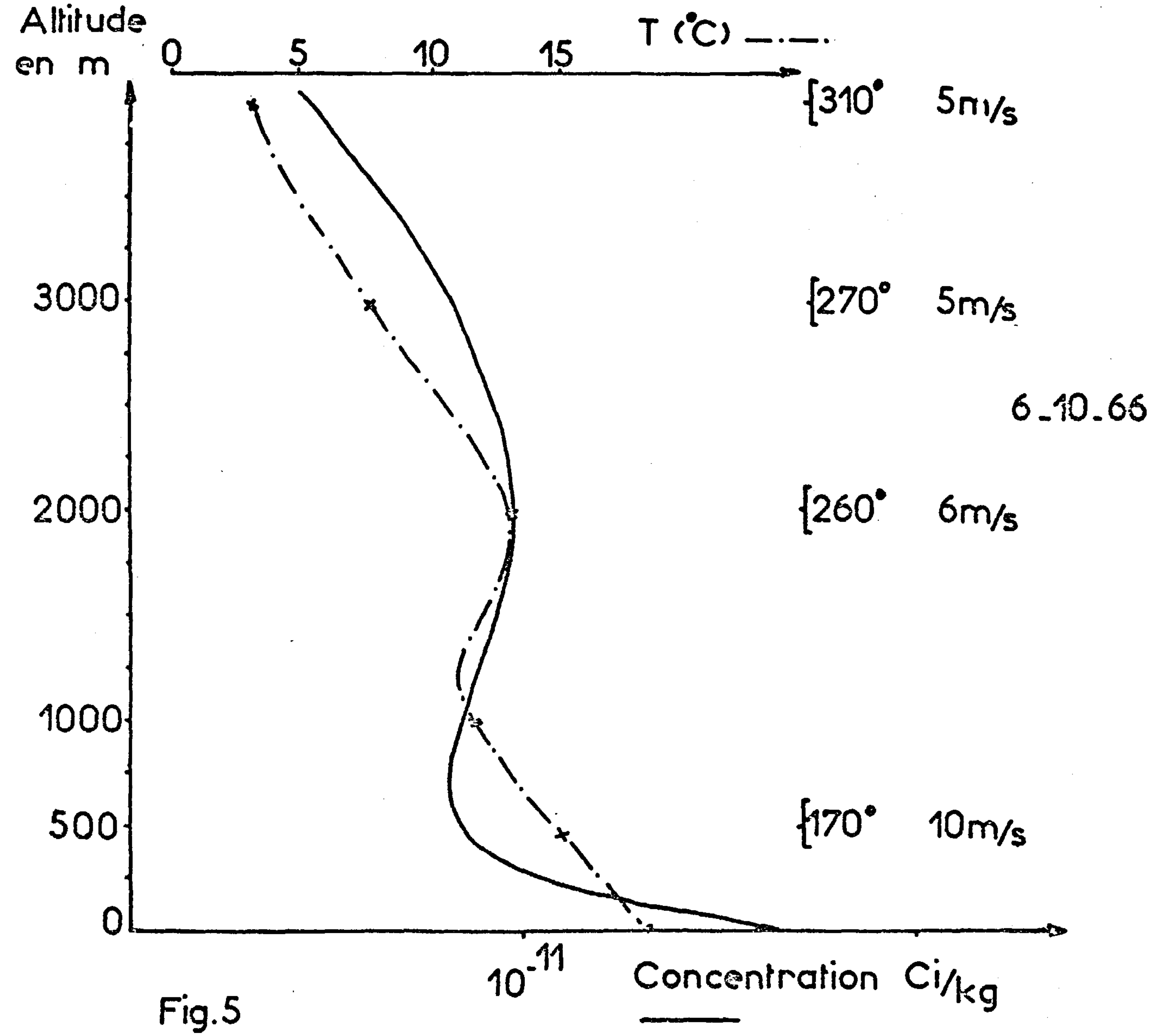

Altitude
en m
0
5
10
15
T (°C)
320° 8 m/s
275° 10 m/s
270° 8 m/s
260 5 m/s
6-6-66
3000
2000
1000
500
0
10^{-12}
10^{-11}
Concentration Ci/kg

Fig. 4



Altitude
en m
0
5
10
15
T (°C)
3000
2000
1000
500
0
{310° 5m/s
{270° 5m/s
6_10_66
{260° 6m/s
{170° 10m/s
10-11
Concentration Ci/kg

Fig. 5

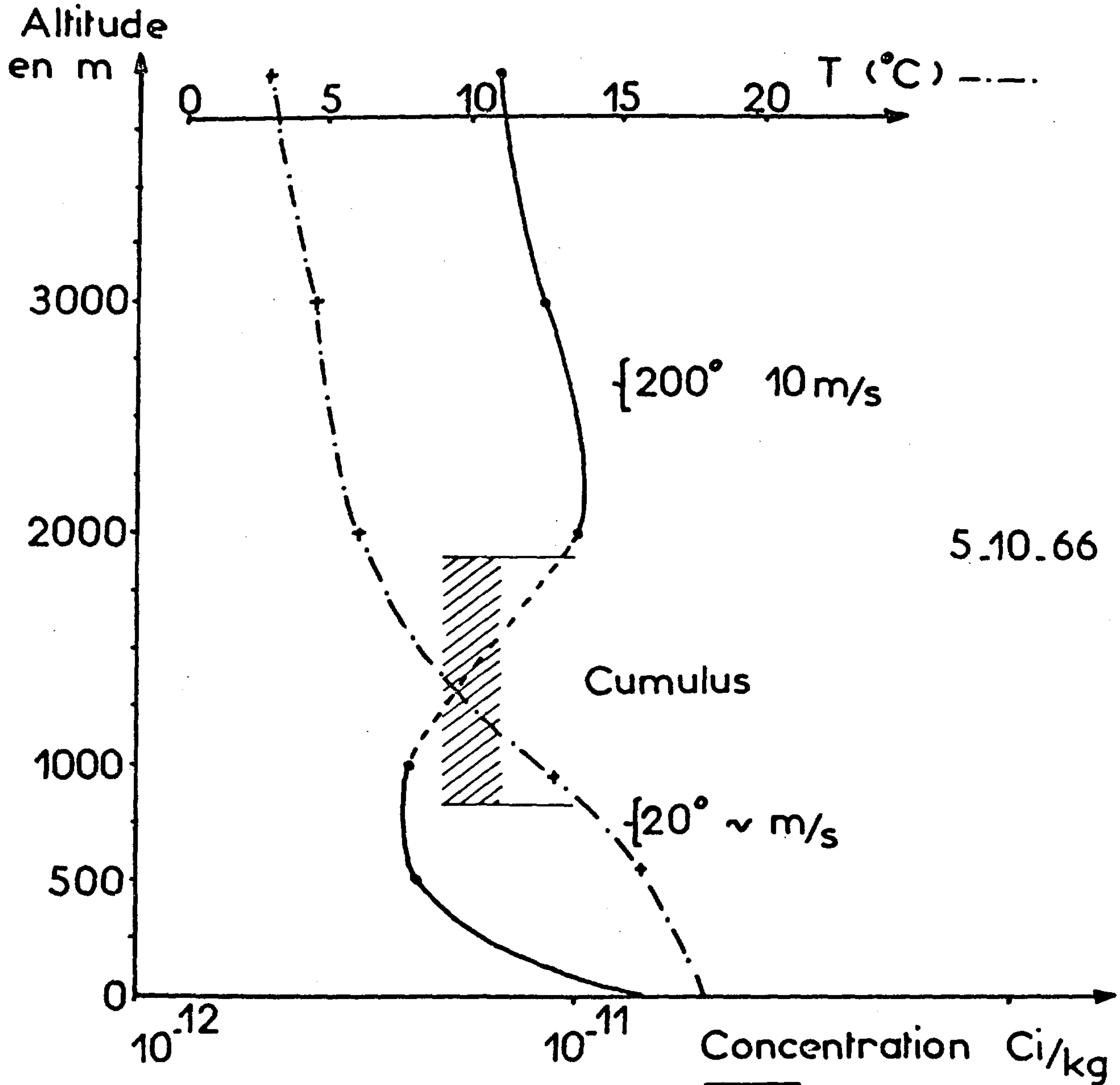
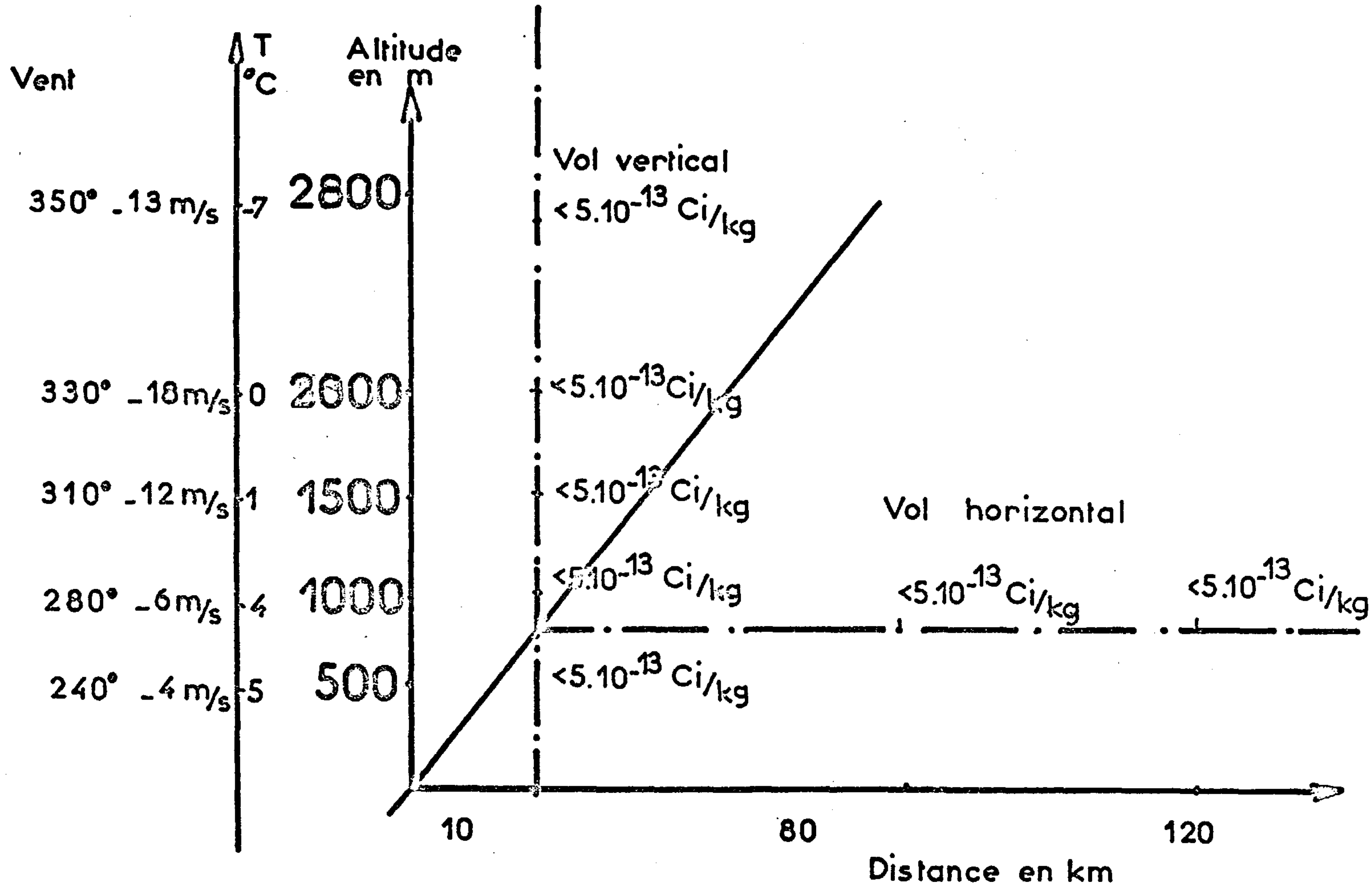

