The Crystal Dragon

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Prof. Sine Larsen, President International Union of Crystallography, Prof. Mitch Guss, President, Asian Crystallographic Association , Prof. Se Won Suh, Chairman of the Local Organizing Committee of AsCA 12, distinguished colleagues, students and friends:

At the outset let me say what a singular privilege it is for me to be able to speak to you this evening about AsCA and the growth of crystallography in the Asia Pacific Region. Organized research in crystallography in Asia has been going on for around 60 years, in other words the subject in Asia is about as old as the IUCr. As always, the growth of science in any part of the world is inextricably linked with cultural, social and economic development and Asia is no exception. Science drives progress and is a key to economic growth. Asia is also a very complex part of the world and some aspects pertaining to the development of crystallography in this continent need special mention.

In this talk I intend to say something about Asia itself, from a historical and social perspective, the growth of IUCr and AsCA in this part of the world, a little about the development of crystallography in five important countries in the Asia-Pacific region and finally something about what the future may hold for us scientists in this again awakened continent.

Let's first talk about Asia. If you take a look at the map we will notice that unlike Europe and America, our continent is mostly water surrounded by bits of land. Movement between the various parts of Asia has always been more difficult than say movement within Europe. The story of Asia is then the story of equilibrium between the land and the sea and how the people who came to live in this continent began to understand and accept their relationship with both land and water. ℗We don't know much about what the ancient tribes of Asia were doing, and how they managed their lives but one day around 10,000 years ago they made their greatest discovery—one that changed their lives and fortunes forever. They discovered the magic cereal, rice. A moderate climate, tempered by the ocean, and an abundance of fresh water from the vast river systems of the continent ensured an abundance of this magic cereal, and this led directly in turn to the enormous number of people that now inhabit Asia.

The story of Asia is largely the story of three countries. First, let us consider a small set of mountainous islands with narrow coastal regions in the north eastern fringes of the continent. The flat land occurred in narrow strips, but these narrow strips were sufficient to grow the magic cereal. The people of these islands who today number around 125 million needed something to eat with their rice but the extent of flat land in these islands was so small that all they could do was to eat their rice with the products of the sea. The second country, to the south west, was very much larger and Nature endowed it not only with an extensive river system but also with wide, alluvial plains. And these arable areas also led into forests and wooded areas in which lived many animals. This second country has today become the most populous nation on the planet and with an abundance of flat land, rivers and forests, the people of this country could afford to eat their rice with all sorts of meat products. So, if in Japan you would eat your rice with anything that swims, in China you may eat your rice anything that moves. Now, we come to the third country. The river system in India is as extensive as in China and the climate is generally warmer than in either Japan or China. So, there was absolutely no problem in growing rice. But without harsh winters, so many people did not die. And being warmer, meat also tended to spoil. And, the forested areas were deep and impenetrable. People were forced to live in the relatively small flat areas near the rivers. India has only a third of the land area of China and much of it is far away from the ocean. The population grew without the corresponding amount of food that would be required to feed all these people. Today, nearly 10% of the world's population lives in a narrow region, 50 kilometers on either side of the Ganges river. When you travel in a train from Delhi to Calcutta, you see that one village simply merges into the next all the way in your 1500 km journey. How did the inhabitants of India solve this gargantuan Malthusian problem? What does one do with a rapidly growing population who lack food supplies? The answer was truly ingenious. India took to large scale vegetarianism. It is the only country in the world where vegetarianism is the norm rather than the exception. Truly, this has been one of the cleverest ways of solving an intractable economic problem. And, in the end, vegetarianism in India is all about economics and has nothing to do with religion.

There is no doubt that Asians are among the savviest economists in the world today. They had to be, because right from the beginning, the main problem was as and will always be how to keep up with the enormous number of people that this continent has. No aspect of life in Asia is very far away from this issue and practically everything we do, even today, is based on the fact that there are so many of us. Given all this, Asians did pretty well in the past. From the beginning of recorded history till 1800 the combined GDP of China and India was equal to that of the rest of the world combined. We had a hiatus for 200 years and things are changing again. Money has entered our continent the second time. How are Asian countries going to manage to feed their enormous numbers and at the same time enter the modern world with its emphasis on education, research, technology, economics and commerce? The present time is one of the most fascinating ones in this respect. As this continent turns the corner, it is thinking in terms of using its enormous population as an asset rather than as a liability.Ⓟ

