Introduction: P.C. Mahalanobis and the Symposium on Frontiers of Anthropology

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The year 1993 marked the birth centenary of Prasanta Chandra Mahalanobis, the founder of the Indian Statistical Institute. Mahalanobis integrated into the Institute a large number of disciplines so that active interaction between statistics as a key technology and other sciences could take place under one umbrella. The Institute organized a series of lectures and conferences in different disciplines during 1992–1993 to commemorate the birth centenary of Professor Mahalanobis. Mahalanobis made some fundamental contributions to anthropology during the field's formative period. It is indeed a great coincidence that the silver jubilee of the Anthropometry and Human Genetics Unit, whose conception and birth are owed largely to this visionary, fell in his centenary year. It was therefore fitting that the Symposium on Frontiers of Anthropology (held December 8–11, 1993) was organized to get an overview of the present state of anthropological research in India. Altogether 40 scientists were invited from different parts of the country to deliver lectures and to contribute papers in different areas of anthropology and human genetics.

The conference began with the Mahalanobis Centenary Lecture, delivered by Madhav Gadgil of the Centre for Ecological Sciences, Indian Institute of Science, Bangalore, who spoke on the peopling of the Indian subcontinent, the interpretations based on the demographic history, and the mitochondrial DNA evidence. This was followed by a special lecture by Ramkrishna Mukherjee on the history and development of anthropological thought.

Commensurate with Mahalanobis's deep interest in human population structure and variation, the next two days of the conference were devoted to papers on this theme. Wide-ranging issues such as sampling methods in anthropology, demographic aspects and anthropometric variation among Indian populations, and genetic affinities among Sri Lankan populations were discussed. In line with Mahalanobis's other interests and the current research activities of the Anthropometry and Human Genetics Unit, the remaining two days were devoted to scientific papers and lectures in the areas of genetics, epidemiology, health and nutrition, and human ecology and adaptation. Pa-

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pers dealing with linkage studies of autosomal prelingual deafness, genetic epidemiology of blood pressure, dental pathology as an indicator of physiological stress in ancient populations, sickle cell hemoglobinopathies, etc. were also presented.

The four papers published here to honor the memory of Mahalanobis are a representative selection of the invited presentations at the conference. From the remaining papers, mostly contributed, 11 more will be published as a special issue of the *Journal of the Indian Anthropological Society.*

Mahalanobis was born on June 29, 1893, in Calcutta, India. He graduated with honors in physics from Presidency College, Calcutta, in 1912. After completing his tripos in mathematics and physics at Kings College, Cambridge University (1915), Mahalanobis was awarded a research fellowship to work with C.T.R. Wilson (of cloud chamber fame) at the Cavendish Laboratory. A couple of events after this were instrumental in transforming Mahalanobis the physicist into Mahalanobis the statistician. Before starting his research work in physics, Mahalanobis decided to return to India for a short vacation. Just before he left England, Mahalanobis was casually shown the journal *Biometrika* by his tutor W.H. Macaulay. Mahalanobis found the journal of interest and purchased an entire set. This action played a decisive role in pushing him toward biometry in later years.

Mahalanobis found many things in India to hold his interest. Moreover, World War I had begun. He therefore decided not to return to England to pursue research in physics. Early in this phase he was deeply influenced by his mentors. Among them, Rabindranath Tagore, a close family friend with whom he had worked as secretary of Visva-Bharati, encouraged him to pursue a scientific career in lieu of government service and later to establish the Statistical Laboratory and the Indian Statistical Institute. Another of his mentors, Acharya Brojendranath Seal, said to him, "You have to do work in India similar to that of Karl Pearson in England. In today's world, whether it is science or social service, without statistical methods there is no way. This is your job" (translated by P.P. Majumder from a note in Bengali, written by P.C. Mahalanobis, dated April 17, 1945). Mahalanobis accepted this challenge seriously and began to critically read Karl Pearson's papers in *Biometrika,* which laid the foundations of Mahalanobis's lasting interest in biometry. Subsequently, Mahalanobis made profound contributions to this field.