Altitude
en m
T (°C) -.-.
0
5
10
15
20
3000
2000
1000
500
0
{200° 10 m/s
5.10.66
Cumulus
{20° ~ m/s
10^-12
10^-11
Concentration Ci/kg

Fig. 6



Vent
T °C
Altitude en m
350° _13 m/s
-7
2800
330° _18 m/s
0
2000
310° _12 m/s
1
1500
280° _6 m/s
4
1000
240° _4 m/s
5
500
Vol vertical
< 5.10-13 Ci/kg
<5.10-13 Ci/kg
<5.10-13 Ci/kg
<5.10-13 Ci/kg
<5.10-13 Ci/kg
Vol horizontal
<5.10-13 Ci/kg
<5.10-13 Ci/kg
10
80
120
Distance en km

Fig. 7

The Extent of Radioactive Equilibrium Between Radon and Its Short-Lived Daughter Products in the Atmosphere

U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

CONTENTS

The Extent of Radioactive Equilibrium Between Radon and Its Short-Lived Daughter Products in the Atmosphere

L. B. LOCKHART, JR. AND R. L. PATTERSON, JR.

Physical Chemistry Branch
Chemistry Division

A set of experimental conditions has been derived which optimizes the accuracy with which the radon content of the atmosphere and its apparent residence time there can be determined from measurement of the filterable gross β activity during two separate 10-minute periods following the end of a 20-minute collection period.

The 20-minute collection is made on a filter of essentially 100% retentivity (glass fiber filter) and counted for β activity through a 10-mil (70. mg/cm^2) aluminum absorber on equipment of known efficiency for the β particles emitted by RaB and RaC. The ratio of measured counts during the 61-through-71-minute decay period to that during the 1-through-11-minute period is employed to obtain the atom ratio of RaC to RaB (ρ) in the air sampled, the apparent age (τ) of the conglomerate of radon and its daughters, and the total counts to be expected from any given radon concentration in the air.

Extensive examples of atmospheric measurements are given which suggest that under most conditions in the free atmosphere radon is essentially at secular equilibrium with its daughter products. Other collections made following addition of radon to a restricted volume show the expected increase in ρ with time, which confirms the basic validity of the procedure.

INTRODUCTION

In a previous report (1) it was shown that the radon concentration of the atmosphere could be deduced from measurement of its short-lived decay products by their collection on a filter for a fixed period of time followed by β-activity measurements during two subsequent periods. In addition to the usual errors associated with air flow measurements and counter calibrations, two sources of error either could not be controlled or were unresolved: the large statistical error inherent in any counting process when a limited number of random events occur and the uncertainty in evaluating the counting efficiency for the conversion electrons emitted by RaB (Pb^{214}) and RaC (Bi^{214}). The radon present in the air sample, moreover, was assumed to have resulted from an instantaneous emission of radon gas from the soil; this was, of course, an obvious oversimplification.

This report considers means of optimizing the accuracy and sensitivity of this method by determining those counting conditions which reduce the effect of the conversion electrons and their uncertain calibration and which also permit the greatest sensitivity in the determination of concentration and age from β-activity measurements made during two fixed decay periods.

THEORETICAL CONSIDERATIONS

The growth of radon daughter products in the atmosphere from a fresh radon source, their growth and decay on a filter during a subsequent 20-minute period of air filtration, and the radioactivity decay relationships between the solid daughter products collected on the filter were presented in the previous report (1). These data have been revised and extended to permit interpretation of the apparent radon age in terms of its continuous emission from the soil rather than its instantaneous emission. A summary of this extension of information is given in Table 1.

Plots of the RaC/RaB atom ratios (ρ) as functions of elapsed time are shown in Fig. 1 for the conditions of instantaneous and continuous addition of radon to the atmosphere. It is evident that the higher ρ values will represent a much longer time of growth of the radon daughters when interpreted in terms of the constant introduction of fresh radon. Similarly, the radon/RaB activity

NRL Problem A02-13; Projects RR 004-02-42-5151 and AEC AT 49-7(2435). This is an interim report; work on this problem is continuing. Manuscript submitted November 9, 1965.

TABLE 1

Growth of Radon Daughters in a Fixed Volume of Air on Addition of Radon at the Rate of 10^4 Atoms per Minute

Elapsed Time (min)	Atoms				Activity (dis/min)		Atom Ratio RaC/RaB (ρ)	Activity Ratio Rn/RaB
	Rn*	RaA	RaB	RaC	Rn	RaB		
0	0	0	0	0	0	0	—	—
10	100,000	36.0	30.8	2.2	12.66	0.71	0.071	17.9
20	200,000	89.7	150.5	20.5	25.33	3.70	0.136	6.85
30	300,000	145.0	352.3	69.3	37.99	8.82	0.197	4.31
40	400,000	200.4	618.7	155.3	50.66	15.58	0.251	3.25
50	500,000	255.7	935.2	279.9	63.32	23.71	0.299	2.67
60	600,000	311.1	1290.4	441.2	75.98	32.85	0.342	2.31
70	700,000	366.5	1675.4	635.5	88.65	42.76	0.379	2.07
80	800,000	421.8	2083.5	858.8	101.31	53.28	0.412	1.901
90	900,000	477.2	2509.4	1106.9	113.98	64.27	0.441	1.773
100	1,000,000	532.6	2949.0	1375.9	126.64	75.62	0.467	1.675
110	1,100,000	588.0	3399.3	1662.0	139.30	87.24	0.489	1.597
120	1,200,000	643.3	3857.9	1962.3	151.97	99.08	0.509	1.534
130	1,300,000	698.7	4322.8	2274.1	164.63	111.09	0.526	1.482
140	1,400,000	754.1	4792.5	2595.2	177.30	123.22	0.542	1.439
150	1,500,000	809.5	5266.1	2923.8	189.96	135.45	0.555	1.402
160	1,600,000	864.9	5742.6	3258.3	202.62	147.77	0.567	1.371
170	1,700,000	920.3	6221.3	3597.7	215.29	160.14	0.578	1.344
180	1,800,000	975.7	6701.8	3940.8	227.95	172.54	0.588	1.321

*The small amount of radon decay has been neglected.

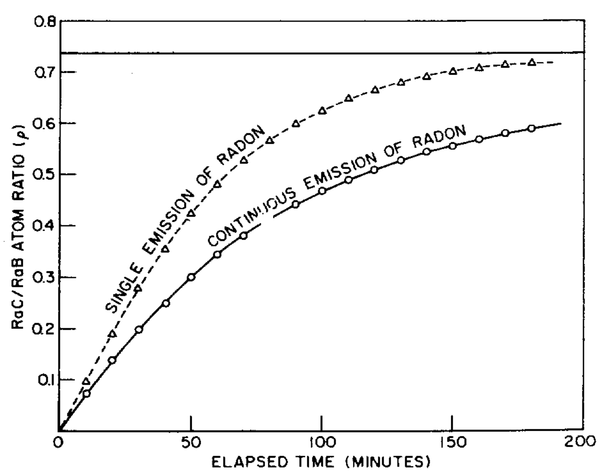


Fig. 1 – Change in the RaC to RaB atom ratio (ρ) with the age of the radon conglomerate after exhalation of radon gas from the earth

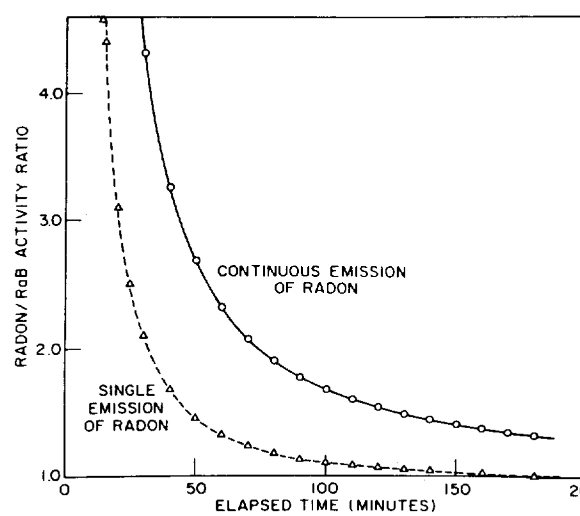


Fig. 2 – Change in the radon to RaB activity ratio with the age of the radon conglomerate

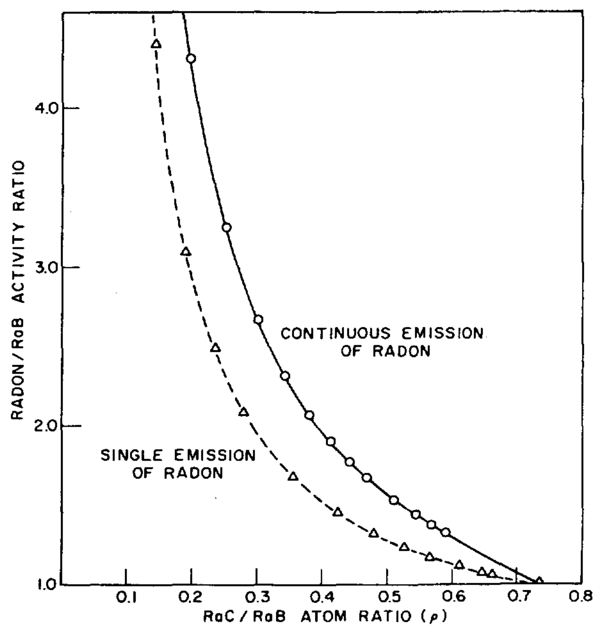


Fig. 3 – Relationship between the radon/RaB activity ratio and the RaC/RaB atom ratio (ρ) for the conditions of instantaneous and continuous emission of radon from the soil. These curves are obtained by combining the data of Figs. 1 and 2.

