RADIATION AND RACIATION

BY NATHANIEL WEYL

From the dawn of the nuclear age until the end of 1960, total radiation from bomb tests amounted to an estimated maximum of about .4 roentgens or about 1/60th of the threshold quantity needed to produce observable medical effects.[1] This rather inconsequential dosage evoked a prodigious scientific and popular literature on the malign effects to be anticipated from the testing, covering both leukemia and other major debilitating diseases, and lethal and sublethally deleterious mutations.

Considering the enormous amount of work done on the genetic and medical effects of the bomb tests, it is remarkable that so little study has been made of the consequences of variations in the natural radiation levels at different places on the surface of the earth.[2] Despite the incompleteness of the data, some speculation concerning the relationship of radiation to the shaping of human —and, for that matter, probably animal and plant—races is possible.

Natural Radiation. Except for areas of abnormally high natural radiation, one can say that dosage in roentgens per year will vary from about .053r over open ocean to about .170r over granite rock in the North Temperate Zone and at an altitude of 5,000 feet. Obviously, dosage will increase sharply at still higher altitudes, but these generally are sparsely populated. Moreover, much greater radiation occurs over such special geological formations as the Swedish alum shales, where dosage is about .700r per annum.[3]

[1] Earl H. Voss, *Nuclear Ambush,* Regnery, Chicago, 1963, p. 7, estimates total bomb-test fallout to 1961 at .25 to .42 roentgens. (The roentgen, or "r," is the amount of gamma radiation which produces about 2 billion ion pairs per cc. of air).

[2] The highest known natural radiation on earth occurs on the New Zealand-owned South Pacific island of Niue, where the dosage is 7r per annum. Although the New Zealand nuclear scientist Sir Ernest Marsden began to study radioactive effects on the population in August 1962, no report had been received by the Atomic Energy Commission a year later. The A.E.C. expressed similar ignorance concerning medical and genetic effects in the monazite sand bearing regions of Brazil and Kerala, India.

[3] *Report by the World Health Organization on Genetic Effects of Radiation,* 13th March 1957, Annex 4 by Professor R. M. Sievert, Institute of Radiophysics, Karolinska Hospital, Stockholm. Reproduced in Joint Committee on Atomic Energy, 85th Congress, 1st Session, *The Nature of Radioactive Fallout and its Effects on Man,* Government Printing Office, Washington, D.C., 1957, Vol. II, p. 1768. (In future, this report will be referred to as *Fallout*).

The estimate of .400r already given for total atom-test radiation during the period from 1945 to 1960 averages out to less than .03r annually, or considerably less than the minimum background radiation encountered over open ocean.

If scientists consider that the genetic effects of bomb-test radiation, occurring over a period of 15 years or so, are serious, then it would seem self-evident that natural radiation—which has occurred continuously over millions of years, from the eras of mountain formation to the present—must be a far more significant agent of genetic change.

About half the natural radiation entering the biosphere is cosmic. In other words, cosmic rays, traveling at speeds approximately that of light, collide with atoms in the atmosphere and send particles hurtling to the earth. The cosmic radiation experienced by man is chiefly secondary or, for that matter, tertiary or of a still higher order of indirection, depending on the number of collisions occurring.

Cosmic radiation varies directly with altitude because the higher one is from sea-level the thinner and weaker is the atmospheric shield which deflects the particles and lessens their velocity. It also increases irregularly as one passes from tropical to temperate latitudes. Particles rushing earthward at equatorial latitudes must penetrate lines of geomagnetic force which are approximately at right angles to their trajectories. When the bombardment is aimed at poleward or temperate zones, however, it tends to strike the earth's geomagnetic field more obliquely, thus increasing the probability that particles will reach the earth's surface. For purposes of this discussion, all the reader need do is visualize the earth's surface as protected by a magnetostatic field.

Almost all of the remaining natural radiation results from radioactive disintegration of the earth's material. There are areas of very intense natural radiation overlying the monazite (thorium-ore bearing) sands in Travancore, India, and along the Brazilian littoral. The average radiation level in Espiritu Santo, Brazil, is approximately .500 rad per annum, whereas in Kerala (Travancore) levels have been estimated as high as 2.814 rad.[4] The Swedish case has already been mentioned. In representative American cities, levels range from .076 rad per annum in Toledo, Ohio, to .176 rad per annum in Colorado Springs, Colorado.[5]

Over a 30-year period roughly corresponding to human fertility, the gonad radiation dose (excluding cosmic radiation) has

[4] Bruce Wallace and Th. Dobzhansky, *Radiation, Genes and Man,* Holt, Rinehart and Winston, New York, 1959, p. 70.

The "rad" is the basic unit of radiation absorption. "The absorption of 1 rad delivers 100 ergs of energy per gram of matter," *op. cit.,* p. 67.