Let us now turn to the scenario in crystallography with reference to Asia. The first Asian countries to join IUCr, just three years after its inception, were Australia, India and Japan all of who joined the Union in 1951. New Zealand joined 10 years later, and China still another 18 years later. Two years back, the concept of the Regional Associate was instituted, largely with the support of Yuji Ohashi the then President of IUCr. In this scheme, a group of small countries associate themselves for the purpose of adherence to the Union. In case some of you are wondering about the years indicated in pink, this represents those years when the IUCr Congress were conducted in Asian locations. You will also notice now that I consider

Australia and New Zealand to be an integral part of Asia. ⓟI do this without any reservation and I will say a little more about it later. For the moment it will suffice to say that the very nature of the Asian experience is an inclusive one. While on the other hand, the people of Australia and New Zealand are largely of European extraction, they were quick to identify that their fates and fortunes would be best served, if they integrated themselves into the pan Asian community. We can actually think about the Asia-Pacific region but I think that just the simple word "Asia" will suffice. Both Australia and New Zealand today are multi-cultural and multi-ethnic in the best traditions of Asia.

What about the Asian Crystallographic Association? The youngest of the IUCr Regional associates, it was formally established in 1987 at the time of IUCr Congress in Perth. The driving force behind the early formation of the AsCA was undoubtedly Syd Hall and I will refer to Syd a bit later in this talk. Because of Syd, Australia was an especially important country in the formation of AsCA and along with Japan, it still plays an important role as a facilitating country that co-ordinates a number of activities and events within AsCA. A number of countries are now members of AsCA. This also raises the interesting question as to what geographical regions fall in the natural jurisdiction of AsCA. I would say that today AsCA would and should cover all those regions which are bounded by Arabia, New Zealand and Siberia, and so we are still looking for a few more countries to join AsCA. I have seen a delegate from Mongolia for example at a previous AsCA meeting. Notably I would say that with the recent rise of modern science in some of the Islamic countries of Western Asia, we could certainly expect to see some new members from there. We now have brand new international level universities in Saudi Arabia and Abu Dhabi and I would hazard to say that the Asian part of the former USSR is geographically, socially and culturally more a part of Asia than it is of Europe, say the Kazakh and Uzbek republics and most certainly Siberia. It is an interesting question as to whether crystallographic activities in Russia lend themselves to divisions between the European and Asian regional associates. Certainly there is a cultural case for doing this. The Russian national committee should be thinking about this. The thought process in Asia is certainly distinguishable from that in Europe, mostly in the manner in which we use inductive logic and intuitive thinking. We apply logic and rationalize events in different ways and this in itself increases the variety and joy of the scientific experience. Scientists all over the world may think about the same goals and problems but the thought and action processes by which these goals are achieved may be different and these differences should be maintained rather than suppressed. It is the uniformity that kills. ⓟ

Let us now turn to a short description of the growth and present status of crystallography in some of the important Asian countries. I have tried to mention the names of some of the early pioneers in this slide. This list does not attempt to be exhaustive and indeed in the description that I will give about the five countries in Asia, the names I have selected are by no means the only names that are important in the development of the subject. S. Nishikawa was the first President of the Crystallography Society of Japan and he made contributions to space group theory. He was one of the first structural chemists to undertake the study of spinels. Some of you will remember the logo of the Osaka Congress was based on Nishikawa's description of this important crystal structure. He had a close academic relationship with Wyckoff and dealt with space group matters in interactions with

Schoenflies. Y. Saito determined the absolute stereochemistry of a metal complex in Tokyo University two years after Bijovet. N. Kato is famous for his studies on extinction theory. He was a winner of Ewald Prize and a former President of the IUCr. M. Kakudo was one of the early workers in the area of macromolecular crystallography and investigated structure of cytochrome-C. Electron microscopy and its relationship to crystallography was studied by M. Kikuchi. T. Sakurai did important work in small molecule crystallography and N. Umeda in Kyoto made contributions in the delineation of electron density maps in crystals. The characteristic of crystallography in Japan is that the country was at the forefront of developing its own instrumentation. Already by 1950 a manual 4-circle diffractometer had appeared. By the 1960s, the Rigaku Corporation was making automated diffractometers. The machines made in 1960 was a copy of the Philips machine and by 1967 Rigaku had marketed its own machine and this fared well vis-à-vis the competition from Europe and America. Protein crystallography began in Japan in the 1970s in the Institute of Protein Research in Osaka university.