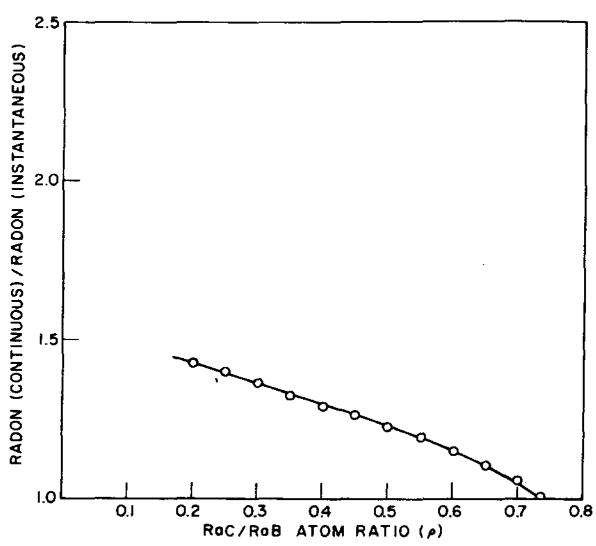


Fig. 4 – Relative radon concentrations in the air under conditions of single and continuous radon influx required to produce identical quantities of radon daughter products. The values plotted are obtained by direct comparison of the curves in Fig. 3.

ratio is quite different for the two conditions, as shown in Fig. 2. The time parameter is removed from consideration in Fig. 3 by comparing directly the radon/RaB activity ratio with the RaC/RaB atom ratio (ρ), wherein smooth curves are obtained which intercept the ρ axis at 0.735 for the equilibrium condition corresponding to infinite time.

Interconversion of the single emission and continuous emission conditions can be obtained from the plot in Fig. 4, where the relative radon concentrations in the air required to give the same β activity on a filter are shown as a function of the measured ρ value obtainable from the same filter.

EXPERIMENTAL PROCEDURE

Air Sampling

Airborne particulate matter and associated radioactivity have been effectively collected on glass fiber filters having an exposed area of about 25 cm^2 through use of positive displacement blowers (Roots-Connersville Models AF-24 or AF-315) driven by 1-hp electric motors. Glass fiber filters have essentially 100% retentivity for the radon decay products at the air velocity employed (2) and, moreover, are essentially surface collectors; furthermore, no retention of the gaseous radon by filters has been detected. In this study Gelman Type A filters were employed with the fairly smooth, screen-imprinted back surface used as the collecting surface to reduce the effect of self-absorption of radiation by the filter.

The quantity of dust collected during the 20-minute periods did not measurably affect the air flow (between 0.42 and 0.52 m^3/min, depending on the unit), though on occasion a definite imprint of the dust was apparent. The air sampling equipment was calibrated against a rotameter-type flow meter as a function of pressure drop across the filter; flow was determined from pressure readings taken at the start and the end of the run.

After the accurately timed 20-minute collection period, the samples were transferred to other holders and counting was started 60 seconds following termination of the collection.

Radioactivity Measurements

All radioactivity determinations were made under conditions of standard geometry and backscattering with lead-shielded, end-window G-M tubes of 5.6-mg/cm² window thickness using conventional β-counting equipment. Counting was timed and recorded by use of Ametron Count Recorders (Streeter-Amet) which had been modified to operate on a 10-minute cycle.

The equipment was calibrated as described in the previous report (1) by use of standards of Cs^{137}, Pb^{210} (Bi^{210}), and UX_2 prepared to simulate as nearly as possible the filter size and arrangement. Typical calibration data are shown in Fig. 5; counting was done through a series of aluminum absorbers to determine the most appropriate system to use in subsequent measurements of RaB

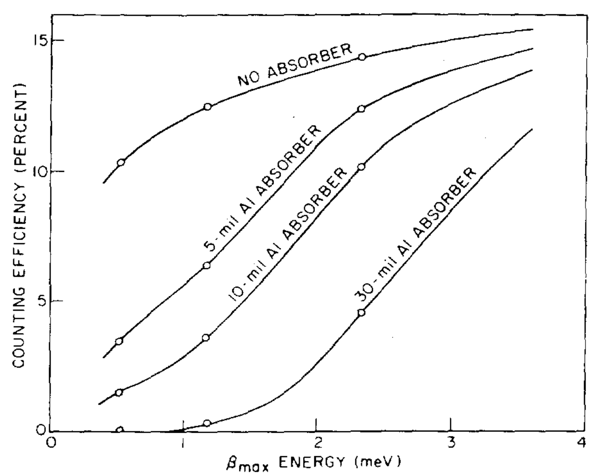


Fig. 5 — Counter calibration curves as a function of β_{max} energy and absorber thickness

and RaC. The efficiency of the equipment toward these radon daughters is shown in Table 2 for the various absorber arrangements.

The accumulated counts to be expected following the filtration of air samples containing 100 picocuries (pCi) of radon per m³ for 20 min at the rate of 1 m³ per min are given in Table 3 for the 10-min periods starting at 1 min and at 61 min following the termination of filtration for different values of ρ and for different absorber thicknesses. The choice of these two time intervals was made on the basis of the sensitivity of the resulting count rate ratio to changes in ρ, as described in the previous report (1). The indicated count ratios during the two fixed time periods ($t_{1\text{-}11}$ and $t_{61\text{-}71}$) have been employed to construct curves for translating measured ratios and total counts into ρ values and radon concentrations, as shown in Figs. 6 and 7, respectively. The radon concentration so determined is that which would have resulted from a single, instantaneous emission of radon from the soil; the radon value corresponding to the steady emission of radon can be found by adjusting the above value by a factor obtainable from Fig. 4.

The greatest sensitivity in the determination of ρ is obtained when a 30-mil aluminum absorber is employed, since this effectively stops all radiation except that associated with the RaC component. On the other hand the counting rates are low with resulting increased statistical uncertainty in

TABLE 2
Efficiency of β Counting Equipment Toward RaB and RaC Deposited on a Glass Fiber Filter

Activity	β_{max} Energy (MeV)	Counting Efficiency From Fig. 5 and After Estimated Correction for the Effect of Conversion Electrons (%)							
		No Absorber		5-mil Al Absorber		10-mil Al Absorber		30-mil Al Absorber	
		From Graph	After Corr.	From Graph	After Corr.	From Graph	After Corr.	From Graph	After Corr.
RaB (Pb^{214})	0.65 (100%) (25% low-energy conversion electrons)	10.90	13.63	4.10	4.51	1.82	1.87	0.0	0.0
RaC (Bi^{214})	3.17 (23%) 1.65 (77%) (5% high-energy conversion electrons)	13.79	14.48	10.17	10.68	7.75	8.14	3.06	3.21

TABLE 3
Calculated β Counts Obtainable From 20-Minute Collections of Radon Daughters on Glass Fiber Filters for a Radon Concentration of 100 pCi/m³ and a Filtration Rate of 1 m³/min

	Disintegrations During 10-Minute Periods		Total Counts During 10-Minute Periods							
			No Absorber		5-mil Absorber		10-mil Absorber		30-mil Absorber	
	$t_{1\text{-}11}$	$t_{61\text{-}71}$	$t_{1\text{-}11}$	$t_{61\text{-}71}$	$t_{1\text{-}11}$	$t_{61\text{-}71}$	$t_{1\text{-}11}$	$t_{61\text{-}71}$	$t_{1\text{-}11}$	$t_{61\text{-}71}$
$\rho = 0.048$										
RaB	3798	864	518	118	171	39	71	16	0	0
RaC	1687	1594	244	231	180	170	137	130	54	51
Total	5485	2458	762	349	351	209	208	146	54	51
Ratio ($t_{61\text{-}71}/t_{1\text{-}11}$)	0.448		0.458		0.595		0.702		0.945	
$\rho = 0.190$										
RaB	13170	2879	1795	392	594	130	246	54	0	0
RaC	8233	5640	1192	817	879	602	670	459	264	181
Total	21403	8519	2987	1209	1473	732	916	513	264	181
Ratio ($t_{61\text{-}71}/t_{1\text{-}11}$)	0.398		0.405		0.497		0.560		0.685	
$\rho = 0.390$										
RaB	22700	4903	3094	668	1024	221	424	92	0	0
RaC	19562	10279	2833	1488	2089	1098	1592	837	628	330
Total	42262	15182	5927	2156	3113	1319	2016	929	628	330
Ratio ($t_{61\text{-}71}/t_{1\text{-}11}$)	0.359		0.364		0.424		0.461		0.525	
$\rho = 0.564$										
RaB	28946	6227	3945	849	1305	281	541	116	0	0
RaC	30758	13775	4454	1995	3285	1471	2504	1121	987	442
Total	59704	20002	8399	2844	4590	1752	3045	1237	987	442
Ratio ($t_{61\text{-}71}/t_{1\text{-}11}$)	0.335		0.339		0.382		0.406		0.448	
$\rho = 0.735$										
RaB	33221	7136	4528	973	1498	322	621	133	0	0
RaC	41689	16562	6037	2398	4452	1769	3393	1348	1338	532
Total	74910	23698	10565	3371	5950	2091	4014	1481	1338	532
Ratio ($t_{61\text{-}71}/t_{1\text{-}11}$)	0.316		0.319		0.351		0.369		0.397	

the true values. With no absorption except for that inherent in the counting tube window, maximum count rates are obtained but also decreased sensitivity results because both RaB and RaC are counted simultaneously; moreover, the effect of the large quantity of low-energy conversion electrons associated with RaB cannot be accurately assessed. Since a 10-mil aluminum absorber will remove nearly all response to the conversion electrons from the RaB and also reduce to a considerable extent the counter response to the RaB itself, use of an absorber of this 10-mil thickness is considered to be a practical compromise.

Estimations of the overall errors (standard deviations) based on the counting statistics to be expected from use of this procedure to determine the radon concentration have been made for the conditions of an air flow of 0.5 m³/min, a background of 30 counts/min, and a 5% contribution

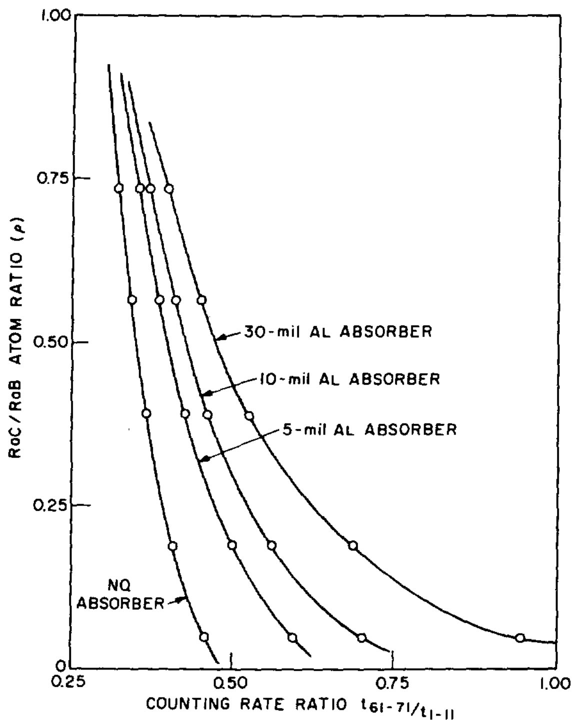


Fig. 6 – Effect of absorber thickness on the relationship between the ratio of the counting rates at $t_{1\text{-}11}$ and $t_{61\text{-}71}$ and the RaB/RaC atom ratio ρ

of longer lived activity (ThB+C and fission products) to the initial count, which conditions approximate those actually encountered. The statistical errors (σ) corresponding to radon concentrations of 100 to 4000 pCi/m^3 and ρ values of 0.735, 0.564, and 0.390 are presented in Fig. 8 for filter samples counted through 10-mil aluminum absorbers. It seems reasonable to expect this method to permit radon concentrations to be determined with a standard error of 5% or less for most conditions where relatively high atmospheric concentrations (> 1000 pCi/m^3) of radon may develop.