[5] Wallace and Dobzhansky, *op. cit.,* p. 69.

been estimated at 4.3r over Alpine granites, 2.0r for North American granites, 1.2r for basalts, 0.8r for sandstone and 0.6r for limestone.[6] The broad relationship between radiation and rock mantle, altitude and latitude is shown in the following table compiled by W. F. Libby.[7]

TOTAL RADIATION DOSAGES IN RADONS PER YEAR

	ORDINARY GRANITE		TYPICAL SEDIMENTARY		OPEN OCEAN	
	Equator	55 N.L.	Equator	55 N.L.	Equator	55 N.L.
SEA LEVEL	.143	.147	.076	.080	.053	.057
5,000′	.150	.170	.083	.103	—	—
10,000′	.190	.230	.123	.163	—	—

Significant differences in radiation at different zones of the earth prevailed long before man's emergence as a *sapiens* species. If it is true, as Crow states, that "*radiation-induced mutations increase almost exactly in proportion to the radiation dose*" (his italics), then these spatial differences should have influenced evolution by determining the degree of radiation and hence the rates of mutation of the various races.[8]

Specifically, *man's exposure to radiation and hence his rate of mutation over the ages must have varied inversely with his distance from the magnetic poles and directly with his altitude above sea-level.* Hence, the mutational stimulus should have been greatest among races inhabiting the mountains, the high plateaus and the poleward zones (such as Mongoloids and Caucasoids), and least among the ethnic groups shaped by lowland tropical environments (such as the Negroids, Australoids and Bushmanoids). To the extent that petrology affects this picture, it serves primarily to increase mutation rates among mountain folk since granites and other igneous rocks are generally associated with mountain formation.

A high mutation rate in one environment may be more than offset by the presence of conditions adverse to their survival. Clearly, the profusion of varieties and species is more lavish in tropical than in temperate zones. Ernst Mayr observes that, while a temperate forest may be inhabited by 60 species of birds, the Amazonian jungle will provide a habitat for 600. Similarly, tropical Amboina in the Moluccas has 780 species of fish in its harbor, more than any other sea-coast community. In searching for an explanation, Mayr suggests that "the rarity or short

[6] *Fallout,* Vol. II, p. 1768.

[7] *Ibid.,* p. 1460.

[8] James F. Crow, "The Estimation of Spontaneous and Radiation-induced Mutation Rates in Man," *Eugenics Quarterly,* Vol. III, No. 4, December 1956, p. 205.

duration of weather-induced catastrophes in the tropics" may permit a contraction in niche size.[9] He adds that the matter remains somewhat enigmatic.

Genetic Aspects. Various estimates have been made of the effectiveness of radiation as a stimulus to mutation. Dr Hermann J. Muller estimated that "exposure to about 40r produces as many mutations as arise spontaneously."[10] In a 1956 article, Dr James F. Crow utilized data from consanguineous marriages to devise a method of estimate somewhat different from that of Muller. Crow concluded that, if human beings reacted as mice do, the dosage needed to double mutations would be about 60r. He added that "both the British and American committees independently and perhaps fortuitously chose the interval 30-80r as the range within which the doubling dosage might reasonably be expected to lie."[11]

Using Libby's data, we find that the additional radiation dosage obtained by living at 55 degrees North Latitude instead of on the Equator varies from 4mr/year (4 thousandths of a roentgen per year) at sea-level to between 10 and 20mr/year at 5,000 feet, depending on rock cover. We shall take 6mr/year as representative.

The additional dosage obtained by living at 5,000 feet altitude as against sea-level is from 7 to 13mr/year when the prevailing formation is sedimentary, as is generally the case. We shall assume the average to be 10mr/year.

Finally, the difference in radiation between granite and sedimentary rock is about 50mr/year.

These differences are all small, but they become massive when the radiation dosage is continued over many thousands of years. Radiation effect on the germ cells is cumulative and independent of the rate of delivery. As Wallace and Dobzhansky[12] put the matter:

> The number of mutations induced by a given number of roentgens is the same regardless of whether the exposure is short or long. The same number of roentgens may also be

[9] Ernst Mayr, *Animal Species and Evolution,* Belknap Press of Harvard University, Cambridge, 1963, p. 88.

[10] Hermann J. Muller, "Comments on the Genetic Effects of Radiation on Human Populations," *Journal of Heredity,* Vol. XLVI, No. 5, September-October 1955, pp. 199-200. Reprinted in Muller, *Studies in Genetics,* Indiana University Press, Bloomington, 1962, p. 585.

[11] Crow, *op. cit.,* p. 208. The committees referred to are probably: British Medical Research Council, *The Hazards to Man of Nuclear and Allied Radiations,* Her Majesty's Stationery Office, London, 1956, and National Academy of Sciences, National Research Council, *The Biological Effects of Atomic Radiation,* Washington, 1956.

[12] Wallace and Dobzhansky, *op. cit.,* pp. 87-88.

> delivered in a contious exposure or in several bursts interspersed with periods of "rest." The manner of delivery is, in general, unimportant as far as the number of mutations induced is concerned.
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> It is easy to see what this means to man. Genetic radiation damage is an insidious thing: very small radiation exposures add up, and if continued for years may amount to as much as, or more than, an accidental brief exposure to intense radiation. Since genetic damage is cumulative, no radiation increment, however small and insignificant by itself, can be neglected. What matters is the total exposure up to the close of the reproductive or childbearing age.