From these early days I have chosen to highlight a paper by T. Sakurai on the crystal structure of the triclinic form of quinhydrone, which is the 1:1 molecular complex of benzoquinone and hydroquinone. This paper was published in 1965. The matter looks rather simple when looked at today. However, we should remember that it was not so easy to do a crystal structure in 1965 and that too of a substance that was a binary crystal of two different molecules that are rather similar to one another. We should also not forget that, in the end, the difference between benzoquinone and hydroquinone is just a matter of two hydrogen atoms. Further, Sakurai was looking at a crystal that was a polymorphic modification. A monoclinic form had been reported a few years earlier. The fact that a substance could have more than one crystal structure was still something new in 1965. If you see this paper more closely you will see that the structure was not solved with Direct Methods. Sakurai solved the structure by obtaining the Patterson functions of the average structure and the difference structure of the benzoquinone and hydroquinone. The average structure gave the gross features. The difference structure provided the positions of the crucial hydrogen atoms. Considering that polymorphism in small molecule crystallography is a hot topic today in the pharmaceutical industry and elsewhere, one feels a little humble looking at this 45 year old paper on the triclinic modification of quinhydrone.

So where is Japan's crystallography today? It's impossible to encapsulate the enormous range of activities that are going on in crystallography groups in Japan today in a single slide. I must mention the work of T. Tsukihara in real time crystallography in Spring 8, for example his recent paper on three-dimensional structure of human gap junction channels, and of S. Wakatsuki in KEK, for example the paper on Complexity in influenza virus targeted drug design. Susumu Kitagawa and Makoto Fujita are world leaders in the areas of crystal engineering and supramolecular chemistry and the slide highlights a recent paper of Kitagawa's on 3rd generation co-ordination polymer that are able to discriminate between various gases as it absorbs only some of them into the micropores in its framework. Yuji Ohashi is of course too well known to all of us here and he has distinguished himself through his studies of solid state transformations especially of resolved and racemic crystals. While he held the office of President of the IUCr he also oversaw the organization of the Osaka IUCr Congress in 2008, not an enviable task. I would also like to mention Reiko

Kuroda who returned to Japan after training in the UK and is notable for being the first woman professor of chemistry in a major university in Japan. Reiko will be giving a keynote lecture in this meeting. I must also mention H. Kobayashi and his wife A. Kobayashi of the Institute of Molecular Sciences in Okazaki for their researches on superconductivity. M. Irie, who has done important work on photochromic solids and S. Ijima who discovered carbon nanotubes have both given fascinating lectures in the Osaka congress in 2008.

I have already mentioned that all nationalities are different. These differences must be maintained and respected even as all nations work with one another. A very notable feature of crystallography in Japan has been that the Japan crystallographers have either been trained in Japan or they have come back to Japan after some training abroad. But what is important is that research in Japan is done using the uniquely Japanese style of thinking and it is not influenced to a large extent by that is happening in Europe and in USA except perhaps a little in the field of molecular biology. Still, ideas and conventions of former times are gradually giving way in the present with the new generation of Japanese crystallographers. A notable feature of the Japanese outreach in science is provided by the large number of young researchers who have had post doctoral training in Japan and have now returned to their home countries and who also take with them a little of the Japanese way of thinking and the Japanese way of doing research.

The strong tradition in physics and mathematics in India set the stage for some outstanding earlier contributions in diffraction physics. C.V. Raman never considered himself to be a crystallographer but the edited volume that he brought out to commemorate the 25th Anniversary of the work of Max von Laué shows the high regard in which he was held by the scientists of his day. These articles were published in a journal called Current Science which was founded by C.V. Raman and which continues to be in existence till the present time. I published a full paper in this journal six months back. We have articles here from Raman himself, from the Braggs, Ewald, Siegbahn, Sommerfeld, Pauling and Hermann Mark. Quite a line up for a fledgling journal published in a country that was still struggling to come out of colonial rule.

