ture which have been irradiated long before can be used to find the radiation dose absorbed by the substance in the past. In fact, measurement of thermoluminescence of limestones has been remarkably successful in determining the geologic age of carbonate sediments (*4*), and dating of potteries by thermoluminescence is now in progress (*5*).

When this method was applied to roof tiles of Hiroshima and Nagasaki, the thermoluminescence intensity of the samples gave some information about the absorbed dose of bomb radiation because the thermoluminescence intensity contributed by natural radiation is small compared with that contributed by bomb radiation. The following experiment shows that thermoluminescence dosimetry is a powerful tool for measuring the gamma ray dose of bomb radiation sustained 17 years ago.

The experimental apparatus consisted of an oven with a silver hot plate, a photomultiplier (2″ϕ), a direct-current amplifier, and a two-pen recorder which recorded the glow intensity and the temperature of the sample. Light resulting from thermoluminescence in the sample was collected on the photomultiplier through an optical filter, a light pipe, and a shutter mechanism. The distance from the hot plate to the photomultiplier was about 10 cm.

Roof tiles, which had been exposed to bomb radiation in Hiroshima or in Nagasaki, were selected for measurement. Samples were chosen whose exact locations were known; none had been exposed to the fire which occurred in large areas of both cities at the time of explosions (*6*). A piece of the sample was ground slowly (*7*), and 300 mg of the powder was spread uniformly over the silver hot plate (25 mmϕ). The sample was heated at a rate of 75°C/min until the temperature reached 450°C, and the glow curve, contributed from the bomb radiation, was recorded. Then the sample was cooled and heated again in the same manner as before to record the background glow curve—that is, the thermal radiation. Since the thermoluminescence sensitivity of different roof tiles is not the same, some calibration must be made for each sample. The same sample was exposed to Co^{60} gamma rays, and after it had absorbed a known amount of gamma dose, the new glow curve was recorded as before for calibrating the thermoluminescence sensitivity of the sample. The equivalent gamma dose of bomb radiation was obtained by comparing the bomb glow curve with the Co^{60} gamma glow ones. The intensity of thermoluminescence from the gamma-irradiated sample was exactly proportional to the absorbed dose.

Table 1. Radiation dose from the atomic bomb.

Sample	Distance from hypocenter of explosion (m)	Equivalent dose (rad)	York's data (*8*)	
			Gamma (rad)	Neutrons (rem)
Hiroshima–1	700	2100–2500	2200	1900
Hiroshima–2	960	1200–1500	780	480
Hiroshima–3	970	700– 900	740	440
Nagasaki–1	980	1500–1800	920	60

Glow curves resulting from bomb radiation in the past and from the Co^{60} irradiation in the present are different in shape. The glow curve resulting from Co^{60} irradiation shows a steep rise above 100°C and a distinct peak at about 180°C. On the contrary, the glow curve resulting from bomb radiation has a negligible intensity below 180°C and does not show any remarkable peak. Such differences come from the natural decay of the number of electrons in shallow traps. Therefore the decay at the normal temperature during 17 years (1945–1962) must be estimated in order to obtain the true equivalent gamma dose.

Qualitatively speaking, the high-temperature part in the thermoluminescence glow curve is contributed from deep traps. When the trap is deeper, the lifetime of the trapped electron is longer. Rough calculation shows that the average lifetime of the trapped electrons corresponding to the part of the glow curve above 330°C is longer than 100 years. Therefore the calibration for the thermoluminescence sensitivity of the sample was made by using the part of the glow curve above 330°C, where the two glow curves show similar shapes.

The equivalent gamma doses thus obtained are listed in Table 1, where York's data are shown for comparison although the origin and the range of error of the data are not known. Absorbed dose of roof-tile samples by bomb irradiation is composed of four components: prompt gamma rays, fast neutrons, induced activities in the sample, and fallout radioactivities. The contribution of the latter two components is not known. But it is probably small compared with the former two when the sample was irradiated within 1.5 km from the hypocenter of the explosion, except in the Nishiyama district in Nagasaki. According to York's data, the fast neutron dose is comparable to the gamma dose in Hiroshima. (In Nagasaki, the neutron dose was much smaller than the gamma dose.) In thermoluminescence dosimetry, the energy transferred to the sample by recoil of fast neutrons is about 1/20 as large as it is in the case of soft tissue because the atomic composition of the sample is much heavier than that of soft tissue. As the first approximation, therefore, the equivalent gamma dose can be regarded as expressing the gamma component of the bomb.

There remain some unsolved problems: experimental confirmation of the decay, the exact separation of the contribution of the fast neutron dose, and the effect of self-shielding of the roof tiles for bomb radiation. The sensitivity of this dosimetry is excellent, and a bomb dose below 100 r can be measured.

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6. We thank Dr. S. Nagaoka who kindly selected and offered the roof-tile samples.
7. Thermoluminescence induced by grinding was not detectable for roof-tile samples.
8. York's data is cited in R. H. Ritchie and G. S. Hurst, *Health Phys.* **1**, 390 (1959).

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Brownian Movement in Color Photomicrography

Abstract. *Crystals, smaller than 1 micron, in Brownian movement have been photographed in color.*

A suspension of green translucent crystals mainly of colloidal size (under 1 μ), but with some crystals of up to 10 microns, has been studied by color photomicrography in which vigorous

Brownian movement was arrested. We believe that Brownian movement may not have been photographed previously in color.