Atmospheric Sampling

Samples of atmospheric radioactivity were collected as described above on a roof 20 feet above the ground. The sampling equipment was contained in a box having louvered sides all around to permit unimpeded access of air; the exhaust was directed upward and away from the sampling site.

In addition to the radioactivity measurements described above, supplementary determinations were made at 5 to 6 hours and 17 to 18 hours following collection to enable corrections to be made for the small quantity of thoron daughter products and fission products retained by the filters.

Chamber Studies

The effect of the residence time of radon in the atmosphere on its experimentally determined concentration and on the measured ρ values was studied by the described technique following release of a known quantity of radon gas (0.20 μCi) into closed volumes of 35 m^3 and 0.31 m^3. Continuous mixing was provided by low-speed fans. Sampling was done at rates of 0.212 m^3/min and 0.00196 m^3/min in the two cases, resulting in the withdrawal of 11.5% and 11.8%, respectively, of the particulate matter with each sample taken. The filtered air was returned to the chamber. Cigarette smoke was introduced into the larger chamber to supply a quantity of aerosol particles to serve as nuclei for attachment of the short-lived radon daughters; a controlled quantity of 0.3μ (dia) dioctyl phthalate aerosol (DOP) was used for this purpose in the second (glove-box) experiment. The results of these two experiments are discussed later in the next section.

RESULTS AND DISCUSSION

Radon concentration measurements in atmospheric samples made by the described technique are summarized in Table 4 for the assumed conditions of continuous and of instantaneous emission of radon from the soil and for secular equilibrium in the atmosphere. The ρ values, also included in Table 4, when compared with the secular equilibrium value of 0.735 given by Fig. 3 suggest that the radon/radon daughter relationship is certainly near secular equilibrium under the conditions prevailing at the sampling site. This reasonably close approach to equilibrium diminishes in importance the assumption made as to the mode of introduction of radon into the sample volume. The agreement between pairs of ρ values or radon concentrations obtained from essentially duplicate determinations falls within the range expected for measurements

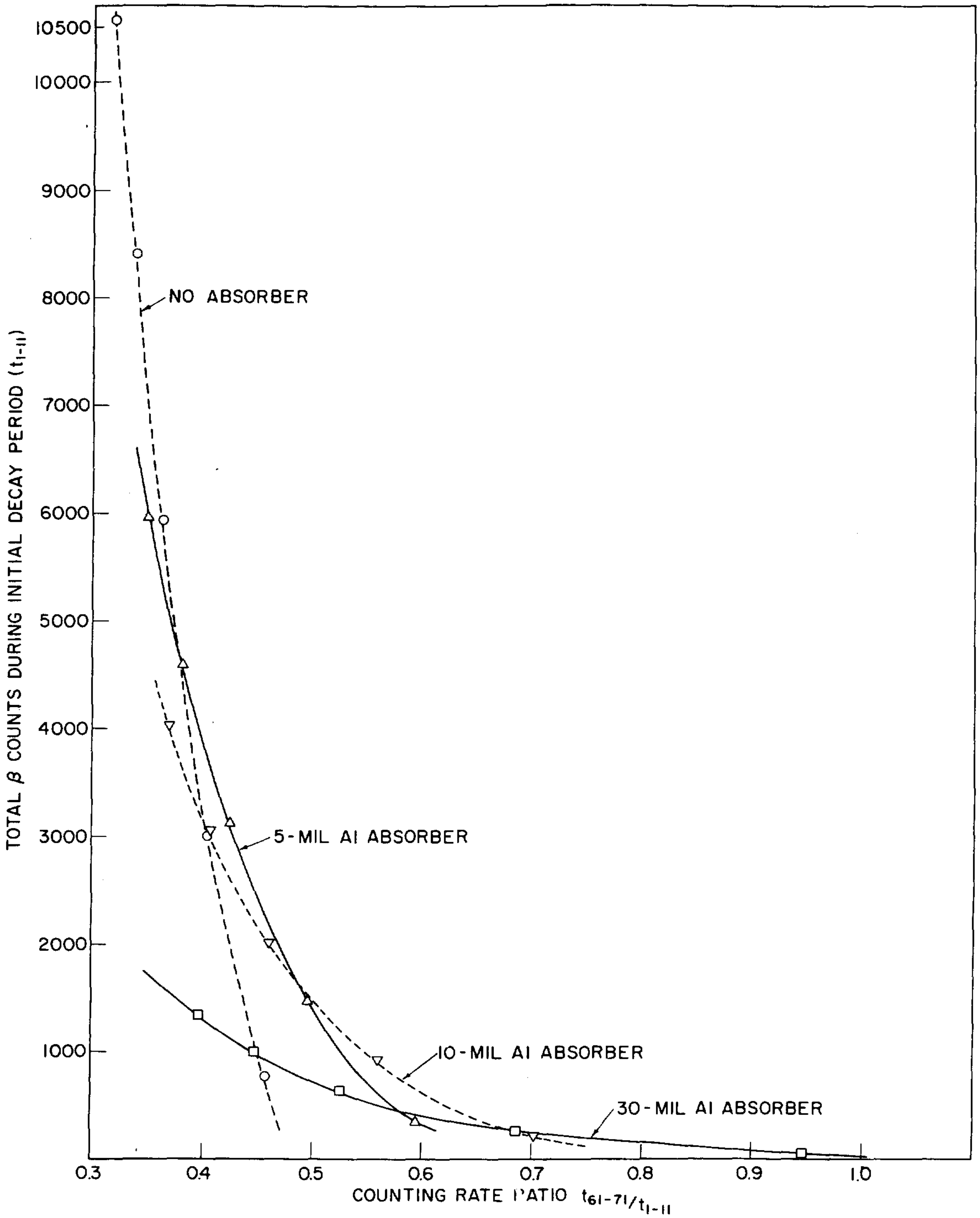


Fig. 7 – Effect of absorber thickness on the relationship between the total counts during the initial period (t_{1-11}) and the ratio of the counting rates at t_{61-71} and t_{1-11}, and for a radon concentration of 100 pCi/m^3 and a filtration rate of 1 m^3/min for 20 min.

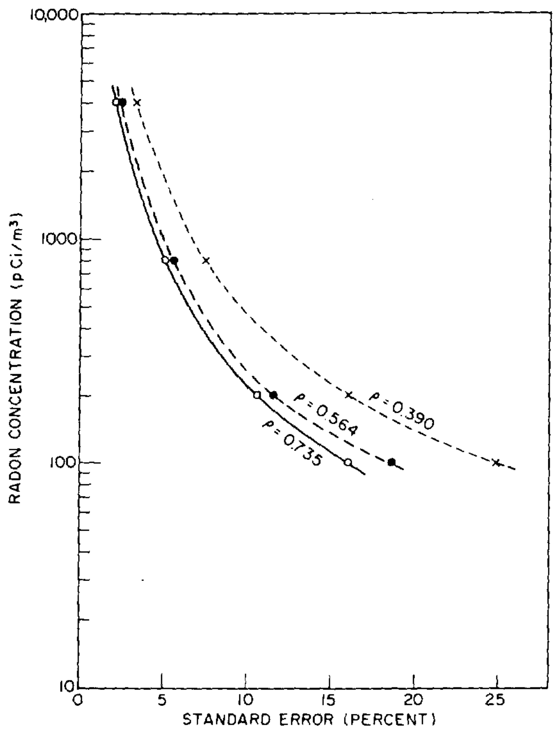


Fig. 8 — Estimations of the statistical error inherent in the determination of radon concentrations using filter samples counted through 10-mil aluminum absorbers assuming a 20-min sampling period at the rate of 0.5 m^3/min, a background of 30 counts/min, and a 5% contribution of ThB+C and fission products.

having the rather large, random errors associated with low counting rates.

For values of ρ in excess of 0.735 to occur in the free atmosphere, as is suggested by a few of the measurements, some mechanism must exist there for removing the gaseous radon from its solid daughters or for fractionating the daughter products relative to one another. Wilkening (3) has demonstrated one such fractionation process in which RaA is preferentially removed by the strong electrostatic charge developed in the atmosphere during thunderstorms. This loss of RaA would interrupt the radon decay chain with the result that the RaC/RaB atom ratio (ρ) would increase above the equilibrium value. There was no indication that such a mechanism was in operation during any of our sample collections; however, no electric field measurements were made.

If the assumption is made that the observed departures of ρ from the equilibrium value of 0.735 are artifacts due to the low accuracy in determing ρ (primarily a function of the total count during the 61-71 minute decay period) and that secular equilibrium did exist, the initial count during the 1-11 minute decay period can be employed to calculate the radon concentration. Such calculations have been made for the extended series of collections made on January 5 and January 7, 1965; the results of both types of measurement are compared in Figs. 9 and 10. The horizontal axis of the diamond-shaped pattern surrounding the points indicates the collection time, while the vertical axis indicates the standard error (σ) in the determination of the radon concentration based on the uncertainty in the measured activity ratio. The statistical errors associated with each of the measurements in the series which assumes equilibrium conditions to exist are not shown but are considerably smaller since the determination is based on a single measurement made during the period of highest activity.

From Figs. 9 and 10 it may be concluded that no advantage ensues from use of the more complicated procedure, at least under the sampling conditions existing here. Indeed, it permits one to place more reliance on the results of the many determinations of radon activity made by numerous investigators who have invariably assumed secular equilibrium to exist in the free atmosphere. It would appear that, in general, this approach is valid. On the other hand, during the developing stages of a strong temperature inversion in the atmosphere, or immediately following ventilation of a mine, tunnel, or similar closed space, departures from equilibrium would be expected and the simple approach could seriously underestimate the radon concentration.