The truly outstanding crystallographic contribution from India in the early days undoubtedly came from G.N. Ramachandran who made outstanding contributions not only in unravelling the structure of collagen but also in the development of the plot that bears his name today. The Ramachandran plot has become an indispensable tool in macromolecular crystallography and it was the first time that someone showed how crystallographic information can be used in a statistical manner to make structural predictions. A large number of other Indian physicists also made interesting contributions. In 1953, S. Ramaseshan and K. Venkatesan wrote a paper on the crystal structure of $KMnO_4$ that has an immediate connection with the use of multi wavelength measurements in phase determination. All Indian crystallographers are proud of the fact that as far back as 1953, these authors were able to say in this paper that “the use of two appropriate wavelengths with one crystal would, in effect, be equivalent to the substitution of one of the atoms of the crystal by an atom of slightly different scattering power”. A. R. Verma made extensive studies of polytypism and polymorphism of crystals. It is interesting to note that once again a topic of such a great importance today, namely polymorphism, was illustrated in such great detail by Verma more than fifty years ago. The book on this topic by Verma and P. Krishna continues to be cited today. Names like M. A. Viswamitra, R. Chidambaram, M. Vijayan and Krishan Lal are well known to many of us in the audience here. Both Ramaseshan and Chidambaram served as Vice-Presidents of IUCr. Chidambaram used neutron diffraction in the 1950 and illustrated several important rules that govern hydrogen bonding in organic solids. Vijayan worked on the take-off of macromolecular crystallography in India in a big way and virtually single handedly for many years he championed its cause with the government bodies responsible for science funding in India. However, times were hard in the 1960s and 1970s with severe import restrictions. Some attempts to make indigenous equipment became non-starters. The first 4-Circle machines from Nonius appeared in the late 1970s in the Indian Institute of Science Bangalore and the Indian Institute of Technology Madras. If you did not belong to one of these institutions you were lucky if you could collect one data set every year.

Unlike in other parts of the world, most crystallographers in India were originally physicists by training. This led to a certain outlook of approach and also determined the nature of the subjects that were taken up for advanced research. The tradition of chemical crystallography is a more recent matter and crystal engineering as a serious research endeavour in India is something that has happened in the last 25 to 30 years. Today the community of crystal engineers in India is both numerous and visible in the international stage. We see a representation in this meeting from Arunachalam Ramanan and Kumar Biradha. Other names on this slide are also well known to the present audience. Pinak Chakrabarti works in an interesting intersection of small molecule and macromolecular crystallography and he attempts to find patterns of interactions in biological structures. M. R. N. Moorthy, who is giving a keynote lecture in this meeting has introduced virus crystallography in India. A rather large group of workers have been involved in a national effort centred around the tuberculosis problem. On this slide you will see some of the past, the present and the future of Indian crystallography. I will draw your attention to the youngsters who are standing in the lower photograph that was taken in a discussion meeting in crystal engineering in Coorg in South India in 2009. In many cases, I think it is more interesting and useful to look at the people who are standing in group photographs rather than those who are sitting. This is because those who are standing will be sitting in a few years time and it's probably wiser to get to know them better before they move into the first row. Asians, as a rule, tend to respect authority and age. One tends to equate age with wisdom in this part of the world. While this may hold true in many facets of human life, it may not always be applicable in science, which is iconoclastic and free-wheeling. I feel one of the problems that Asian scientists and Asian crystallographers, in particular, will have to face is how to reconcile these two rather different value systems. There is a tendency to over revere the past in Asia, particularly in India, in a world that often errs towards the other extreme of over glorifying the young. We need to find a balance somewhere, and Asians are good at balancing things. We have to be, given the ground realities of our continent, and so I am hopeful.

We move now to survey the crystallographic situation in Australia and New Zealand. As I mentioned before, the cultural and social ethos in these two countries is a fascinating blend of European rigour and Asian expansiveness. Australia and New Zealand have been the birth places and original home of a number of crystallographers who made their mark elsewhere. As representative examples only I show the pictures of W. H. Bragg and Maurice Wilkins. I would like to spend a little more time in describing the contributions of the two other gentlemen in this slide. Hans Freeman was in the front rank of Australian scientists and an inspirational role model, a meticulous and innovative researcher and a ceaseless campaigner for science in Australia. It was a long journey for a nine year old Jewish boy, who fled from his home in Breslau, Germany, and from the Nazis, to begin a new life with his parents and family in far away Australia. Two quite different cultures influenced Freeman's life, the German Jewish world of hard work, perseverance, reserve and order, and the more liberated pragmatic, open minded and informal Australian ethos. I would not be exaggerating if I said that it was Hans Freeman who founded the crystallographic enterprise in Australia, and most notably the macromolecular crystallography enterprise. Syd Hall is another Australian crystallographer who was always thinking ahead of his times. If AsCA was founded as early as it was, this is largely because of Syd. Syd worked in North America and was influenced by the ACA which we all know is an important part of the crystallographic activity there. The ACA influenced his plans to get AsCA going. Syd had travelled widely and was able to observe scientists all over the world. He took the best part of other scientific cultures in trying to set up a firm and platform for Asian crystallography. He definitely deserves the primary credit for founding AsCA. Syd was also ahead of his time in terms of setting up formats for the deposition of crystallographic data. The Crystallographic Information File or CIFs that all of us use today in small molecule crystallography have their origin in some of Syd's work in the 1980s. As a Section Editor of Acta C, he had an opportunity to translate many of these ideas into practice and once again he showed that he was a person ahead of his times.