The first opportunity came his way during the annual meeting of the Indian Science Congress Association at Nagpur in 1920. Mahalanobis met Nelson Annandale, the Director of the Zoological and Anthropological Survey of India, who asked Mahalanobis to analyze some anthropometric data on a group of Anglo-Indians from Calcutta. Mahalanobis analyzed the data and published a paper titled "Anthropological Observations on the Anglo-Indians of Calcutta, I, Analysis of male stature" (Mahalanobis 1922). In this paper, which happened to be his first paper in statistics, Mahalanobis proposed

a rough measure of interpopulation distance and concluded that stature decreases with declining caste status.

Mahalanobis continued to analyze the other anthropometric measurements on this Anglo-Indian sample and presented a synthesis of results in his Presidential Address to the Anthropology and Archaeology Section of the Indian Science Congress in 1925. In his address, "Analysis of Race-Mixture in Bengal" (Mahalanobis 1927), Mahalanobis posed several pointed anthropological questions and sought to provide statistical answers to them. For example, do Anglo-Indians show greater affinity with the higher castes of Bengal or with the lower castes? Is there any appreciable admixture with aboriginal tribes? To answer such questions, one needed a measure of distance between population groups based on anthropometric measurements. Karl Pearson's coefficient of racial likeness, popularly known as CRL, was the only available statistic then for comparing resemblance between populations. Realizing that CRL was a test of divergence between samples drawn from two populations rather than a measure of actual magnitude of the divergence, Mahalanobis proposed and used a measure of actual magnitude of divergence, which he called the "first (provisional) measure of caste distance," D. Mahalanobis proposed another "theoretically preferable" distance, D', along with publication of his Presidential Address (Mahalanobis 1927). The inferences derived in this study have been found to be largely valid from his own work conducted later in the United Provinces (Mahalanobis et al. 1949) and from the research of Majumder and Rao (1960) in Bengal and others using more extensive data and more sophisticated statistical techniques. Some of the salient observations made in those later studies of the United Provinces and Bengal are that different castes of the same region are more similar to each other than different subgroups of the same caste inhabiting different regions. This observation made untenable the then prevalent notion that castes, clearly isolated social groups, were distinguishable by racial criteria.

Mahalanobis undertook an extensive analysis of anthropometric data of various European population groups during his 6-month stay (1926–1927) at Karl Pearson's laboratory at University College, London. While examining the utility of CRL for measuring population relationships, Mahalanobis realized the statistical shortcomings of this method. Mahalanobis's ideas on the problem of incorporating the observed correlations into the anthropometric measurements used in computing the distance took more concrete form. He published a seminal paper, "On Tests and Measures of Group Divergence" in 1930 in which the famous D^2 statistic was proposed (Mahalanobis 1930a). Mahalanobis published another paper in *Biometrika* in the same year (Mahalanobis 1930b) based on his work in Pearson's laboratory and dealing with populations of Sweden. This paper was the first application of CRL to the discrimination of ethnic differences to be ascertained from measurements on the living. Mahalanobis presented some innovative graphical displays of anthropometric interrelationships among the populations, taking two additional

extrinsic variables into account: geographic location of the habitat and occupation. This gave rise to the concept of forming clusters of populations.

Mahalanobis subsequently proposed the natural generalized distance D^2 for correlated variables and its Studentized form using sample values of parameters (Mahalanobis 1936a). The practical impact of the D^2 statistic is enormous and continues to be used in all branches of science. It is indeed through this measure of distance that Mahalanobis is known to the scientific community all over the world.

Mahalanobis did not stop with simply providing a tool (D^2) for cluster analysis. He raised fundamental issues about the application of the D^2 statistic and argued that inferences about affinities among populations may depend on the number of measurements chosen for assessing distance between populations; distance configurations can change if one set of measurements is replaced by another, hence leading to conclusions that have no desired practical significance. Thus Mahalanobis laid down an important axiom for the validity of cluster analysis: dimensional convergence of D^2 (Mahalanobis 1937). The formulation of the D^2 statistic, derivation of its properties, and its applications are undoubtedly the most profound contributions Mahalanobis made to biometry. However, Mahalanobis made many other contributions. He reconstructed and revised Risley's large series of anthropometric data that was earlier condemned as faulty and unsuitable for statistical analysis (Mahalanobis 1933b, 1934b). This revision was highly praised by Fisher (Rao 1974), who visited the Indian Statistical Institute many times.

