

occasion to meet with Dr. Livio Raggi for whom I had a small gift sent by my veterinary medicine professor in India who had met Dr. Raggi during his visit to the U.S.A. Meeting Dr. Raggi was a notable event in my professional life. He invited me to join his laboratory where I began graduate training in avian medicine.

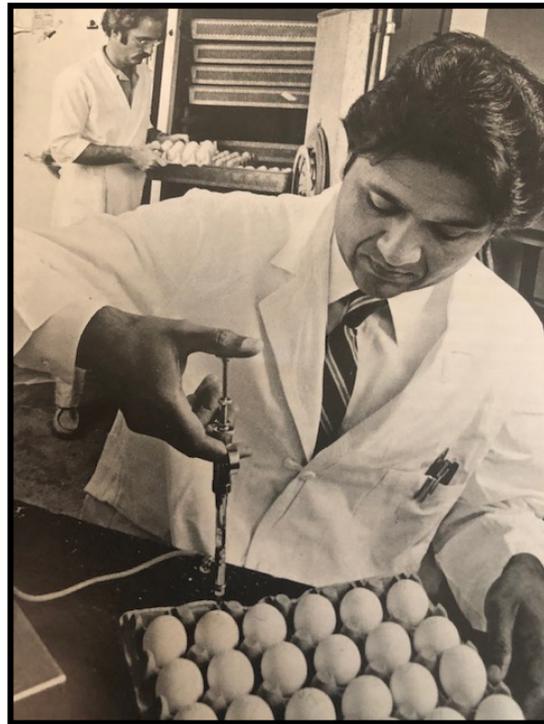
While in Davis, I met a very beautiful undergraduate coed and in 1919, Sylvia and I celebrated our 50th wedding anniversary. Our son, Dave, lives in Chandler, AZ and daughter, Susan, in Colorado Springs, CO. We have three grandsons, Dylan, Simon and Ryan. I have been blessed with unconditional support of my family in all aspects of my life.

After earning a Masters and a Ph.D. from the University of California, I spent four years as a post-doc at Washington State University, Pullman. My first job was with the United States Department of Agriculture in East Lansing, Michigan as a Veterinary Medical Officer at the Regional Poultry Research Laboratory, now called Avian Disease and Oncology Laboratory (ADOL).

ADOL

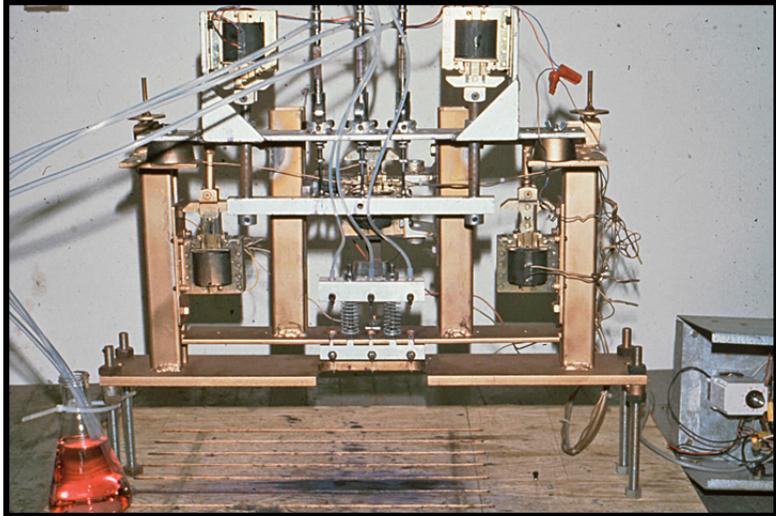
In East Lansing, I joined a group of scientists engaged in cutting edge research on avian tumor viruses. The ADOL had several inbred genetic lines of chickens, a rare and valuable tool in avian research. One of the genetic lines, Line 6, was highly resistant to Marek's disease (MD) in comparison to Line 7 which was highly susceptible. My first project at ADOL was to explore the possible mechanisms behind resistance. This project initiated my interest in the avian immune system and its role in neoplastic and non-neoplastic viral disease pathogenesis, the disciplines that dominated my entire research career. There was a great sense of collaboration and team building among scientists at ADOL. I flourished in this environment all through my stay, first under Ben Burmester's leadership and subsequently when Dick Witter became director. The collegial work environment, mutual respect and healthy competition among scientists distinguished ADOL as a reputable research laboratory in its field. During my 17-year tenure at ADOL, one of my most exciting and impactful projects was the discovery of the *in ovo* vaccination system.