Crow stated recently that "the amount of genetic harm done is strictly proportional to the radiation dose."[13] H. J. Muller[14] and the National Academy of Sciences, National Research Council,[15] have expressed the same view.

The denizens of sea-level lands at 55 degrees North Latitude would acquire a radiation dosage over and above that of similarly situated persons on the Equator sufficient to double their mutation rate after 10,000 years. In the case of the inhabitants of high land (5,000 feet), as compared with those living at sea-level, the doubling time would be about 6,000 years. For the people living on granite, the doubling time would be about 1,200 years.

When we consider these processes of differential radiation exposure as persisting over the tens of thousands of years during which the different races and subraces of man occupied approximately their present climatic and altitude bands, then the variations in evolutionary pace appear to be highly significant. If our hypotheses are correct, we should expect a considerably greater degree of biogenetic uniformity among Australoids, Negroids and Bushmanoids than among the white and yellow races. Correspondingly, other things remaining equal, the tempi of evolution should have been swifter among the Caucasoids and Mongoloids.

It may be objected that these differentials in radiation should have produced "millions of hopeless monsters"[16] among the light-skinned races; yet such products of mutational deformation are not present *en masse*. Under normal ecological conditions, about 20 per cent of all mutations are believed to be lethal. The harsher the environment, the more relentless the processes of biological

[13] "Possible Consequences of an Increased Mutation Rate," *Eugenics Quarterly*, Vol. IV, No. 2, June 1957.

[14] In *Bull. Atomic Scientists*, Vol. XI, pp. 329-338, 352.

[15] *The Biological Effects of Atomic Radiation*, *op. cit.*

[16] Mayr, *op. cit.*, p. 438.

winnowing. Mutations which are harmful, but not absolutely lethal, will usually lessen the survival and reproduction chances of those who bear them.[17] When natural radiation continuously injects detrimental mutations into the gene population, a point is eventually reached (and this can be expressed in simple algebraic equations) at which there is equilibrium between mutation inflow (from radiation) and mutation outflow (from higher death rate).[18]

The elimination of the most genetically damaged individuals by death should not as a rule impose any special handicap on the small minority which bears those few mutations that improve the ability of the organism to cope with its environment. To be sure, these individuals belong to a race or population which bears a more-than-average load of detrimental mutations and which might hence be subjugated, dispersed, conquered or killed by those bearing a lesser one. However, the penalty of a heavy mutational load may be counterbalanced by a more rapid evolution toward environmental mastery. Furthermore, these different races are normally allopatric.

The hypotheses here advanced contribute additional possible causes for the torpor of the Tropics and the sluggish evolutionary pace of the three primarily tropical races. As to the significance of these factors in the cerebral progress of man from apery to civilization-building, a crucial issue is the respective rôles of mutation and genetic recombination in shaping the evolution of those animals which reproduce sexually.

[17] An important exception is when the gene is lethal or severely damaging when homozygous, but protective when heterozygous. One of the best known examples is the gene which causes sickle cell anemia when homozygous, but which protects against malaria when heterozygous.

[18] Wallace and Dobzhansky, *op. cit.*, pp. 130-136.

THE ANTHROPOLOGICAL STRUCTURE OF THE POPULATION OF SCHWALM

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TRANSLATED FROM THE GERMAN BY DONALD A. SWAN

This short article is concerned with the anthropological structure of the population of Schwalm, Germany, which was the subject of a heredito-biological investigation by Dr Schade in 1940.[1]

Schwalm, which is located between Marburg and Kassel in West Germany, is thickly surrounded by forests, and by the Knull mountains in the east and branches of the Keller mountains in the west. Dr Schade writes: "The population is marked by distinctive cultural traits and is molded by the milieu into a specific type." In this investigation the mean values of the anthropological traits of 483 men and 454 women were calculated. From his anthropological analysis Dr Schade concluded that the population in this region was predominantly Faelic-Nordic.* There was also to be observed in this population an Alpine as well as a Mediterranean strain. Unfortunately nothing was stated about the origin of this unique population group. It is possible that in this case we are concerned with isolating processes, which are caused in paricular by the unique geographical location.

The arithmetical mean values of the Schwalmian population are given as follows:

ANTHROPOLOGICAL TRAIT	MEN N=483	WOMEN N=454
Stature	167.8 (N=450)	156.4 (N=408)
Cephalic Index	82.6	83.4
Morphological Facial Index	86.7	85.2
Nasal Index	60.3	61.1
Eye Color 1-6 (Martin-Schulz)	70.1% (N=447)	68.1% (N=423)
Hair Color A-O (Fischer-Saller)	27.4% (N=447)	26.2% (N=423)

The arithmetical mean values characterize a population group quite well. I have therefore attempted to determine the racial structure of the population according to Wanke's approximation

[1] Schade. H., 1940, "Anthropologische Befunde bei einer erbbiologischen Bestandsaufnahme in der Schwalm," *Verhandlung der Gesellschaft für Rassenforschung,* Vol. X, pp. 36-39.

* "Faelic" is the same as "Atlantic" as usually used in English.—EDITOR.