The validity of this approach for determining radon concentrations from measurements of its filterable decay products was tested by the chamber studies in which a measured quantity of radon was released into closed spaces of known volume as described earlier. The data accumulated in two experiments are summarized in Tables 5 and 6. In both instances the expected progressive increases in ρ with time were found. The experimental values of ρ obtained through use of the described procedure are compared in Figs. 11 and 12 with calculated results which duplicate as nearly as possible the actual conditions

TABLE 4

Summary of Radon Concentrations Deduced from Count Ratios Under the Assumptions of One Instantaneous Emission of Radon From the Soil at Some Past Time, of Continuous Emission of Radon From the Soil at a Uniform Rate Beginning at Some Past Time, and of Secular Equilibrium of Radon and Its Daughters in the Atmosphere

Collection Date	Time (EST)	Air Flow Rate (m^3/min)	RaB+C Count ($t_{1\text{-}11}$)	Count Ratio $t_{61\text{-}71}/t_{1\text{-}11}$	Absorber Thickness (mils Al)	ρ	Radon Concentration (pCi/m^3)		
							Instantaneous Emission	Continuous* Emission	Secular Equilibrium
1964									
Oct. 29	0730-0750	0.501	1475	0.398	30	0.73 ± 0.09	223 ± 30	224	220 ± 6
	0732-0752	0.430	10896	0.322	0	0.71 ± 0.06	249 ± 18	256	240 ± 3
Nov. 9	0940-1000	0.428	7117	0.331	5	0.86 ± 0.06	303 ± 20	—	279 ± 4
	0942-1002	0.501	2234	0.369	30	0.85 ± 0.08	286 ± 28	—	333 ± 8
Nov. 10	0810-0830	0.518	12006	0.388	10	0.64 ± 0.03	670 ± 35	744	579 ± 6
	0812-0832	0.436	9829	0.378	10	0.69 ± 0.04	602 ± 37	635	562 ± 6
Nov. 12	0800-0820	0.513	9640	0.391	10	0.63 ± 0.04	556 ± 30	623	470 ± 5
	0802-0822	0.436	2832	0.384	30	0.78 ± 0.06	452 ± 39	—	485 ± 10
Nov. 13	0805-0825	0.515	764	0.402	30	0.72 ± 0.13	115 ± 23	117	111 ± 5
	0807-0827	0.436	1871	0.382	10	0.68 ± 0.09	118 ± 16	126	107 ± 3
Nov. 16	0945-1005	0.515	1870	0.412	30	0.68 ± 0.07	299 ± 34	318	271 ± 7
	0947-1007	0.433	4214	0.386	10	0.65 ± 0.06	277 ± 24	305	243 ± 4
Nov. 23	0835-0855	0.521	2468	0.377	10	0.70 ± 0.08	126 ± 17	131	118 ± 3
	0837-0857	0.442	1882	0.369	10	0.74 ± 0.10	106 ± 18	106	106 ± 3
Nov. 24	0815-0835	0.521	5956	0.388	10	0.65 ± 0.05	331 ± 26	364	286 ± 4
	0817-0837	0.439	4799	0.382	10	0.67 ± 0.06	302 ± 27	326	273 ± 4
Nov. 25	0814-0834	0.515	2042	0.389	10	0.64 ± 0.10	115 ± 17	128	99 ± 3
	0816-0836	0.433	1600	0.364	10	0.76 ± 0.11	88 ± 16	—	92 ± 3
Nov. 27	0850-0910	0.515	4874	0.381	10	0.68 ± 0.06	259 ± 23	276	237 ± 4
	0852-0912	0.439	4052	0.371	10	0.73 ± 0.06	233 ± 24	234	231 ± 4
Nov. 30	0810-0830	0.513	3834	0.372	10	0.72 ± 0.07	190 ± 20	194	187 ± 3
Dec. 7	0935-0955	0.521	1296	0.362	10	0.78 ± 0.12	58 ± 12	—	62 ± 2
Dec. 9	0830-0850	0.521	4331	0.393	10	0.62 ± 0.06	250 ± 23	283	208 ± 4
	0832-0852	0.442	3310	0.405	10	0.58 ± 0.05	246 ± 27	286	187 ± 4
Dec. 14	0808-0828	0.521	2623	0.361	10	0.78 ± 0.09	117 ± 16	—	126 ± 3
	0810-0830	0.430	2154	0.337	10	0.90 ± 0.15	94 ± 12	—	125 ± 3
1965									
Jan. 5	0710-0730	0.541	4589	0.384	10	0.66 ± 0.07	238 ± 21	259	212 ± 4
	0755-0815	0.541	4918	0.393	10	0.62 ± 0.05	272 ± 24	307	227 ± 4
	0840-0900	0.541	5302	0.365	10	0.76 ± 0.06	236 ± 22	—	245 ± 4
	0925-0945	0.541	3637	0.358	10	0.80 ± 0.07	152 ± 17	—	168 ± 3
	1010-1030	0.541	4564	0.368	10	0.75 ± 0.06	208 ± 20	—	211 ± 4
	1055-1115	0.541	3489	0.365	10	0.76 ± 0.07	155 ± 19	—	161 ± 3
	1310-1330	0.541	2711	0.392	10	0.62 ± 0.07	149 ± 18	168	125 ± 3
	1520-1540	0.541	2342	0.351	10	0.84 ± 0.10	91 ± 13	—	108 ± 3
Jan. 7	0820-0840	0.541	6315	0.369	10	0.74 ± 0.05	292 ± 24	292	292 ± 4
	0905-0925	0.541	6534	0.370	10	0.74 ± 0.05	304 ± 24	304	302 ± 4
	1015-1035	0.541	4761	0.375	10	0.71 ± 0.06	229 ± 21	236	220 ± 4
	1530-1550	0.541	2235	0.361	10	0.79 ± 0.09	96 ± 14	—	103 ± 3

*No conversion factors derivable for conditions where $\rho > 0.735$.

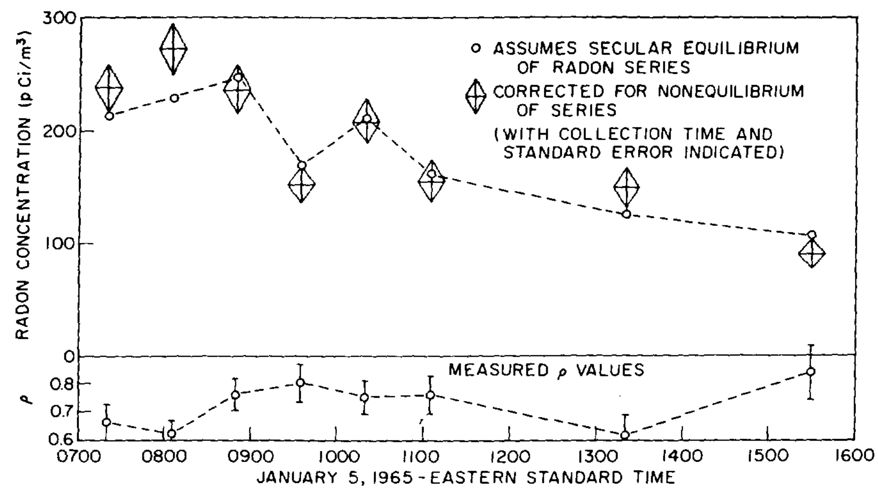


Fig. 9 – Atmospheric radon concentrations on January 5, 1965

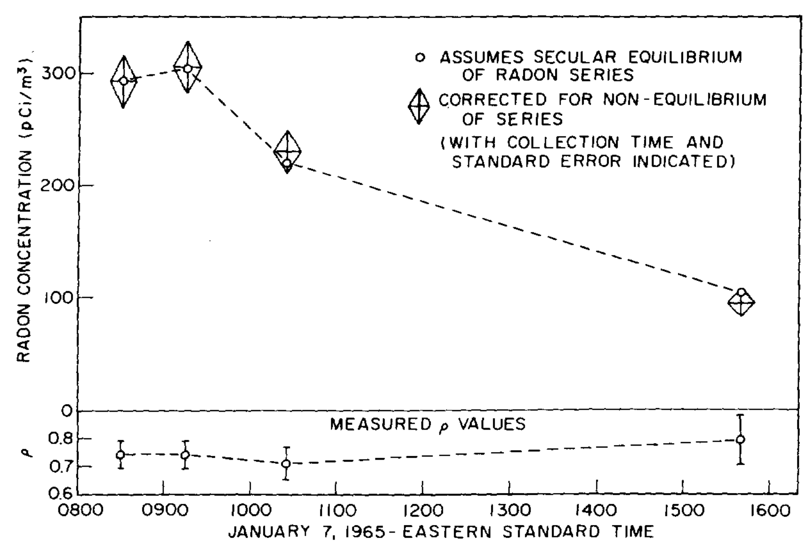


Fig. 10 – Atmospheric radon concentrations on January 7, 1965

encountered during the experiment. Account has been taken of the changes in ρ with time during the collections as described in the Appendix (this was ignored in the general solution of the experimental procedure), the changing composition caused by withdrawal of samples, and the background of other airborne radioactivity. The agreement is entirely satisfactory in view of the difficulty in setting an exact zero time for introduction of the radon, which was degassed from a radium solution, and the impossibility of evaluating the affect of the chamber walls both in removing aerosols and in removing radioactive atoms or ions. This wall effect could result in the lower ρ values observed and in the lack of closer approachment to the 0.735 equilibrium value.

The lack of quantitative agreement between the measured radon concentrations and the added quantity of radon was rather disturbing. Studies currently underway, however, show that there is a decided wall effect and that the chamber surfaces are in competition with the aerosol for attachment of the radioactive atoms or ions of the radon decay products and that, in the absence

TABLE 5

Experimental Evaluation of 0.20 μCi Radon Released into a Chamber (Room) of 35 m^3 Volume and Sampled at the Rate of 0.212 m^3/min*

Sample	Elapsed Time (min)	Counter Unit	Count $t_{1\text{-}11}$				Count $t_{61\text{-}71}$				Ratio $t_{61\text{-}71}/t_{1\text{-}11}$	Count Correction Factors		Corrected Count $t_{1\text{-}11}$	Expected Count $t_{1\text{-}11}$ From 100 pCi/m^3 Radon	Calculated Radon Conc. (pCi/m^3)		ρ§
			Gross	Background	ThB+C; Fission Products	Net	Gross	Background	ThB+C; Fission Products	Net		Flow†	Filter Efficiency			Corr. for ρ	Equilibrium Assumed‡	
1	0-20	D	8840	−313	−122	8405	4740	−313	−114	4313	0.513	4.72	1.00	39670	1395	2844	961	0.29
2	30-50	D	16900	−313	−122	16465	7700	−313	−114	7273	0.442	4.72	1.00	77715	2370	3279	1882	0.45
3	60-80	M	18500	−270	−122	18108	7800	−270	−114	7416	0.410	4.72	1.00	85470	2895	2952	2183	0.56
4	90-110	M	17700	−270	−122	17308	7390	−270	−114	7006	0.405	4.72	1.00	81694	2950	2769	2086	0.58
5	120-140	D	17400	−313	−122	16965	7205	−313	−114	6778	0.400	4.72	1.00	80075	3270	2449	1939	0.60
6	150-170	D	15400	−313	−122	14965	6310	−313	−114	5883	0.393	4.72	1.00	70635	3455	2044	1711	0.63
7	285-305	M	16500	−270	−122	16108	6600	−270	−114	6216	0.386	4.72	1.00	76030	3460	2197	1942	0.66
8	310-330	D	16000	−313	−122	15565	6700	−313	−114	6273	0.403	4.72	1.00	73467	3205	2292	1779	0.59

*Radon was added during the first 3 min (approx.) of the experiment; cigarette smoke was added 10 min before and 170 min and 305 min after the start of the run. The background of old radon in the room was approximately 500 pCi/m^3.