Crystallography in Australia today is a flourishing enterprise. I highlight here a paper by Richard Robson that is considered by many to signal the beginning of the field of co-ordination polymers and which in turn led to the more practically oriented field of metal organic framework structures. Many other names on this slide are well known to the audience and many of the people are indeed present here for this evening. Jenny Martin, is a well known macromolecular crystallographer and is also the program chair for this meeting. She very kindly invited me to give this evening lecture. David Rae, an expert in twinned and disordered structures, is a crystallographer's crystallographer and will be speaking in this meeting. Mark Spackman has come up with a very novel and informative way of visualizing small molecular crystal structure with his Hirshfeld plots. Peter Colman, my colleague on the IUCr executive, is a distinguished protein crystallographer. His work on the influenza virus, especially the work with the neuraminidase inhibitors Relenza and Tamiflu, is most notable. Mitch Guss, is recognised for his work in structural biology. As the current President of AsCA, he has come up with an innovative idea in the form of the rising star program. I believe this is a first for a meeting of one of the Regional Associates. Mitch has been actively involved with the Australian Synchrotron in Melbourne. This facility has really raised the quantity and quality of research in all areas of crystallography in Australia. Many crystallographers from Asia now travel to Melbourne to collect data at the synchrotron. Asia is a far flung continent. Many parts of it are far away from Europe and America. The presence of the synchrotron in Australia, China and of course Japan has made a great difference to crystallographic activities in this area. Travel to and from Australia and

New Zealand has always been a problem. The tyranny of distance was keenly felt in these countries. To some extent, daily contact with colleagues in other parts of the worlds is easy now with e-mail. In any case, all this is less of an issue than in the past.

Crystallography in New Zealand has always been strong with respect to inorganic chemistry and structural biology. Ward Robinson has trained several generations of crystallographers in New Zealand and elsewhere, and once again he is a person who was ahead of his time. In the late 1980s and early 1990s, when I interacted with Ward he was already talking about high throughput small molecule crystallography. Let's come now to macromolecular crystallography. It's a real privilege for me to recall here the contributions of Ted Baker to macromolecular crystallography in New Zealand, and in general to record his contributions to the Union. His review in 1984 on hydrogen bonding and globular protein is still a classic and his work on lactoferrins is extremely well known. Ted and Heather, who has collaborated with him throughout, are well known to many of us here. Let me also acknowledge here Ted's distinguished tenure as the President of the IUCr and the wise words that he has spoken on many an occasion always with the idea of making a positive contribution and moving the discussion forward. As we know very well, these are not the qualities that are the forte of many scientists. In the context of macromolecular crystallography in New Zealand, I should also mention the work of Peter Metcalf on the cypovirus, a cubic 103 Å cell, an outcome of a New Zealand, Japan and Switzerland collaboration.

Crystallography in China has had an uneven development in the past. The first part of the 20th century was a period of great turmoil in the country. Qualified students who returned to China after foreign training had little or no opportunity to function. Y. C. Tang worked with Pauling in the 1950s and developed a group in Peking University. D. C. Liang opened up biological crystallography and his researches into the insulin problem elicited respect and regard from Dorothy Hodgkin herself. In 1971 and 1972, the Chinese group obtained crystal structures of porcine insulin with resolutions of 2.5 and 1.8 A °, respectively, signalling that crystal structure determination in China had reached the first-class international level. This was a particularly influential achievement. C. S. Lu was a co-author on a paper with Jurg Waser, written in 1944, on the crystal structure of biphenylene, a $P2_1/c$ structure with six molecules in the unit cell. He returned to the Fujian Institute of Research on the Structure of Matter. H. F. Fan, one of Tang's students, made contributions in Direct Methods. Times were extremely difficult for Chinese crystallographers in the 1950s and 1960s. Very often they could not even use their own names in their papers. Only the names of the research groups or institutions could be used.

