time elapsed, however, the probability increased until, following the elapse of 2 minutes after a reinforcement, the first lever press was always reinforced. The strength of the response chain which began with a reinforced lever press and terminated with licking behavior may thereby have increased as time elapsed after a reinforcement. It is also conceivable that responses which compete with dipper approach and rapid licking behavior (that is, grooming or swallowing behavior) were strongest just after a reinforcement. In any case, it is evident that identical reinforcing stimuli may evoke licking behavior which varies in relation to subtle environmental parameters (*7*).

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Quantum Efficiency of Cytochrome Oxidation in a Photosynthetic Bacterium

Abstract. Illumination of *Chromatium* with light absorbed by bacteriochlorophyll causes the oxidation of intracellular cytochrome. The quantum efficiency of this reaction approaches one electron per photon at 589 millimicrons and at wavelengths between 862 and 908 millimicrons. The efficiency of converting excitation energy to chemical energy is estimated to be about 30 percent.

The oxidation of intracellular cytochrome pigments when photosynthetic bacteria are illuminated with light absorbed by chlorophyll appears to be a general phenomenon (*1*). This observation, coupled with the fact that these pigments are present in all the photosynthetic bacteria investigated so far (*2*), has led to the supposition that cytochromes are involved in electron transfer even in bacteria which have no respiratory capability.

If a cytochrome is directly involved in photosynthetic electron transfer, the light-induced oxidation reaction must proceed with an efficiency comparable to that for overall photosynthesis. For the purple sulfur bacterium *Chromatium* the quantum efficiency of cytochrome-423.5 oxidation has been estimated to be 0.5 electron per photon absorbed at 589 mμ (*3*). (Bacteriochlorophyll has a minor absorption band at 590 mμ in vivo.) This estimate was made on the assumption that the differential absorbancy index $\Delta\epsilon_{423} - \Delta\epsilon_{470}$ for cytochrome 423.5 was 100 cm^{-1}mmolar^{-1}.

The results of this earlier work have been recalculated in the light of the quantitative spectral data of Bartsch and Kamen (*4*) for *Chromatium* cytochrome *c* which appears to be identical to cytochrome 423.5 in the intact organism. In addition, the measurements of quantum efficiency have been extended to the far-red region where the main absorption peaks of bacteriochlorophyll are located, and the possibility of a drop in efficiency for wavelengths on the red side of the bacteriochlorophyll band at 890 mμ has been investigated.

The experimental methods have been described in detail previously (*3*). *Chromatium*, strain D, was grown in liquid inorganic medium and resuspended in fresh medium before examination. Fractional absorption of actinic light was determined by the integrating sphere method. Intracellular cytochrome oxidation was measured in terms of $\Delta D_{423} - \Delta D_{470}$ with a double-beam spectrophotometer. Actinic light was furnished by a 100-watt projector lamp and the following filters: 1 cm-H_2O, Wratten 88A, and Bausch and Lomb second order interference filter(s). Intensities up to 10^{-9} einstein cm^{-2}sec^{-1} were measured by means of a calibrated thermopile. For each wavelength of actinic light the initial rate of absorbancy change, $d(D_{423} - D_{470})/dt$ (see Fig. 1), was plotted versus the rate of absorption of actinic light, and the average slope was determined. The quantum efficiency was obtained by dividing the slope by the differential absorbancy index for *Chromatium* cytochrome *c*, 62.3 cm^{-1}mmolar^{-1} (*5*).

Some of the experimental data is

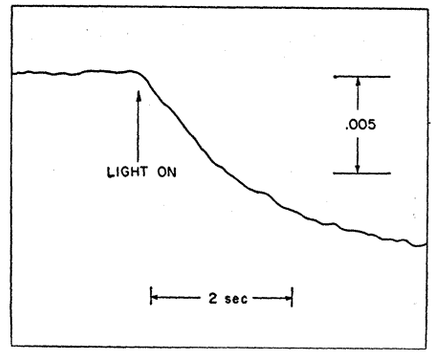

Fig. 1. Oscillographic recording of the absorbancy change $\Delta D_{423} - \Delta D_{470}$ caused by irradiation of bacteria with 892-mμ light of intensity 2×10^{-10} einstein cm^{-2}sec^{-1}.