†Reciprocal of 0.212 m^3/min.

‡The expected counts from 100 pCi/m^3 of radon in equilibrium with its daughters are 4130 for counter unit D and 3915 for counter unit M.

§Determined from $t_{61\text{-}71}/t_{1\text{-}11}$ using the 10-mil-absorber curve shown in Fig. 6.

TABLE 6

Experimental Evaluation of 0.20 μCi Radon Released into a Chamber of 0.31 m³ Volume and Sampled at the Rate of 0.00196 m³/min*

Sample	Elapsed Time (min)	Count† $t_{1\text{-}11}$	Count† $t_{61\text{-}71}$	Ratio $t_{61\text{-}71}/t_{1\text{-}11}$	Count Correction Factors: Flow‡	Count Correction Factors: Filter Efficiency	Corrected Count $t_{1\text{-}11}$	Expected Count $t_{1\text{-}11}$ From 100 pCi/m³ Radon	Calculated Radon Conc. (pCi/m³): Corrected for ρ	Calculated Radon Conc. (pCi/m³): Equilibrium Assumed§	ρ
1	0-20	2390	1660	0.695	510	1.00	1.22×10^6	225	5.42×10^5	0.30×10^5	0.052
2	30-50	10400	5360	0.515	510	1.00	5.30×10^6	1370	3.87×10^5	1.28×10^5	0.27
3	60-80	16100	7000	0.435	510	1.00	8.21×10^6	2500	3.28×10^5	1.99×10^5	0.46
4	90-110	16900	7100	0.420	510	1.00	8.62×10^6	2810	3.07×10^5	2.09×10^5	0.51
5	120-140	20200	8120	0.402	510	1.00	10.31×10^6	3230	3.19×10^5	2.50×10^5	0.58
6	150-170	19920	7920	0.398	510	1.00	10.16×10^6	3320	3.06×10^5	2.46×10^5	0.60
7	180-200	20380	7980	0.392	510	1.00	10.39×10^6	3480	2.99×10^5	2.52×10^5	0.62
8	260-280	21480	8220	0.383	510	1.00	10.95×10^6	3730	2.94×10^5	2.65×10^5	0.67
9	285-305	16940	6600	0.390	510	1.00	8.64×10^6	3530	2.45×10^5	2.09×10^5	0.63

*An 0.3μ (dia.) DOP aerosol was added 10 min before the start of the experiment to a concentration of 10^4 particles/cc; the radon addition was made during the initial 3 min of the experiment.

†Corrected for counter background; a negligible background of airborne radioactivity was present. All results were normalized to the D counter as calibrated August 2, 1965.

‡Reciprocal of 0.00196 m³/min.

§Expected counts were obtained from Fig. 7; for the equilibrium condition this value was 4130 counts.

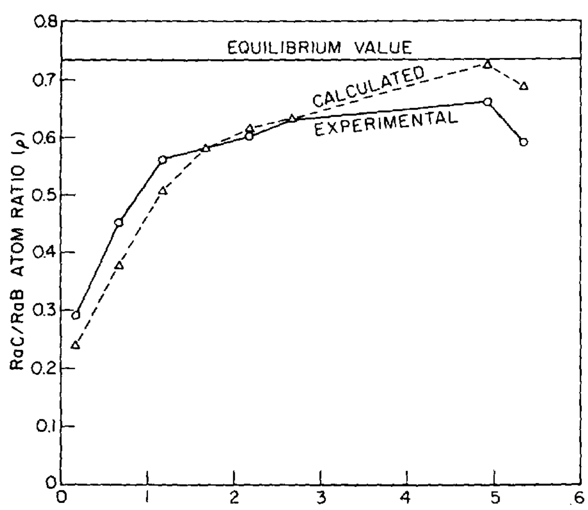


Fig. 11 – Temporal changes in the RaC/RaB atom ratio (ρ) following release of 0.20 μCi of radon into a chamber (room) of 35 m³ volume. The samples were taken at 0.212 m³/min for 20 min. The background of old radon was approximately 500 pCi/m³.

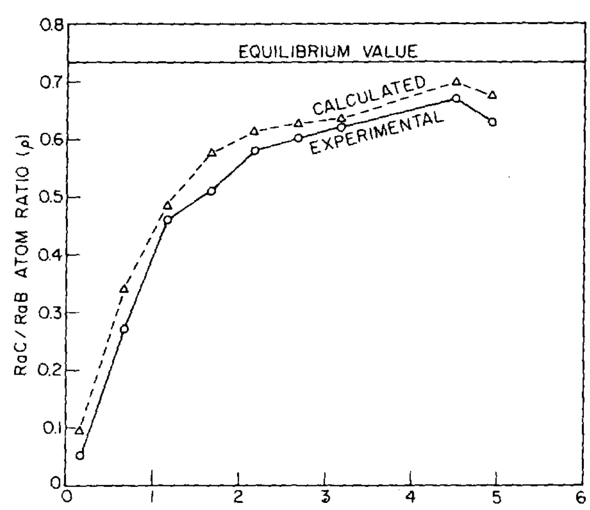


Fig. 12 – Temporal changes in the RaC/RaB atom ratio (ρ) following release of 0.20 μCi of radon into a chamber of 0.31 m³ volume. The samples were taken at 0.00196 m³/min for 20 min. The background of other airborne radioactivity was negligible.

of aerosol, little of the radon daughter activity remains airborne. The progressive decrease in observed radon with time is in accord with the loss of aerosol through coagulation and deposition, during which time the relative surface area of the wall increases. The wall effect is greatest in the large chamber, which contains so much permanently mounted equipment that it has a large surface-to-volume ratio. The apparent increase in radon concentration with introduction of additional smoke, as noted in Table 5, is to be expected if the relative surface areas of aerosol and wall are of significance.

The application of correction factors based on the ρ values does give a rather high degree of internal consistency to the measured radon concentrations, except for the first few measurements involving extreme degrees of nonequilibrium. Even these fall reasonably well into agreement when corrections are applied for the rapid changes in ρ occurring during the early collections (see Appendix). In any case the corrected values are more realistic than those derived from the assumption of secular equilibrium between radon and its daughters. The discrepancy between the experimental and the true radon concentration should not be encountered in measurements made of the radon concentration in the free atmosphere, since in that environment interaction with the ground surface would be much more restricted. On the other hand, use of this technique to measure radon concentrations in mines, tunnels, or other closed spaces might be expected to show a wall effect whose magnitude would depend on the configuration of the restraining walls and the rate of mixing within the volume.

CONCLUSIONS

Reasonably accurate estimations can be made of the radon concentrations in the free atmosphere by collection on efficient filters of the short-lived descendants of radon and measurement of their β activity during two fixed periods following collection. The measurement of the extent of secular equilibrium of radon and its daughter products may be conveniently determined by 10-min counts starting 1.0 min and 61.0 min after a collection of 20.0 min duration; counting on calibrated equipment with a 10-mil aluminum absorber inserted between the sample and counting tube gives a good compromise between sensitivity and the uncertainties introduced by the complex group of conversion electrons emitted and by counting statistics.

This method will detect any gross departures of radon in the atmosphere from secular equilibrium with its daughter products and permits a determination of the apparent age of the mixture.

In the free atmosphere radon is apparently near secular equilibrium with its daughters at most times; however, during initial stages of inversions and in recently ventilated spaces equilibrium departures can be expected. Chamber studies using artificial aerosols indicate a loss of radon daughter products to the walls or other surfaces and suggest that underestimation of radon by this method may result when the surface-to-volume ratio is high or when mixing promotes intimate contact between the air and a surface.

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Appendix

CHANGES IN ρ DURING NONEQUILIBRIUM CONDITIONS

The rapid changes in the RaC/RaB atom ratio (ρ) encountered in the chamber studies immediately after the addition of radon necessitated the development of new tables relating the growth and decay of radon daughter activity collected during 20-min filtration periods to the radon concentration in the air. Such an approach was not required for determinations of atmospheric radon, since in that case it was assumed that the atmosphere could be considered to be in or near a state of dynamic equilibrium during periods of 20-min duration.

Calculations of the collection and growth of RaA, RaB, and RaC on a filter during a 20-min collection were made taking into account the changes in RaA, RaB, and RaC occurring in the air prior to and during filtration. These changes are a function of the time during which the radon daughter products have been growing into equilibrium. The decay of these activities on the filter following termination of collection and taking into account the successive decay of members of the series is shown in Table A1 for collections made during periods of growth of the radon mixture corresponding to ages of 0-20 min, 40-60 min, 80-100 min, and infinite age (secular equilibrium established). The data used to construct working curves for determination of ρ and the radon concentration are contained in Table A2.

Application of the information contained in Tables A1 and A2 to the results of the chamber studies does increase the accuracy of radon determinations during early states of growth of the radon daughters; however, its affect on the determination of ρ is not of great significance. A comparison of the results of the small chamber run based both on the standard procedure and on this more realistic procedure is shown in Table A3. Only during periods of low ρ values are any substantial differences noted in the derived radon concentrations. In addition to the comparison of the experimental values of ρ and radon concentration for the two procedures, the expected values are also indicated; the experimental values of ρ (by either procedure) and the expected values are in good agreement, while the measured radon concentrations are about 50% low. This latter result is attributed to a "wall effect" due to the large surface-to-volume ratio and to the mechanical mixing within the chamber making the walls more accessible to impingement of diffusing ions and unattached atoms. The sampling process itself removes 11.8% of the aerosol and radon daughters with each collection, which results in effectively 6% of the radon being in a daughter-free, unmeasurable conditon during any collection.

TABLE A1
Radioactive Decay of Radon Descendants on a Filter Following a 20-min Collection During Which the Radon Conglomerate Progressively Increased in Age*

Counting Interval (min)	Radioactive Decays RaA	RaB	RaC	Counting Interval (min)	Radioactive Decays RaA	RaB	RaC
Age 0-20 min; $\rho = 0.0$ to 0.190				Age 80-100 min; $\rho = 0.564$ to 0.623			
0-1	Sample Manipulation			0-1	Sample Manipulation		
1-6	2226	4112	1709	1-6	2316	15867	16655
6-11	715	3775	2069	6-11	745	14109	16380
11-16	230	3370	2311	11-16	239	12454	15874
16-21	74	2977	2450	16-21	77	10962	15196
21-26	24	2622	2504	21-26	25	9640	14223
26-31	7	2307	2498	26-31	7	8474	13533
31-36	3	2027	2443	31-36	3	7431	12630
36-41	1	1782	2353	36-41	1	6544	11717
41-46	0	1566	2244	41-46	0	5753	10814
46-51	0	1375	2119	46-51	0	5057	9938
51-56	0	1209	1983	51-56	0	4443	9101
56-61	0	1063	1847	56-61	0	3904	8301
61-66	0	934	1707	61-66	0	3432	7552
66-71	0	821	1576	66-71	0	3017	6851
Age 40-60 min; $\rho = 0.355$ to 0.478				Age ∞ (secular equilibrium); $\rho = 0.735$			
0-1	Sample Manipulation			0-1	Sample Manipulation		
1-6	2316	12780	10802	1-6	2316	17594	21219
6-11	745	11397	11006	6-11	745	15627	20470
11-16	239	10069	10960	11-16	239	13788	19533
16-21	77	8866	10715	16-21	77	12134	18467
21-26	25	7798	10325	21-26	25	10670	17320
26-31	7	6855	9839	26-31	7	9379	16136
31-36	3	6025	9285	31-36	3	8245	14950
36-41	1	5295	8699	36-41	1	7245	13782
41-46	0	4654	8094	41-46	0	6367	12654
46-51	0	4090	7491	46-51	0	5594	11572
51-56	0	3594	6900	51-56	0	4916	10551
56-61	0	3158	6329	56-61	0	4321	9589
61-66	0	2776	5785	61-66	0	3798	8696
66-71	0	2440	5272	66-71	0	3338	7866

*Based on sampling of 100 pCi of radon per unit volume in various stages of equilibrium with its descendants.