IN OVO VACCINATION



Jagdev Sharma injecting HVT in 18-day embryonating eggs to test the concept of *in ovo* vaccination under laboratory conditions. Laboratory Technician Barry Coulson standing next to the incubator provided valuable assistance in all aspects of the laboratory work.

Although the epornitics of MD that had plagued the industry for decades were under control by widespread usage of protective vaccines, some flocks continued to experience excessive losses due to early post-hatch exposure to the virus. As an industry practice, vaccines containing turkey herpesvirus (HVT) were administered at hatch, however within hours of vaccination, chicks were placed in heavily contaminated houses. Newly vaccinated chicks



A prototype of an egg-injection machine developed at ADOL by a team comprising Tim Caswell, Brian Doyle (both from the maintenance staff) and Jagdev Sharma. This prototype simultaneously injected three eggs on the push of a button.

were exposed to the virulent virus in the environment well before the vaccines had adequate time to establish protective immunity. We had long discussions at ADOL in an attempt to find a solution to protect chickens against early exposure, without success.

In my Ph.D. thesis research, I regularly propagated infectious layngotracheitis virus, an avian herpesvirus, in embryonating chicken eggs. I also published a paper at ADOL on the propagation of HVT and MD virus (MDV), two serologically related herpes viruses, in embryonated chicken eggs. However, in graduate school or at ADOL, I did not examine the chicks that hatched from virus-exposed eggs. The unanswered questions were: a) would HVT, which is non-pathogenic for hatched chickens also be non-pathogenic for developing embryos and allow the chicks to hatch and live normally? And b) could it also be possible that as the virus replicates in the embryo, it also stimulates the developing immune system of the embryo and mounts a protective immune response? These questions prompted me to conduct the first preliminary trial.

I injected HVT in 18-day-old embryonated eggs of Line 7. The 18th day was chosen because previous studies had shown that by this day of embryonal development, most of the functional immune system was in place.

The eggs inoculated with HVT hatched at about the same rate as the uninoculated eggs. However, about a week later, as I came to work in the morning, I was notified that my chicks were dying. The obvious conclusions from this trial was that *in ovo* exposure to HVT was not safe. Even though virus-exposed chicks hatched, they did not survive. This result was not totally unexpected. I continued working on other ongoing projects. Yet, the unsuccessful *in ovo* experiment stayed on my mind. Had I missed something important in designing the trial? As I repeatedly examined the design, I began to question the suitability of using eggs from a genetic line of chickens with such an extreme susceptibility

to MDV as Line 7. Was it justified to spend additional resources in time and money to repeat the trial in eggs of a different genetic background? I wrestled with this decision for a while before repeating the trial using eggs from a cross between Lines 15 and 7. Chickens from this cross were susceptible to MDV but not nearly as susceptible as those from Line 7. The decision to modify the experimental design and repeat an unsuccessful preliminary trial was pivotal in the successful development of the *in ovo* vaccination system for poultry.

The repeat trial with Line 15x7 eggs was successful beyond all expectations. The HVT-exposed eggs hatched, the chicks survived and were resistant to a challenge as neonates with virulent MDV. We had succeeded in finding a solution to the difficult problem of protecting chicks against an early environmental exposure to MDV.