summarized in Fig. 2. Nine efficiency determinations in the far red (862 to 908 mμ) gave an average value of 1.0 electron per photon. The average value for 589-mμ light (*3*) was recalculated on the basis of 62.3 cm^{-1}mmolar^{-1} and found to be 0.8. These two values are in good agreement in view of the different methods used to measure light intensity in the two cases. The efficiency approaches the theoretical maximum of one and appears to be essentially independent of wavelength. Although the value at 908 mμ is somewhat low, this is probably not significant in view of the fluctuation in the other values obtained in the far red.

Since each photon absorbed by bac-

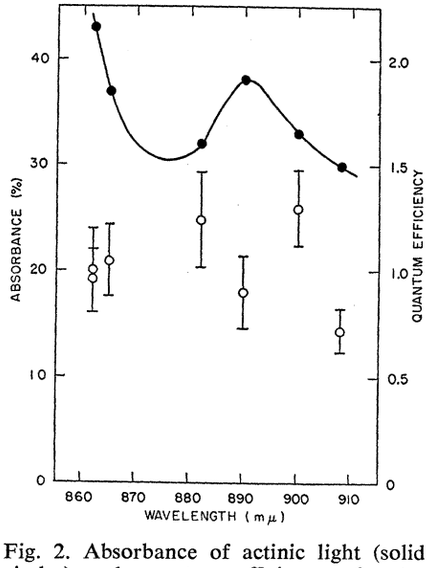

Fig. 2. Absorbance of actinic light (solid circles) and quantum efficiency of cytochrome oxidation (open circles) for wavelengths of 862, 865, 882, 890, 900, and 908 mμ. The horizontal bars indicate the r.m.s. deviation from the average efficiency value at each wavelength.

teriochlorophyll may withdraw one electron from cytochrome at −170°C as well as at 30°C (*6*), the primary conversion of electronic excitation energy to useful chemical free energy may involve the oxidation of *Chromatium* cytochrome *c* ($E_0' = +0.01$ volt) and the simultaneous formation of a powerful reductant. If the hypothetical reductant has a redox potential around the level of the hydrogen electrode at *p*H 7 (−0.41 volt), the thermodynamic efficiency of energy conversion from the lowest excited state of bacteriochlorophyll (32 kcal) would be about 30 percent (*7*).

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Cerium-144 in Food

Abstract. Small amounts of cerium-144 have been found in samples of food and animal bone obtained from Ibaraki, Japan. The highest level of radioactivity was detected in clams (Schizimi, *Corbicura* sp.) harvested from Hinuma Marsh. In view of the widespread occurrence of cerium-144 in tested samples, it is assumed that the presence of this radionuclide is due to fallout.

The predominant fission product contributor to total radioactivity 0.85 to 3 years after detonation is Ce^{144} (Pr^{144}) (*1*). Because Ce^{144} is abundant in fallout, it is reasonable to expect that food will be contaminated by this radionuclide.

Recently Van Dilla (*2*) reported that although grazing animals ingest large amounts of Ce^{144} and other radionuclides as foliar contamination, very little Ce^{144} is absorbed. Investigations at our laboratory have revealed the presence of Ce^{144} in a wide variety of substances, with prominent occurrence in animal bone and clams.

Table 1. Results of Ce^{144} and Sr^{90} analysis of different environmental samples.