Diffractometers came into China in the 1970s. Syntex was the very first, followed by Philips and Nonius. The period from the 1970s to the mid-1980s was relatively slow while the methodologies were developing and improving. In the early 1980s, the first 4-Circle machines made their appearance. China opened up in 1979 and by the late 1980s, there was enough money to get diffractometers in the main universities and research institutes. China was around 7 to 10 years ahead of India in this regard, for in India the regular appearance of diffractometers in the top universities and institutes only occurred by 1995 or later. After 2000, second and third tier universities in China could afford diffractometers and this in turn led to the deluge of crystallographic contributions from China, especially in the area of metal-organic compounds.

At this stage I must mention the unique and important contributions of Thomas Mak in the City University of Hong Kong. Thomas ran a very productive group in inorganic crystal chemistry and trained a large number of students from China who returned to China, Singapore and elsewhere and began their independent careers there. Thomas played a very important role in facilitating the exchange of crystallographers from China to the outside world through his vantage location in Hong Kong. He visited China very often and was familiar with the situation there. His research contributions, among other aspects, include a very informative resource book on common crystal structures and detailed studies on the argentophilic interactions between silver atoms in crystals. I would say that in large measure, it was Thomas who introduced influential members of the Chinese crystallographic community to the standards and traditions of the subject elsewhere in the world. This holds most notably for people who worked in the area of small molecule crystallography.

Modern crystallography in China has two notable highlights. The development of macromolecular crystallography has been strongly encouraged by the Chinese government and the contributions of Zihe Rao in Tsinghua university are notable. The determination of the crystal structure of the first inactive ribosomal protein, trichosanthin, in the early 1980s was another main achievement. During the 1990s, widespread application of technologies for DNA recombination and synchrotron
radiation led to a profound revolution in quantity and quality for protein crystal structure determination. Simultaneously, progress in methodology set the stage for structural biology, NMR and cryo-electron microscopy. Gradually, structural biology has progressed into a leading frontier of current life sciences research in China. The recent China National Human Liver Proteomics Project is a very good example.

The second highlight of Chinese crystallography today is the abundance of work in the crystallography of metal-organic compounds, the so-called co-ordination polymers and metal-organic framework compounds. Notably, Chinese crystallographers have used their strengths, the people power, use of simple and inexpensive equipment, and high throughput techniques to put themselves on the world map of crystal engineering. Xiao-Ming Chen from Guangzhou is an international authority in this subject and he will be giving a keynote lecture at this meeting. Mention should also be made of Shilun Qiu from Jilin, who has done original work in this area. Coming now to Chinese Taipei, I must mention S. M. Peng's work in structural inorganic chemistry. Yu Wang, who is well known in AsCA, organised a very successful meeting of AsCA in Taipei a few years ago. Andrew Wang is giving a keynote lecture in this meeting and is a well known macromolecular crystallographer. In a personal aside, let me say that Andrew Wang, Yu Wang and myself all obtained our PhD's from the University of Illinois in Urbana-Champaign in the early to mid-1970s, and this meeting is a nice occasion for us to get together. The family of crystallographers is, in the end, quite small and it is this smallness that allows us to maintain our informality and closeness to one another.

We finally come to the smaller countries of Asia. Things are beginning here, in Singapore, Malaysia, Vietnam and especially in South Korea, our hosts at the present meeting. If we are to go by the experience of smaller countries anywhere in the world, in Latin America, in eastern Europe, in north Africa, let me say that progress in these countries will depend on a certain amount of help offered by larger countries in the area in terms of mentoring, influence and providing opportunities, it will depend on what AsCA and IUCr can do for these countries. Beyond a point, AsCA and IUCr are not really required to improve crystallography in Australia, India, China and Japan. They are needed in the smaller countries. But more than this, there needs to be a real desire within these countries that they do want to enter the world of high science and they should be convinced that through science and may be only through science can these countries achieve even long term economic stability. Money without education is a sinful thing, there are no short cuts, one cannot buy one's way into science, and I am no votary of any such scheme of things.