Following the success of the initial trials, my laboratory redoubled efforts to examine various scientific and practical aspects of the *in ovo* vaccination system. To visualize the potential practical application of the technology in hatcheries, we developed a prototype of an automatic egg injection machine (see photo). This prototype was used in some of the follow-up laboratory trials on *in ovo* vaccination. We published a number of scientific papers to provide proof of the concept of the technology and I became convinced that the technology was suitable for potential practical application. In cooperation with industry colleagues, we conducted successful field trials in which HVT was manually injected in 17- or 18-day embryonated eggs and hatched chicks were raised under field conditions. The results of these trials and our laboratory data prompted me to initiate concerted efforts to transfer the technology to the market place. I contacted major poultry companies by mail and personal visits to explain the potential benefits of the *in ovo* technology.

One afternoon, Harold Smith, an entrepreneur from California, arrived in my office at ADOL. He said, "Dr. Sharma, I have read your papers and would like to start a company to sell your technology." This was the start of Embrex. The rest is history.

However, as it turned out, the robust acceptance by industry of the *in ovo* technology was not necessarily to solve the early MDV exposure problem. There were other more attractive benefits such as savings in the labor cost of MD vaccine administration and simultaneous immunization against multiple agents.

The *in ovo* vaccination delivery system, automated by machines developed by private entrepreneurs, is being used to immunize over 90% of the 10 billion broilers produced annually in the U.S.A. Major hatcheries practice *in ovo* vaccination as a standard protocol for health management of commercial chicken flocks in over 38 countries, covering six continents. This technology transfer reduces the cost of poultry products at the grocery store.

Ben Burmester and I had many discussions over the data of the preliminary trials. These discussions were helpful as I remained focused on pursuing an idea potentially beneficial to the poultry industry. He was a co-author on the first publication and the USDA patent application. The patent on *in ovo* vaccination was granted in 1984. Several years later, I was notified that this patent was one of the most lucrative USDA patents. In 2000, I secured another patent showing it was possible to use an *in ovo* vaccine containing a mixture of

five infectious agents. The hatched chickens developed a protective immune response against each of the five agents.

THE AMERICAN ASSOCIATION OF AVIAN PATHOLOGISTS (AAAP)

While in graduate school at Davis, I applied for membership in the AAAP. My application was denied. I am grateful that my second attempt, a year later, was successful. The AAAP has been the backbone of my professional development. I have served as a member or chair of a number of committees, on the board of directors and as AAAP president. From 2003 to 2013, I was Editor of *Avian Diseases*, an international peer-reviewed scientific journal published quarterly. I began my tenure as Editor at the advent of the digital age in publishing. During the first year of editorship, office manager Dr. Sylvia Sharma and I initiated the transition of *Avian Diseases* from hard copy to online submission and review. This switch reduced the lag period between submission and publication of the articles. I also established a 5-member *Avian Diseases* Advisory Board to: Develop a mission statement for the journal, update the journal format, initiate policies to enhance the impact factor and address occasional problems and disputes. *Avian Diseases* is the official journal of the AAAP and all modifications had to be preapproved by the AAAP Board. I found the AAAP Board to be most cooperative and receptive to the changes in the journal. My proposal to initiate a lay-oriented companion journal, *Avian Diseases Digest*, was approved. This journal published in lay language summaries of each scientific article published in *Avian Diseases*. The aim was to share latest scientific developments with non-scientific avian community. After several years, the publication of *Avian Diseases Digest* was discontinued.



Two age-matched scavenging chickens. Left: Kuroiler; Right: Local backyard chicken.

