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An Interview with a Distinguished Pharmaceutical Scientist

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Sung Wan Kim is Professor of Pharmaceutics and Pharmaceutical Chemistry. Adjunct Professor of Bioengineering, and Director of the Center for Controlled Chemical Delivery. He received his B.S. and M.S. at Seoul National University in 1963 and 1965, respectively, and his Ph.D. in Physical Chemistry at the University of Utah in 1969 (under Professor Henry Eyring). Dr. Kim is a pioneer and has engaged in drug delivery research since 1974 in the areas of hydrogels, biodegradable drug conjugates, self-regulating drug delivery and stimuli sensitive polymers. He also worked extensively in medical polymers, especially blood compatible polymers. Dr. Kim's present research includes design of novel polymers for the delivery of protein drugs, cells and genes. Dr. Kim has received numerous awards, among them are the Americans Association of Pharmaceutical Scientists (AAPS) Dale Wurster Award (1998), the Controlled Release Society (CRS) Founders Award (1995), the Clemson Basic Biomaterials Award (1987), (AAPS) Research Achievement Award in Drug Delivery (1995), the Annual Award of the ISBP (1994), the Japanese Biomaterials Research Award (1996), the Utah Governor's Medal of Science (1988), University Distinguished Research Award (1997) and the outstanding Paper in the *Journal of Controlled Release* (1989, 1991, and 1998). Dr. Kim is Founder and Co-Chairman for the International Symposium on Recent Advances in Drug Delivery, which is held biennially in Salt Lake City, since 1983.

Dr. Kim was a visiting Professor at the University of Paris (1991 and 1997), Tokyo Women's Medical College (1988), Zhejiang Medical College (1987), Twente University of Technology (1979), and the Korea Advanced Institute of Science and Technology (1975). Dr. Kim was also coordinator of the USA-USSR Biomaterials Scientist Exchange program (1984–90). He served as an NIH study section member in Surgery and Bioengineering (1984–88), and is now serving a second term (1995–99).

Dr. Kim has published approximately 400 papers and owns 20 U.S. Patents. He has trained over 100 scientists from 12 countries. He is on the Editorial Board of the *Journal of Controlled Release, Pharmaceutical Research, Journal of Biomedical Materials Science, and Biomaterials Science*. Dr. Kim is a Fellow of AAPS, Biomaterials Society and AIMBE.

WHAT DO YOU THINK HOLDS THE KEY TO YOUR SUCCESS AS A PHARMACEUTICAL SCIENTIST?

Response: I was trained in a multidisciplinary fashion having received my Ph.D. in Physical Chemistry from the late, great Dr. Henry Eyring and then studied polymer science for biomaterials under the artificial organs pioneer, Dr. Willem Kolff. In the early 1970's, I initiated biomaterials-based pharmaceutical research and expanded this area into novel drug delivery research. A strong background in fundamentals (physical chemistry) coupled with the more applied biomedical sciences has been enormously helpful. I have been promoting a multidisciplinary approach to drug delivery research for the past 25 years in my personal research and training of young scientists. The value of such training is evident in that most successful drug delivery work stems from a multidisciplinary approach. Naturally, at the end of the day, it is good ideas that separate success from mediocrity or failure; but, good training establishes a foundation for creation of good ideas.

WHAT DO YOU CONSIDER TO BE YOUR KEY RESEARCH ACCOMPLISHMENTS?

Response: My greatest accomplishment is the training of young scientists and watching their careers blossom. I take considerable pride in the success of my students and postdocs. On the personal research side, there are a number of areas in which I hope I have made a contribution. These are:

- My early research in blood compatible polymers including the mechanisms of surface-induced thrombosis and its prevention (e.g. heparinized surfaces).
- The concept of self-regulated drug delivery including insulin delivery using competitive binding of glycosylated insulin and glucose to conconavalin A.
- A variety of hydrogels and stimuli-sensitive polymers for drug delivery.
- Recent work on tailor-made polymeric gene carriers and targeting.

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WHAT WAS THE TURNING POINT IN YOUR DISTINGUISHED CAREER?

Response: I was a physical chemist until I joined the Institute for Biomedical Engineering as a Postdoctoral Fellow. I obtained the basic knowledge of biomaterials and joined the Department of Pharmaceutics in 1974. I felt strongly that biomaterials research could be combined with pharmaceutics research with the primary aim of improved therapeutics through improved drug delivery systems.

WHO ARE THE INDIVIDUALS WHO HAVE INFLUENCED YOUR CAREER?

Response: Many individuals helped shape may career and a few were very important. Professor Henry Eyring taught me to be bold in my thinking and approach each problem from a fundamental point of view. Professor Willem Kolff showed me how to plan research and obtain research funding, conduct research effectively and remain at or beyond the cutting edge of a research field. Naturally, the leadership in the Department of Pharmaceutics and elsewhere at the University of Utah has always been very supportive of my research activities.

