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Researching malaria in the developing world

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I was born and brought up in Secunderabad in a middle-class family that valued education highly. My parents were formally educated only up to middle school, but they gave all six of their children the best education. In the early 1960's, when girls in our community were not even allowed to get a bachelor's degree, my father encouraged me to join the master's degree course and supported me financially.

My career in science started at the undergraduate level, where I had three majors—botany, chemistry and zoology. Organic chemistry was my favourite subject and zoology my least favorite as it involved animal dissections. Ironically, I had the highest score in zoology and I got into the M.Sc. zoology programme. I graduated in 1964 with a specialization in helminthology. My formal exposure to genetics was in the final year of my undergraduate studies. I was fascinated by Mendel's Laws of Inheritance and their predictability on the phenotypic characters in the progeny and the double helical structure of DNA that is responsible for the systematic inheritance of characters from parents to progeny. It was around the same time that the Nobel Prize in Physiology or

Medicine was awarded to Watson, Crick and Wilkins for unraveling the structure of DNA. All these factors put together made a lasting impression on me and inspired me to study genetics further, though the opportunity to do so did not present itself immediately. After my M.Sc. I taught zoology to undergraduates at Osmania University, Hyderabad.

In 1967, I got married and went to America with my husband. There I got a chance to work with Professor John R. Laughnan, a distinguished corn geneticist. The topic of my doctoral degree dissertation was "The nature and sensitivity of breaksites in the long duplication of X-chromosome following X-irradiation". Cytological analysis of the exceptional offspring from stable line after X-irradiation indicated that the breaksites corresponded to those that occurred in exceptional offspring produced spontaneously in related unstable lines. This finding supported the hypothesis that the breaksites were heterochromatic in nature. The difference in the unstable/stable strains in producing exceptional strains was considered quantitative rather than qualitative, that is, the amount of heterochromatin present at the breaksites. Today this phenomenon may be best explained by involving the role of transposable elements.

Our first daughter was born in 1970. It is after she was born that all my experimental work for the dissertation was done. I obtained my doctoral degree in Genetics in 1973 from the University of Illinois, Urbana-Champaign.

Soon after we returned to India, I got an Insect Geneticist's post in 1974 in a World Health Organization (WHO)-Indian Council of Medical Research (ICMR) funded *Genetic Control of Mosquitoes* project in New Delhi, where I worked on *Culex quinquefaciatus*, a filaria vector, to resolve the variations seen in the cytoplasmic incompatibility/compatibility between Indian and European strains of this species. My research in malaria started in 1975 when the project staff was shifted to the newly-established ICMR institute - Malaria Research Centre (MRC), Delhi. I worked on genetics of phenotypic and biochemical markers for inheritance pattern and linkage analyses, chromosomal aberrations, insecticide resistance patterns etc. in malaria vectors and polymor-

phism in malaria parasite antigens.

My major contribution to malaria entomology has been unraveling the unique biological/taxonomical phenomenon prevalent among anopheline species i.e. identification of morphologically similar but reproductively isolated biological species within morphological taxa. Using genetic and cytological analyses, five sibling species in *Anopheles culicifacies* and three species in *Anopheles fluviatilis* were identified while in *Anopheles stephensi* only ecological variants were found. These three malaria vectors together transmit to about 90 percent of malaria in India. Our extensive field studies have shown that the sibling species have distinct distribution pattern in India. Furthermore, variations were found in resting habits, feeding time and place of feeding, preference to feed on human or animal hosts, susceptibility to malaria parasites, malaria transmission potential and response to insecticides etc. among the sibling species.

These variations suggested that malaria control strategies have to be planned carefully based on the prevalence of sibling species in an area. The identification method used for the sibling species to study the biological variations was species specific diagnostic inversions readable on polytene chromosomes. But there was a need to develop simpler diagnostic assays for field use in malaria control programmes. This need has necessitated the establishment of biochemical- and molecular-genetic laboratories at MRC, and simpler PCR-based diagnostic assays have been developed.

The opportunity to lead research that is relevant to the national health program has been very gratifying. Twenty-five years of research in this area have given me an opportunity to train and guide younger colleagues and research fellows, many of whom have obtained doctoral degrees, and also post-doctoral fellows. In recognition of this research, the World Health Organization (WHO) designated the Malaria Research Center a "WHO Regional Reference Center for the Identification of *Anopheles culicifaces* and Intra-specific Variations". I was also awarded the M.O.T. Ayengar Memorial Award of the Indian Council of Medical Research for Malaria Research.

Though my research has been appreciated and supported by colleagues and superiors, day-to-day difficulties when carrying out research were annoying. It was not easy to accomplish research objectives maintaining research standards. Organizing and planning in the lab, procedural delays in getting reagents, lack of optimal infrastructure, frequent power breakdowns that led to wiping out of mosquito colonies that we reared for years were all a part of day-to-day problems. I had to put in long hours not only in the lab but also at home while taking care of growing children, who had many needs even though they were very cooperative. It was my strong desire to continue research that is of social relevance, cooperation of the supporting staff at the lab and of the family at home that helped me achieve my research objectives. I must also add that never was I discriminated against in my career because I am a woman.

In retrospect, I can now say that I do not regret having declined job offers that I had in the Unites States in 1973, when I decided to come back to India to pursue research.

From 1975 to 2003, I worked at the Malaria Research Centre, retiring as Director. I am a Fellow of the National Academy of Sciences, Allahabad; Indian National Science Academy, New Delhi, and the Indian Society for Malaria and other Communicable Diseases.