ACADEMIA AND AFRICA

In the summer of 1988, I joined the University of Minnesota as the Benjamin Pomeroy Endowed Chair in Avian Health, the first Chair of its kind in the world. Joining the University of Minnesota enabled me to run an active research laboratory on diverse areas of avian medicine, mentor graduate students, teach in the veterinary curriculum and interact with the Minnesota industry leaders and state legislators. In 2009, I retired from the university and was named Professor Emeritus. The same year, I joined the Arizona State University (ASU) in Tempe, AZ as Research Professor in the Biodesign Institute and Visiting Professor of Life Sciences in the School of Life Sciences.

At ASU, with the support of the faculty, most notably Roy Curtiss III, I initiated a project aimed at reducing poverty and improve the quality of life for rural households in Uganda. The approach was to enhance backyard poultry production and empower women. As in most counties in Africa, over 85% of the Ugandan population resides in villages. Small-scale poultry production in rural households managed largely by women is one of the most efficient and sustainable farming systems designed to meet the

increasing demand of food in the country. Backyard farming also provides a socially acceptable means for women to generate income and improve social standing in their communities.

Local chickens used most commonly in backyard flocks in Africa usually perform poorly. An average hen lays approximately 40 eggs per year and a typical year-old male chicken has a live weight of between 1.5-2.5 kg. In addition, because of poor disease control, the flock mortality rates can often reach 80%. The poor level of production coupled with the small size of flocks, usually comprising 5-20 chickens, are often unable to meet the nutritional and economic needs of an average family.

In our project, with generous grants from the Bill and Melinda Gates Foundation, we introduced in rural family flocks a high performance hybrid chicken called Kuroiler. This chicken, commercially available in India, is a low-maintenance, highly productive scavenger that thrives in African environments. Kuroiler chickens produce nearly five times the number of eggs per year and attain almost twice the body weight in less than half the time of local chickens. During the 7-year duration of the Kuroiler project, we established local breeding stocks, developed marketing and distributions systems and placed vaccinated Kuroilers in 142,000 rural households. In addition, we held seven empowerment workshops for women and youth in different locations in the country and developed a 20-minute video outlining the important role women play in rural agriculture. Follow-up project evaluation indicated that the households raising Kuroilers experienced improved nutrition and family income. Currently, the Kuroiler production and distribution are being continued by the government and private entrepreneurs with an estimated yearly production of 2 million Kuroilers in Uganda and additional production in other African countries including Nigeria, Ethiopia, Tanzania, Rwanda and Kenya.

REFLECTIONS

I have had a stimulating and rewarding journey. A career in avian medicine gave me opportunities to occupy an Endowed Chair at a major university, conduct research, mentor students and scientists, teach, serve as Editor of a peer-reviewed scientific journal, interact with scientific community and industry leaders and use my professional background to work toward reducing poverty in rural Africa. In addition, I have traveled the world and met wonderful people resulting in many lasting friendships. I have five patents and published 192 articles in peer-reviewed scientific journals, 75 proceedings articles and



The staff of Chick Masters Ltd., the company that is currently producing and distributing Kuroilers in Uganda and other African countries. The owners, Dr. and Mrs. H. Kaaya are third and fourth from right.

225 abstracts. My awards include the Upjohn Achievement Award, AVMA Council of Research Award for Excellence in Poultry Research, Calnek Applied Poultry Research Achievement Award, Life Membership in the AAAP, Avian *Diseases* Editor's Award and the University of Minnesota's Mark of Excellence and Recognition of Excellence Awards. In 2013, I was inducted in the Hall of Honour of the World Veterinary Poultry Association and in 2016, in the Hall of Honor of the AAAP. For someone leaving his comfort zone and taking a chance to follow a dream in a new country, the results are most satisfying. My journey has been sustained by people I came in contact with along the way who supported and inspired me. I wish similar good fortune for those walking behind me.

Biography solicited by the Committee on the History of Avian Medicine, American Association of Avian Pathologists.

Additional biographical materials may be available from the AAAP Historical Archives located at Iowa State University. Contact information is as follows:

*Special Collections Dept. & University Archives
403 Parks Library
Iowa State University
Ames, IA 50011-2140*