Sample	Date of sampling	μμc/kg (wet wt.)		μμc/g of ash	
		Ce^{144}	Sr^{90}	Ce^{144}	Sr^{90}
Soil (depth 0–10 cm)	Jan. 1960	(2670 ± 59)*	(130 ± 20)*	(2.76 ± 0.06)*	(0.13 ± 0.02)*
Spinach (leaves)	Mar. 1960	49.1 ± 3.4	21.2 ± 2.1	2.50 ± 0.17	1.1 ± 0.1
Radish (root)	Mar. 1960	9.9 ± 5.0	12.4 ± 1.0	1.5 ± 0.8	1.98 ± 0.16
Clams, muscle	June 1960	68.0 ± 3.6	2.8 ± 0.8	15.4 ± 0.8	0.65 ± 0.19
Cuttlefish (total)	Feb. 1960	77 ± 9.0	1.6 ± 0.6	4.67 ± 0.56	0.10 ± 0.038
Crucian carp bone	Apr. 1960	31 ± 10	705.8 ± 8.1	0.30 ± 0.10	6.937 ± 0.081
Mixed animal bone (cattle and horse)	Jan. 1960	932 ± 24	9293 ± 60	3.10 ± 0.80	30.98 ± 0.20

* μμc/dried sample.

Environmental substances, including some food, obtained from Ibaraki, Japan, during January to June, 1960, have been analyzed for Sr^{90} and Ce^{144}. Strontium-90 concentration was determined by the "Method of Analysis for Radioactive Strontium," compiled by the Science and Technics Agency of Japan. This is a method of fuming nitric acid separation.

The method of Ce^{144} determination is as follows: A sample solution was prepared from the ashes of about 1 kg of dried sample by hydrochloric acid extraction and alkaline fusion. After addition of a cerium carrier solution to the sample solution, rare earths were isolated from the sample solution as hydroxides. Oxalates were separated from the hydroxides and converted into oxides by ignition in an electric furnace at 600° to 700°C. The oxides thus obtained were dissolved in hydrochloric acid, and hydroxides were again precipitated from this solution. This procedure was repeated two or three times for removal of calcium, phosphate, and other cations except for rare earths. After being dissolved in concentrated hydrochloric acid, the hydroxides were passed through a column containing anion exchange resin equilibrated with concentrated hydrochloric acid. By this procedure iron, uranium, and plutonium are absorbed. The effluent was dissolved in nitric acid solution (7.5*M*), and again passed through a column containing anion exchange resin equilibrated with nitric acid (7.5*M*). By this step thorium is absorbed. From the effluent, rare earths were precipitated as hydroxides. Cerium was isolated from other rare earths by the iodate method and finally prepared as oxalate. The radioactivity of each sample was measured under standard conditions with a Geiger-Müller counter. The concentration of Ce^{144} was determined by the chemical yield of added carrier and by comparison with a standard sample of known concentration.

The cerium fractions were combined, and the gamma spectrum was determined by using a 1¾ by 2 inch NaI (Tl) well-type crystal and a 256-channel pulse height analyzer. The distinct peaks of the spectrum were consistent with that of the $Ce^{144} + Pr^{144}$ standard sample.

The $Ce^{144} + Pr^{144}$ spectrum would be expected to show peaks at 0.134, 0.100, and 0.071 Mev due to Ce^{144}, and at 2.18, 1.48, and 0.700 Mev due to Pr^{144}. The peaks due to Ce^{144} are more than 60 percent of the total gamma radiation of $Ce^{144} + Pr^{144}$, but the peaks due to Pr^{144} are only a few percent (*3*) of the total.

Observed peaks on this spectrum were 0.134, 0.100, and 0.069, Mev. With our instrument, the ordinals lower than 0.100 Mev are not in correct proportion to the energy. The gamma radioactivity of the cerium fraction was so low that the peaks due to Pr^{144} could not be observed. From our data, the individual peaks due to Pr^{144} cannot be distinguished from the Compton background. The maximum energy of beta rays, calculated from the beta-ray absorption curve of the cerium by the method of Bleuler and Zunti (*4*), was 2.92 Mev. The decay curve of the cerium fraction showed that the half-life was 282 days.

The radioactivity of the cerium fraction seems, therefore, to owe its origin to $Ce^{144} + Pr^{144}$. The Ce^{144} concentrations of representative samples are summarized in Table 1. This radionuclide was present in every sample tested. The higher levels of Ce^{144} in clams, as compared with levels in the other biological samples, are not unexpected, in view of the findings of Goldberg *et al.* (*5*), who demonstrated that some marine organ-