TABLE A2

Calculated β Activity from 100 pCi of Radon per m^3 of Air Sampled at the Rate of 1 m^3/min for 20 min

Radon Age* (min)	Initial Activity (t_{1-11})			Final Activity (t_{61-71})		Activity Ratio Final/Initial	
		Disintegrations	Counts†	Disintegrations	Counts†	Disintegrations	Counts†
0-20	RaB	7887	153.8	1755	34.2		
(ρ = 0 to 0.190)	RaC	3778	315.5	3282	274.0		
	Total	11665	469.3	5037	308.2	0.432	0.657
40-60	RaB	24177	471.5	5216	101.7		
(ρ = 0.355 to 0.478)	RaC	21808	1821.0	11057	923.3		
	Total	45985	2292.5	16273	1025.0	0.354	0.447
80-100	RaB	29976	584.5	6449	125.8		
(ρ = 0.564 to 0.623)	RaC	33035	2758.4	14403	1202.7		
	Total	63011	3342.9	20852	1328.5	0.331	0.397
∞	RaB	33221	647.8	7136	139.2		
(ρ = 0.735)	RaC	41689	3481.0	16562	1382.9		
	Total	74910	4128.8	23698	1522.1	0.316	0.369

*Continuously changing age during the 20-min filtration period.

†Collected on glass fiber filter of 100% retentivity; counted through 10-mil aluminum absorber.

TABLE A3

Comparison of Derived ρ Values and Radon Concentrations in the Small Chamber Run (Radon = 6.41×10^5 pCi/m^3) Based on a Fixed and a Variable Age of the Radon/Radon Daughter Mixture

Elapsed Time (min)	RaC/RaB Atom Ratio (ρ)			Radon Concentration (pCi/m^3)		
	Standard Procedure*	Modified Procedure†	Expected Value‡	Standard Procedure*	Modified Procedure†	Expected Value‡
0-20	0.052	0.070	0.095	5.42×10^5	3.93×10^5	6.03×10^5
30-50	0.27	0.27	0.34	3.87×10^5	3.66×10^5	6.04×10^5
60-80	0.46	0.45	0.49	3.28×10^5	3.28×10^5	5.93×10^5
90-110	0.51	0.50	0.58	3.07×10^5	3.09×10^5	5.90×10^5
120-140	0.58	0.57	0.61	3.19×10^5	3.22×10^5	5.89×10^5
150-170	0.60	0.59	0.63	3.06×10^5	3.09×10^5	5.85×10^5
180-200	0.62	0.61	0.64	2.99×10^5	3.02×10^5	5.84×10^5
260-280	0.67	0.66	0.70	2.94×10^5	2.96×10^5	6.01×10^5
285-305	0.63	0.62	0.67	2.45×10^5	2.48×10^5	5.81×10^5

*The value of ρ is assumed to be constant during the sampling period.

†The value of ρ is assumed to increase with the age of the radon conglomerate during collection.

‡Calculations based on modified procedure and taking in account changes produced by removal of 11.8% of the aerosol with each sample.

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The 20-minute collection is made on a filter of essentially 100% retentivity (glass fiber filter) and counted for β activity through a 10-mil (70. mg/cm²) aluminum absorber on equipment of known efficiency for the β particles emitted by RaB and RaC. The ratio of measured counts during the 61-through-71-minute decay period to that during the 1-through-11-minute period is employed to obtain the atom ratio of RaC to RaB (ρ) in the air sampled, the apparent age (τ) of the conglomerate of radon and its daughters, and the total counts to be expected from any given radon concentration in the air.

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ENVIRONMENTAL RADON CONCENTRATIONS

AN INTERIM REPORT

by

Harold Glauberman and A. J. Breslin
Industrial Hygienists

Health and Safety Laboratory
New York Operations Office
U. S. Atomic Energy Commission
New York, New York

March 1957

II

ABSTRACT

Preliminary data showing ambient concentrations of radon in the Metropolitan New York area are presented. An attempt has been made to define the variability of concentration of radon in the general atmosphere with location, time, and weather conditions. Samples have been analyzed from the outdoor air, inside of buildings, and above and below the surface of the ground. Comparisons with the data obtained by other investigators are also shown.

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New York Operations Office
U.S. Atomic Energy Commission

The Health and Safety Laboratory is investigating the variability in space and time of natural radon concentration as a portion of its contribution to the United Nations scientific endeavor. This is an interim report of that work. Measurements were begun in late November 1956 and will continue indefinitely. One hundred and twenty samples have been collected and analyzed to date. Most of the sampling has been done in and around New York City; a few samples have been collected in New Jersey.

The present phase of the investigation is primarily a pilot study. Attention is being directed to instrumentation, sampling technique and sample variability, and the development of a systematic sampling program. Although the collected samples have yielded valuable data, they are more important as a basis for designing an integrated pattern of collection.

PROCEDURE

The basic measurement is one of instantaneous radon concentration. A grab-sample is collected in a one-liter glass flask and analyzed in the laboratory by a pulse counting ionization technique.(1) The results are reported in curies/liter of elemental radon in air. The analytical capacity is limited to six flasks per day. Whenever practicable, samples have been replicated so that the sampling error could be computed. When replicates have been obtained, individual successive samples have been collected as rapidly as possible at a fixed location.

Measurements are also being made of the daughter products of radon. At each sampling location, the daughters are sampled for ten minutes by drawing air at ten liters per minute through a one-inch diameter molecular filter disc. Alpha activity is measured in the laboratory with a scintillation counter. Initially, we attempted to measure the daughter decay as a function of time according to the method described by Tsivoglou, Ayer, and Holaday. (2) However, the counting statistics proved to be too unreliable at the activity levels measured. Nevertheless, a means is being sought whereby the daughter activity can be used to define the state of radioactive equilibrium of the decay products with radon.

RESULTS

Most of the samples have been collected in the streets and buildings of New York City. A few have been collected on the rivers around Manhattan and in mines in the northeastern part of the United States. Individual measurements are listed in the appendix.

A summary of the radon flask data appears in the following table.

TABLE I

SUMMARY OF RADON CONCENTRATIONS MEASURED WITH FLASK SAMPLES

Description	No. of Locations	No. of Samples	Avg. Rn Conc. 10^{-15} c/l	Range 10^{-15} c/l
Manhattan				
Streets	23	45	127	20-490
Precipitation	9	17	102	20-230
No Precipitation	14	28	142	20-490
Buildings	6	33	211	70-410
Precipitation	3	10	190	70-300
No Precipitation	4	23	220	100-410
Rivers	6	8	111	10-170
Subway Station	1	2	220	180-260
Vehicular Tunnel	1	2	120	50-190
Rural and Suburban				
Surface	4	7	73	10-150
Mines*	15	42	--	80-110,000
Iron	5	29	--	80-41,000
Zinc	3	5	--	100-2,100
Talc	3	3	--	8,000-20,000
Salt, Gypsum, etc.	4	5	--	100-110,000

Hess has been measuring radon concentration in New York City for many years. His reported average concentrations are listed in Table II. Average radon concentrations inside and outside of buildings in Sweden reported by Hultqvist are also shown for comparison.

* Much of these data have been published by Saul J. Harris (3)

TABLE II

RADON CONCENTRATIONS MEASURED BY OTHER INVESTIGATORS IN COMPARATIVE LOCATIONS

Description	Avg. Rn - Equiv. Content 10^{-15} c/l	Investigator
New York City - Outdoors - 1943	97	Hess (4)
" " 1952	103	Meyers & Hess (5)
" " 1953	53.8	Hess (6)
Sweden - Outdoors	100	Hultqvist (7)
" Buildings	1680	Hultqvist (7)

Portions of the data have been analyzed for variance. For the street samples, the variability between locations was $\pm$ 29.2 x 10^{-15} c/l, and within replicates it was $\pm$ 56.7 x 10^{-15} c/l. In contrast, the variability between buildings was $\pm$ 148 x 10^{-15} c/l, and within replicates it was $\pm$ 68.3 x 10^{-15} c/l. Work is now being done to determine how much of the variability may be attributed to analytical error. Triplicate flask samples are being collected simultaneously through a manifold in order to insure that each flask receives an identical sample. For the first three sets of triplicates collected by this procedure, the variation within triplicates was $\pm$ 22.6 x 10^{-15} c/l, and the variation between sets was $\pm$ 46.5 x 10^{-15} c/l. These data viewed in relation to the earlier analysis of variance strongly suggest that wide concentration fluctuations may occur in any one location over a short period of time.

FUTURE WORK

At present the study is confined to New York to facilitate sample collection and analysis while the program is being developed. Eventually, the study will be expanded geographically. We hope to obtain reasonable coverage of the United States.