DO YOU THINK THAT CUTTING EDGE SCIENCE WILL NOT LIKELY BE FEATURED IN THE PHARMACEUTICAL SCIENCES FORUM?

Response: I suspect that in all multidisciplinary work you direct publications to the appropriate audience. My group has published extensively on basic polymer work and I direct such work to *Macromolecules, Journal of Polymer Science, Bioconjugate Chemistry, Nature* and others. These publications include new and novel polymers and/or biomaterials application. However, when the subjects emphasize more specific drug delivery and therapeutic applications, we publish in *Pharmaceutical Research, Journal of Pharmaceutical Sciences* and *Journal of Controlled Release.* This cross-fertilization of published work tends to expand the reading audience.

YOU ARE A POLYMER CHEMIST BY TRAINING. WHAT MOTIVATED YOU TO PURSUE DRUG DELIVERY RESEARCH?

Response: As mentioned earlier, my training was in physical chemistry and polymer science. When I worked in Dr. Kolff's group, I studied basic medicine by taking additional classes. I acquired enough knowledge in hematology and physiology to carry out research in blood- compatible polymers. I received an NIH Research Development Award in 1976, which was recommended by the Hematology Study Section. My motivation for drug delivery research was due to my biomaterials background and the logical application of this area to the design of drug delivery systems and devices. The products of ALZA in the mid-1970's, such as Ocusert™, Progestasert™ and Oros™ stimulated my curiosity and interest since their success is dependent on biocompatible biomaterials.

WHAT ARE YOUR RESEARCH INTERESTS? WHAT IS THEIR COMMON DENOMINATOR?

Response: My current research includes tailor-made polymeric gene carriers. The common denominator of my research has been to design novel polymers, physical characterization, and their in vitro and in vivo evaluation. I believe novel polymeric materials can solve many different types of drug delivery problems. My research has almost always been directed at the cellular or molecular level so that my current interest in polymeric gene carriers is a logical extension of this orientation.

WHAT IS YOUR VIEW ON THE CURRENT STATUS OF RESEARCH IN DRUG DELIVERY?

Response: Drug delivery research is presently an active area, as shown by the abundant publications and various meetings especially, the CRS meeting. Strong participation and enthusiasm at the Utah Drug Delivery Symposia (nine since 1983) reflects great interest among multidisciplinary-seeking scientists. The growth of small cap companies in drug delivery will enhance research activity in this area, although interest in large pharmaceutical companies is still marginal. Scientists are now well aware of the multidisciplinary approach in drug delivery research, and continuous efforts are essential to accomplish successful research development, particularly given the difficult physico-chemical and biological properties of new chemical entities. More successful cases are emerging in business sectors. It is projected that drug delivery products will have an estimated market of $30 billion within a few years.

WHAT ARE FUTURE CHALLENGES IN DRUG DELIVERY RESEARCH?

Response: Most research in drug delivery, up to now, has been directed towards modification for better and convenient delivery of existing drugs and their administration methods. The real challenges come when researchers initiate novel concepts with bioactive agents which are not possible to deliver using currently available methods. These include the design of new carriers and delivery systems for the delivery of protein drugs, cells and genetic materials.

WHAT ARE FUTURE CHALLENGES IN PHARMACEUTICAL SCIENCES?

Response: I think the role of the pharmaceutical scientist is pivotal in the future success of drug delivery research. Pharmaceutical scientists among different disciplines, such as polymer science, biology and biotechnology can generate an acceptable hypothesis and establish final therapeutic goals. This means that any new research can be initiated and completed by pharmaceutical scientists. Success then depends on assembling and organizing a research team utilizing a multidisciplinary approach between the initial and final stage.

WHAT IS THE KEY TO DEVELOPING SUCCESSFUL COLLABORATIVE RELATIONSHIPS?

Response: My accomplishments have historically depended on the contributions of my collaborators. A triangular collaboration involving Jan Feijen (Netherlands), Teruo Okano (Japan) and myself for decades has fueled the high productivity of my research group. We have exchanged many young scientists, published together and shared financial resources.

Marcel and Jacqueline Jozefowicz (France) contributed significantly to my collaborative research. In addition, encouragement and collaboration in many other aspects, i.e., symposium organization, exchange of information and intellectual stimulation have been very helpful for the success of my past research. I have received such support from Jim Anderson, Joe Andrade, Jorge Heller, Jindrich (Henry) Kopecek, Bob Langer, Vincent Lee, Kinam Park, Joe Robinson, Y. Sakurai and many others.

YOU ARE EXCEEDINGLY WELL FUNDED. WHAT ARE THE INGREDIENTS OF YOUR SUCCESS?

Response: Yes, my research is and has been well funded. I have maintained three to four NIH grants (as Principal Investigator) during the past 20 years. I have been writing successful NIH grant applications each with a new and novel hypothesis, some convincing data and well described experimental methods with an emphasis on the ultimate goal of the application strongly documented. For competing renewal applications, publishing in reputable journals is important. New concepts and innovative ideas are important ingredients for the success in NIH funding. In addition, the knowledge I have obtained while serving on NIH Study Sections (2 terms for 8 years, Surgery and Bioengineering Section) has assisted me in the preparation of strong and fundable applications.