But it is here that I think that the Asian ethos is going to become particularly useful. Asia is inclusive but it is not a melting pot like America. All Asians are alike and in ways in which they are easily distinguished from Europeans and Americans. But at the same time, Asians can also be quite different from one another, and these differences are respected. The thing, however, is that an Indian can also be different from another Indian and a Chinese person can be different from another Chinese. You can call it constructive anarchy. It's a question of finding areas of agreement and consonance in thought. It's a question of finding areas where we can make fast progress by coming together. In a recent meeting of the two Asian giants, scientists from China and India met, of all places, in Singapore. Scientists from three countries with populations of 1.2 billion, 1.1 billion and 4 million met as equals and talked about matters at the scientific cutting edge in the area of crystal engineering.

This is an important area in the Asian context and in the crystallographic context. I have already talked about Richard Robson in Australia, Susumu Kitagawa in Japan and Chen-Xiao Ming in China. The field itself and its relationship to crystallography are interesting. It all began with the work of Gerhard Schmidt in Israel who in the 1950s and 1960s said that crystal structures <u>should</u> be designed. His pupils, notably Leslie Leiserowitz and Meir Lahav showed in the 1970s that crystal structures <u>could</u> be designed but only in specific systems. There were others too like J. M. Thomas in Cambridge and Gerhard Wegner in Freiburg, later Mainz, who designed specific crystal structures in the early 1980s. Now we come to Asia. In the late 1980s and the early and mid-1990s, Richard Robson in Australia and I in India showed that crystal structures could be designed <u>in a general sense</u>, not just in specific systems, Robson for co-ordination compounds and I for organic compounds. By the late 1990s the floodgates opened and people like Susumu Kitagawa started looked at specific systems again but now with a keen interest in properties. He and others showed that gas absorption and permanent porosity could be achieved in co-ordination polymers, also called metal organic frameworks or MOFs. The wealth of crystallographic data from China in the past decade has been a real boost to the idea of crystal engineering. Now why am I telling you all this? Crystal engineering is an area in which Asian crystallographers have excelled. There is a domination by Asian workers in this area. This is why the China-India-Singapore trilateral symposium was a big success. AsCA in particular and IUCr in general should try and ensure that this large active group of workers stay firmly within the crystallography family and don't drift here and there. We lost the solid state chemists, we lost the materials scientists, but we didn't lose the macromolecular crystallographers. We should not lose the crystal engineers. Crystal engineering has the potential of becoming a large and very important sub-set of crystallographic activities worldwide and in Asia in particular.

You can see it all on this map. I end as I began with a map. But this is a different map, one that is scaled to the populations of the respective countries. I think this map is perhaps is more significant than the one I showed at the beginning of this talk. ℗Having more people was always disadvantageous when a country was poor. But money has now entered Asia, and with money, education. Having money and a large population is an irresistible combination and I can see much synergy and joy emerging in the Asian scientific community to which I belong. It is people, people, people all the time. Asia is all about its people And this vast mass of humanity has now become an advantage to the countries to which they belong.℗ Lee Kuan Yew speaks about it in a pragmatic way. I think his words have much meaning for all of us here and especially in the context of what is happening in crystallography in Asia.

I will end with the dragon because I am sure that by now some of you are wondering why I called this talk "Crystal Dragon". Practically all of us here know that the dragon is a symbol of good luck in Asia. It is not the fearsome medieval beast one finds in European mythology. Even the word "Dragon" is, I feel, a bad translation. If you go to the great temple of Sanjusangendo in Kyoto, there is a detailed explanation as to why the Chinese and Japanese "dragon" is nothing other than the "serpent" in India, and that the dragon symbolism in China and Japan originate from the snake symbolism in India. In fact the explanation invokes the ancient and uncommon Sanskrit word "uraga" which means snake. Snakes and dragons evoke the same good sentiments in all Asian countries. In India, they are even worshipped on some occasions. They are seen as the adornments or artefacts of the Gods. Look at these two photographs, both of which I have taken personally in two locations in Asia that are 5533 kilometers apart. Don't they look the same? Snakes, dragons, call them whatever you will, all of these are good luck symbols. And heaven only knows, we Asians are superstitious people. All of us. The happiest set of auguries we believe can yield nothing if that mysterious luck factor is not operating. So let us wish for this elusive commodity even as we look towards a bright scientific future for all of us, and an interesting and enjoyable conference.

It only remains for me to thank Yuji Ohashi, Peter Colman, Thomas Mak and Jim Simpson all of who provided me with invaluable insights, and in some cases visual materials, pertaining to the development of crystallography over the last 60 years in their respective countries. I thank Jenny Martin for her kind invitation to me to speak today. I thank Se Won Suh for the hospitality and kind co-operation. I thank all of you for your kind attention.