In one of his early papers (Mahalanobis 1928), Mahalanobis also argued for standardization of anthropometric measurements. He undertook a systematic comparison of different definitions of anthropometric measurements based on data published by 10 eminent anthropologists and found a lack of agreement in definitions and techniques. Mahalanobis concluded that the lack of agreement between observers constitutes an insurmountable obstacle to comparative studies in anthropology of the living, making much of the then existing anthropometric data useless. He appealed to the community of anthropologists to convene another international conference to agree on a more satisfactory set of standards than those of the 1906 agreement, already in place but generally not adhered to.

Mahalanobis's pioneering research and his keenness in anthropometric investigations led to the founding of the Anthropometry Unit at the Indian Statistical Institute in 1963. The hematology unit was already in existence (since 1960) and was sustaining inquiries into the characteristics of populations in terms of blood groups and cross-checks of the inferences obtained from anthropometric measurements that had been collected earlier during a Bengal study (Majumdar and Rao 1960). These units were later (1968) merged to form the present Anthropometry and Human Genetics Unit.

Apart from anthropometric studies Mahalanobis conducted many other interesting investigations, for example, maternal death rates and proportion

of stillbirths in Calcutta and in Bengal (Mahalanobis 1933a, 1934a), hospital records of delivery cases in Calcutta (Mahalanobis 1935b), fertility rates based on sample surveys (Mahalanobis 1940), growth projections for the Indian population (Mahalanobis 1937), distribution of Muslims in the Indian population (Mahalanobis 1946), hematological parameters of newborns (Mahalanobis 1935a), measurement of blood pressure (Mahalanobis 1936b), and nutrition among college students of Calcutta (Mahalanobis 1941). In many of these studies Mahalanobis developed novel statistical methods or made innovative applications of known methods. For example, in one of his early statistical studies on prevalence of dysentery and its correlates, Mahalanobis (1926) developed some useful smoothing techniques for time-series data using Fourier series. Such techniques are now commonly used.

Mahalanobis made many significant and lasting contributions in other areas of statistics, for example, to large-scale sample surveys. He was responsible for many other pioneering efforts, such as the statistical quality control movement in India, founding of the Central Statistical Organization and National Sample Survey Organization, and acquiring the first digital computer in India.

Mahalanobis also worked for promotion of international understanding and collaboration in scientific research. He established contacts with scientific associations and individual scientists abroad and negotiated for exchange of scientists and collaboration in research projects. As Foreign Secretary of the Indian Science Congress, he succeeded in attracting top-ranking scientists from all over the world to participate in the annual sessions and to make short visits to research institutes in India. Under his initiative the Indian Statistical Institute grew to be a meeting place of renowned scientists from all over the world. The late J.B.S. Haldane and Helen Spurway joined the Institute as faculty members in 1957. Norbert Weiner spent 6 months working at the Institute. Ronald Fisher, A.N. Kolmogorav, Harold Hotelling, and many others visited periodically. Because of these efforts, the Indian Statistical Institute grew into an internationally renowned scientific institution.

For his outstanding contributions, Mahalanobis was bestowed with many honors and awards. Notable among those are the Weldon Medal of Oxford University (1944), Fellowship of the Royal Society, London (1945), Presidencies of the Indian National Science Academy and the International Statistical Institute (1957), Foreign Membership of the USSR Academy of Sciences (1958), the Ramanujan Gold Medal of the Indian Academy of Science (1968), the Padma Vibhushan by the President of India, and the Deshikottama of Visva-Bharati (1961).

As a scientist Mahalanobis was above all a great applied statistician. He believed that theory grows out of a practical need and thus influences subsequent practical work. Innovation, systematization, and concrete application are the hallmarks of the applied statistics practiced by Mahalanobis (Ghosh and Majumder 1995).

We take this opportunity to thank all our colleagues at the Anthropometry and Human Genetics Unit and others at the Indian Statistical Institute who helped us to organize the conference honoring P.C. Mahalanobis.

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