A xenon flash-tube with flash duration of 65 μsec (above half-peak) from a 5- by 5-mm source, operated from a 100-μf capacitor charged to about 2 kv, was positioned under the substage condenser lens of a microscope and fired with the camera shutter held open manually. Acceptable transparencies were obtained on 35-mm high-speed daylight Ektachrome film at magnifications up to 800. Our microscope has a built-in camera with interchangeable cassettes; a second cassette, loaded with Kodachrome II type A, was used to obtain a paired time exposure of each field. By comparison, the crystals in Brownian movement were later readily identified. Slides were prepared by simply trapping a drop of suspension under a cover slip.

Similarly prepared slides of cows' milk containing stained fat globules in Brownian movement have also yielded acceptable transparencies. But the main purpose of this technique is to study the distribution of fine color markers in suspensions.

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Note

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Mosquitoes: Comparative Serology of Four Species of Aedes (Ochlerotatus)

Abstract. *Antigens of female adult* Aedes communis *(DeG.),* A. punctor *(Kby.),* A. trichurus *(Dyar), and* A. excrucians *(Walk.) were compared by precipitin tests. There is a wider divergence among species than is indicated by external comparative morphology.*

Certain intrageneric groups or "complexes" of mosquitoes show marked morphological similarities although physiological and behavioral differences often exist. The phylogenetic relationships among members of such groups are difficult to ascertain and often must be postulated from the subjective interpretations of morphological or behavioral variations (*1*). Recent applications of serological techniques to insect taxonomy (*2*) showed that precipitin reactions with insect antigens differentiate species and indicate their relative taxonomic positions.

Extracts from adult females of *Aedes communis* (DeG.), *A. punctor* (Kby.), *A. trichurus* (Dyar), and *A. excrucians* (Walk.) were compared by precipitin tests. The mosquitoes were collected in the vicinity of Ottawa, Ontario, in the third- and fourth-instar larval stages. Adults that emerged were maintained in the laboratory for 72 hours and fed 10 percent sucrose solution but not blood.

The antigens for the preliminary experiments were prepared from whole, freshly-killed mosquitoes by extraction with buffered physiological saline, *p*H 7 (*3*). Subsequent experiments were made with the antigenic protein-containing fraction separated from extracts of whole mosquito by continuous filter-paper electrophoresis in veronal buffer, *p*H 8.6, ionic strength 0.02, 30 ma (*4*). The fraction so obtained was identified by its mobility and its characteristic pattern in single-diffusion antiserum-agar tests. A comparable fraction was obtained from all species tested, additional studies (*5*) indicated that it was present in pupal and adult mosquitoes but not in larvae. In gel-diffusion tests the fraction which showed three precipitate zones appeared less antigenically complex than whole-mosquito extracts which showed 8 to 12 precipitate zones. The antisera were prepared by injecting rabbits with three subcutaneous doses (1, 1½, and 2 ml) of mosquito antigen on alternate days.

The Libby photronreflectometer, a photoelectric instrument designed to measure the turbidities of antigen-antibody reactions was used to compare the mosquito antigens (*6*). Serial dilutions of antigen were made in buffered saline, and 0.7 ml of each dilution was mixed with 0.3 ml of undiluted antiserum. The resulting turbidity of each mixture was recorded in galvanometer units from the photronreflectometer and the sum of the turbidity values (ST) for each series of mixtures was determined. For all tests the concentration of antigen was adjusted so that the turbidity reading of the inital antigen dilution was zero. This was done so that the entire range of reaction from antigen excess to antibody excess could be measured. The *homologous* reaction was that which occurred between the antigen from one species of mosquito and the antiserum produced when this antigen was injected into a rabbit. *Heterologous* reactions were those which occurred between the same antiserum and antigens from other species of mosquito. Percentage relationship values were estimated by the calculation of (ST heterologous/ST homologous) 100 (*7*).

Table 1. Percentage-relationship values (and ST values) determined by turbidity of precipitin reactions of antigens from adult, female *Aedes* mosquitoes.

Source of antigen	Antisera to			
	A. communis	*A. punctor*	*A. trichurus*	*A. excrucians*
	Saline extract from whole mosquitoes			
A. communis	100 (140)	84 (143)	62 (172)	20 (45)
A. punctor	82 (114)	100 (170)	76 (210)	25 (55)
A. trichurus	31 (43)	48 (82)	100 (276)	47 (104)
A. excrucians	23 (82)	21 (36)	18 (49)	100 (219)
	Electrophoresis fraction from whole extracts			
A. communis	100 (162)	69 (98)	43 (97)	
A. punctor	59 (72)	100 (158)	52 (106)	(Not
A. trichurus	28 (45)	31 (49)	100 (204)	obtained)
A. excrucians	10 (17)	18 (28)	9 (19)	

The results of turbidity tests (Table 1) indicated that mosquitoes were readily distinguishable by precipitin reactions; *A. communis* and *A. punctor* were most antigenically similar and *A. trichurus* appeared more closely related to these species than did *A. excrucians*. Comparisons with antigens obtained by electrophoresis showed an order of species relationships similar to that obtained in tests with extracts of whole mosquitoes. The tests with the isolated fractions showed greater distinction between species, suggesting that the antigens in the reactions were highly specific. Unfortunately, a sufficiently potent antiserum against the fraction from *A. excrucians* was not obtained and the limited supply of this fraction