We are particularly interested in the variability of radon concentration as it may be influenced by different phenomena. The kinds of variation which we will attempt to observe are:

1. Absolute sampling and analytical reproduceability.

2. Instantaneous variability at a given location.

3. Temporal variations -- diurnal and seasonal with emphasis on correlation with meteorology.

4. Locational differences -- intra-city and geographical, correlating with geology.

5. Differences with elevation -- above and below the surface.

6. Effects of structures and variability with height within structures.

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APPENDIX

MEASUREMENTS OF RADON CONCENTRATIONS

Location	Prec.	Date	Time	Flask Results 10^{-15} c/l
Street Samples				
57th & Columbus Ave.*	None	12/4/56	1425	230
19th & Ninth Ave. *	None	12/4/56	1459	490
	Prec.	12/14/56	1115	130
Vandam Street & 6th Ave.*	None	12/4/56	1520	320
E. Housten & Allen Sts.*	None	12/4/56	1541	240
68th between 2nd & 3rd Avenues*	None	12/4/56	1626	70
61st & Ninth Ave.*	None	12/11/56	1500	120
89th & Central Park W.	None	12/18/56	1425	20
			1426	80
			1427	190
	Prec.	1/29/57	1415	230
			1416	60
			1417	100
Duane St. & W. Broadway	None	12/18/56	1505	70
			1506	150
			1507	110
E. 87th St. & First Ave.	None	12/26/56	1342	160
			1343	50
			1344	210
W. 120th & Broadway	None	12/26/56	1432	100
			1433	50
			1434	150
	Prec.	1/23/57	1338	80
			1339	100
107th & Second Ave.	Prec.	1/23/57	1410	100
			1412	120
21st & Third Ave.	Prec.	1/23/57	1450	120
			1452	100
24th & Tenth Ave.	Prec.	1/23/57	1520	90
			1521	110

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Location	Prec.	Date	Time	Flask Results 10-15 c/l
Street Samples				
58th & Tenth Ave.	Prec.	1/23/57	1545	60
			1546	70
93rd & Riverside Dr.	Prec.	1/29/57	1330	30
			1331	50
			1332	180
C. Park - Lot	None	1/30/57	1110	120
			1112	120
		2/6/57	1400	110
			1402	120
132nd & Twelfth Ave.	None	1/30/57	1322	190
			1323	70
			1324	100
C. Park - 72nd St. Exit	None	2/6/57	1430	160
			1431	90
			1432	100
Building Samples				
Warehouse A - 1st Floor	None	12/11/56	1445	390
			1446	140
Office A*	None	12/13/56	1545	390
Office A	None	1/7/57	1545	270
			1546	180
			1547	160
		1/10/57	1530	230
			1531	120
			1532	120
		1/15/57	1436	130
			1437	150
			1438	190
Office A*	Prec.	1/16/57	1402	160
Office A	Prec.	1/16/57	1500	130
			1501	70
			1502	70
Apartment A	None	12/20/56	1343	410
			1344	380
			1345	370
		2/7/57	1401	270
			1402	330

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Location	Prec.	Date	Time	Flask Results 10-15 c/l
Building Samples				
Apartment B	None	12/20/56	1438	170
			1438	190
			1440	110
		2/7/57	1438	140
			1439	100
			1440	130
Apartment C	Prec.	12/27/56	1348	70
			1349	270
			1350	300
Basement A	Prec.	12/27/56	1442	330
			1443	240
			1444	260
River				
Between Riverside Chapel & Grant's Tomb	None	1/7/57	1110	170
Spyten-Duyvil - Under Bridge	None	1/7/57	1145	80
Pier 80 - No. River	None	1/21/57	1040	140
So. of G.W. Bridge (100yd)	None	1/21/57	1125	170
No. of G.W. Bridge (150yd)	None	1/21/57	1125	160
So. of G.W. Bridge (100yd)	None	1/21/57	1205	80
E. Bank Palisades	None	1/21/57	1220	10
Battery (1/4 mi.)	None	1/21/57	1505	80
Roof Samples				
Warehouse A Roof*	None	12/11/56	1335	110
Office A Roof*	None	12/13/56	1430	160
Subway				
68th St. Uptown	None	11/27/56	1330	260
			1331	180

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Location	Prec.	Date	Time	Flask Results 10-15 c/l
Tunnel				
Tunnel A	None	1/31/57	1605 1607	50 190
Mine Samples				
Mine A				
0 ft.		2/13/57	1445 1445	2010 1800
1,000 ft.			1230 1230	2140 3710
1,700 ft.			1240 1240	370 2780
2,100 ft.			1330 1330	4230 3700
2,600 ft.			1340 1340	2870 3860
Mine B				
50 ft.		2/20/57	1245 1245	15,260 12,280
350 ft.			1150 1155	180 80
475 ft.*			1113 1113 1127	210 250 150
600 ft.			1225 1225	180 120

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Location	Prec.	Date	Time	Flask Results 10^{-15} c/l
Rural and Suburban Samples				
Palisade Parkway*	None	1/30/57	1353	90
Englewood Boat Basin	None	1/30/57	1435	150
			1436	110
Mine A Outside	None	2/13/57	1445	50
			1445	50
Mine B Outside	None	2/20/57	1107	50
			1107	10

* Replicate samples taken at these locations. However, due to instrument failure, only one result was reported.

date? 1957?

THE RADIUM-D AIR/SOIL CYCLE AND ITS RELATION TO THE Sr^{90} AIR/SOIL RATIOS

L. B. LOCKHART, JR.

In soil radium decays to radon which diffuses into the atmosphere and there reestablishes an equilibrium with its decay products, RaA, RaB and RaC. These' products in turn decay to the long-lived RaD (Pb^{210}, 22 years). Due to the short residence time of radioactivity in the lower atmosphere (average lifetime 5-30 days), most of the radium-D activity will be deposited on the ground by natural processes. In time equilibrium will be established between the rate of evalution of Radon from the soil and the rate of deposition of RaD in the soil. The emission of radon from the soil and thus the radon concentration in the air will be the rate-controlling step.

At the present time effective equilibrium must have been reached between the average air concentration of radon and the concentration of radium-D in the soil at any given location. Thus the ratio between these concentrations represents the "coupling" between air and ground at that location and will include the a effects of fallout, rainout and impaction processes averaged over several years.

In practice the determination of this ratio will be difficult because most soils contain some uranium (or radium). Experimentally the following procedure would be required:

A. Determine the average radon (or RaB+C) concentration of the air at a given location

b. Measure the RaD content of a soil sample. The depth to which the soil should be sampled aix must be determined by running samples representing consecutive 2-inch increments in depth. This method would be most accurate in soils of lowest uranium (radium) content.

c. The uranium (preferably the radium) content of these same samples should be determined. Alternatively, if the soil composition is the same for a considerable depth, it may be possible to determine the "normal" RaD content of the soil resulting from the radium to radium-D conversion within the soil. The excess or deficiency of RaD in the top most portion of the soil would be representative of the ratio of emission of radon to deposition of RaD. In certain areas (deserts) there should be a deficiency of RaD in the top soil; in other, there should be an excess. Erroneous results would be obtained in areas with much rainfall due to run off and/or leaching. To determine the absolute rate of emission of radon, it might be necessary to construct a dead air space above the soil and determine the equilibrium value of radon in this space.

The importance of such a determination of radon in air to RaD in soil is that the same sort of relation should be developing between Sr^{90} in air and in soil. The radon/RaD ratio should be an equilibrium value and should give a "coupling" factor to use with Sr^{90} air concentrations to give the ultimate Sr^{90} soil concentrations to be expected. This would mean that such "coupling" factors could be developed for a given location and perhaps transferred to other locations if corrections for the different meteorlogical conditions could be applied. The average air concentration of Sr^{90} could then be used to estimate the deposition rates at any location where such air concentrations were available. This would be of even more value when Sr^{90} air concentrations become more uniform throughout the world. Then continuous air sample would be required in only a few representative areas.

Some possibilities of an attack of this sort on the problem of Sr^{90} accumulation in the soil can be shown from a few pieces of data that are presently available.

A. Calculation of soil/air ratios of RaD at Washington, D. C. (data from NRL Report 4069):

RaD in rainwater $\simeq$ 20 d/m/gal (June-November 1950)

Rainfall at Washington $\simeq$ 43"/year

$\simeq$ 27 gallons/sq. ft.

∴ Total RaD deposited $\simeq$ 540 d/m/sq. ft.

If this rate of deposition is continued for a number of years ($\gg$ 22y), an equilibrium value of RaD in the soil will be attained as given by the relation:

$$\text{RaD } (\text{d/m/ft}^2) = \frac{540 \text{ d/m/sq. ft./year}}{0.693/22 \text{ yr.}} = 1.7\text{x}10^4$$

Air concentration of RaD $\simeq$ 4×10^{-4} d/m/cu. ft.

$$\text{Soil/air ratio} = \frac{1.7 \times 10^4}{4 \times 10^{-4}} = 4 \times 10^7$$

B. Whether ratios of any great accuracy can be obtained will be dependent on finding suitable soil samples of low radium content.

Ra content of "average" rock $\simeq$ 1×10^{-12} g/g of soil (varies from $\sim 5 \times 10^{-12}$ for some granites to as low as 0.12×10^{-12} for certain chalks, etc.)

Ra = Rn = RaD activity = 1×10^{-12} C/g x 2.2×10^{12} d/m/C

= 2.2 d/m gram of soil

For a 1 ft. square soil sample 1 inch deep there are 2360 cc of soil or $\sim$ 6000 grams of soil

∴ Top inch of "normal" soil would contain 13,000 d/m of RaD assuming no gain or loss of Rn and its decay products (range 65,000 to 1600)

The radioactivity profile of the soil at Washington can thus be depicted schematically as:

1. For granite			2. For chalk	
Surface of Soil			*Surface of soil*	
1"	73,000 *d/m/ft²*	excess 17,000 d/m per sq. ft.	1"	9600 *d/m/ft²*
1"	70,000		1"	6600
1"	68,000		1"	4690
	66,000			2600
	65,000			1600
	65,000			1600
	65,000			*1600*

It is obvious that the loss of radon from granites could complicate the picture excessively and that no accurate determinations of the accretion of RaD could be made. However, on low radium-content soils loss of Rn would not be such a serious factor and reliable figures could be obtained.

Other areas of the world should show depleted zones in the top layers of the soil due to the excess of diffusion over deposition. Over the earth as a whole-land plus sea - there can be no overall gain or loss. This means that there will be a pattern of RaD in the top layers of the soil which differs from the Uranium-radium distribution.

C. Calculation of Sr^{90} levels in Washington, D. C. soils through use of above approach.

Strontium-90 air concentration at NRL (May-July 1957) = 5.1×10^{-4} $d/m/ft.^3$

If same mechanism holds for deposition of Sr^{90} as for deposition of RaD, the same soil/air factor can be used. The mechanism should be the same since both types of activity are long-lived, ~~an~~ *are* probably attached to extremely small uncharged particles, are present at ground-level (or in the lower ~~xx~~ atmosphere) and are removed primarily by rain. The only difference involved is the manner in which

~~theyxarrixaxat~~

they arrive at the lower tropospheric levels.

∴ Ultimate Sr^{90} soil concentration, if present tropospheric activity levels are maintained,

$= (5.1 \times 10^{-4})(4 \times 10^{7}) = 2 \times 10^{4}$ d/m/ft.^{2}

or, by multiplying by 2.8×10^{7} ft^2/mi^2 = 5.6×10^{11} d/m/mi^2

and, by dividing by 2.2×10^{9} d/m/mc = 2.5×10^{2} mc/mi^2

If the present level has been in existence for 3 years and if negligible Sr^{90} levels were encountered prior to this:

present Sr^{90} soil level at Washington, D.C.

$= (2.5 \times 10^{2}$ mc/mi$^2) \times (1-e^{-\lambda t})$ where λ) $= \frac{0.693}{22 \text{ yr}}$

and t = 3 yr.

$= 0.07\ (2.5 \times 10^{2}$ mC/mi$^2)$

$= 17$ mC/mi^2

These calculations consider only that rain is the principle mechanism of Sr^{90} and RaD deposition and that similar efficiencies are obtained. Soil analysis for either RaD or Sr^{90} would serve as a check on these values.

Libbey, in an address before the American Physical Society, Philadelphia, Pa. April 20, 1956, reported average total deposit of Sr^{90} in US to be about 13 mc/mi^2, which is in reasonable agreement with the 17 mc/mi^2 we estimated for a year later.