I AM CERTAIN THAT, FROM TIME TO TIME, DISTINGUISHED INSTITUTIONS FROM ALL OVER THE WORLD HAVE ATTEMPTED TO RECRUIT YOU. YET, YOU CHOSE TO STAY AT THE UNIVERSITY OF UTAH? WHY?

Response: The University of Utah is the cradle of biomaterials research. I have taken full advantage of the scientific talent, research environment and other opportunities during my tenure at the University of Utah, a leading institute for biomaterials and drug delivery research. I don't think I would be able to establish the same caliber of research at other institutions.

WHAT IS YOUR VIEW ABOUT SCIENTISTS TAKING UP ADMINISTRATIVE AND PUBLIC SERVICE RESPONSIBILITIES?

Response: I consider administrative and public service very important. Leading scientists should take administrative activity and public service responsibilities. Although I have limited myself from these obligations, I have encouraged several able scientists to accept these responsibilities. I have also observed many excellent scientists demonstrating their talents in administration and public services.

MANY OF YOUR FORMER GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS ARE EXCEPTIONALLY SUCCESSFUL. WHAT DO YOU THINK CONTRIBUTED TO THEIR SUCCESS?

Response: First, I have been fortunate to recruit many talented and excellent young scientists. I trained them with a mission that strong basic science and learning a multidisciplinary concept will make their careers successful. I tried to provide them with the understanding of an end point to their research. They all had valuable experience in multidisciplinary research and international exchange, during their training in my laboratory. Both quality and quantity of their research productivity was frequently emphasized by encouraging them to publish their work in reputable journals and participating in scientific meetings.

HOW HAS YOUR PHILOSOPHY OF EDUCATING GRADUATE STUDENTS CHANGED OVER THE YEARS?

Response: My philosophy has not changed much. I do not see the value of teaching students old subjects repeatedly since science is progressing so rapidly. In terms of subject matter, I advise my students to learn more biology in-depth. Graduate students will confront tough assignments in the future, due to rapid progress in molecular and cellular biology. However, I also insist that my students be well grounded in the physicochemical sciences. Without this foundation, it is difficult to do cutting-edge research.

HOW HAS YOUR PHILOSOPHY OF MENTORING JUNIOR FACULTY CHANGED OVER THE YEARS?

Response: It has not changed. My philosophy of monitoring junior faculty is to review their performance in training graduate students, publications and NIH funding. I believe that if a young faculty member is part of a viable research-oriented faculty in a first-rate university, junior faculty should flourish.

WHAT WOULD BE YOUR ADVICE TO OUR JUNIOR PHARMACEUTICAL SCIENTISTS EMBARKING ON THEIR CAREERS, PARTICULARLY IN THE DRUG DELIVERY AREA?

Response: In my opinion, pharmaceutical science, in spite of the appearance of a huge and progressive area, has not been strong and productive compared to other disciplines for the past decades. Junior faculty are obligated to evaluate the past history of pharmaceutical research and to establish a new productive direction. Engaging in a narrow research subject, which has already been explored by chemists, biologists and others should be discouraged. There are enormous opportunities in drug delivery research and they can enter this area rather quickly if they are willing to participate in multidisciplinary research. Strong knowledge in basic science is important, but they should view the research topic with an open mind with an appreciation of a clear and meaningful end point.

WHAT WOULD BE YOUR ADVICE TO THE JUNIOR PHARMACEUTICAL SCIENTISTS PURSUING RESEARCH IN THE MATERIAL SCIENCE ASPECTS OF DRUG DELIVERY? DO YOU THINK THAT THERE ARE AREAS OF RESEARCH THAT SHOULD BE PURSUED BY WHICH ARE NEGLECTED BY THE PHARMACEUTICAL COMMUNITY?

Response: It is up to junior pharmaceutical scientists to decide if materials science aspects of drug delivery are

important. This is the area I have been investigating for the past 25 years. Our Department has adopted a platform to pursue drug delivery research based on biology and biomaterials. I understand that the pharmaceutics graduate research program at the University of Wisconsin is shifting in the same direction. There will be a tremendous pay off in the future. Biomaterials research is moving into a cellular and molecular base and the addition of therapeutically oriented drug delivery is a great synergism to new pharmaceutics research in the 21st century.

WHAT IS THE PLACE FOR ENTREPRENEURSHIP IN ACADEMIA?

Response: I am strongly supportive of academic entrepreneurship. I encourage university faculty to play some role between technology transfer and forming companies. I have asked research scientists in my lab to file patents (over 20 U.S. patents). Several of these patents have been transferred to companies. Innovative research in drug delivery is always patentable and, furthermore, it has commercial potential. This process is a winning situation for everybody and provides another important contribution to society.