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Chemistry in Taiwan and Academia Sinica

*Chi-Huey Wong**

President, Academia Sinica, Taipei and Professor of Chemistry, The Scripps Research Institute, La Jolla

The research activities in the chemical sciences in Taiwan cover a number of subjects ranging from traditional chemistry to the interface with both life and materials sciences. Currently about 3% of the national gross domestic product (GDP) is spent on research and development (R&D), one-third of which is provided by the government. Academia Sinica, the national academy of sciences and humanities, receives about 12% of the government investment in science and technology.

Academia Sinica was founded in 1928 in China and moved to Taiwan in 1949. It is the highest-ranking academic institution in the country and is involved in cutting-edge research in the sciences and humanities. Currently the academy comprises about 9000 people, including 900 principal investigators, 100 postdoctoral fellows, 2000 graduate students (the academy does not offer degrees but collaborates with local universities to train students), and more than 400 research assistants working in 24 institutions and 7 research centers. In addition to research, the academy is also responsible for nurturing young talent and making policy recommendations. Since 2014, the academy has also selected the awardees of the Tang Prize, a new international prize established by entrepreneur Samuel Yin to recognize those who have made important contributions in the areas of sustainable development, biopharmaceutical sciences, sinology, and the rule of law. The academy elects new academicians every two years and currently has about 270 members, two-thirds of whom reside in the United States and more than 80 of whom are members of the US national academies. The President of the academy is elected by the Council of Academia Sinica. In addition to overseeing the operation of the academy, the president also serves as the chief scientific advisor to the government.

[*] Prof. C.-H. Wong
Academia Sinica
128 Academia Rd., Sec. 2, Taipei (Taiwan)
E-mail: chwong@gate.sinica.edu.tw
wong@scripps.ed

Every year more than 200000 college students graduate from more than 100 public and private universities in Taiwan. Of these institutions, around 10 are major research universities that include National Taiwan University, National Cheng-Kung University, National Tsing-Hua University, and National Chiao-Tung University. Over the past 50 years, Taiwan has moved from an agriculture-based to a technology-based economy. With regard to chemical products, Taiwan is recognized for its textile and petroleum-related plastics industries. Since the 1980s, Taiwan has successfully developed semiconductor, and information and communication technology (ICT) industries which have spawned such leading products as computer chips, solar cells, notebooks, and smartphones. These high-tech products have earned Taiwan a good reputation that has led to the "made in Taiwan" (MIT) movement, and brought prosperity to the country. However, during the course of this development, the annual GDP growth over the past 50 years has recorded a steady decline from 12% to about 4% most recently. In order to improve the economy and meet new challenges, the government has recently recognized the need for the development of a knowledge-based economy through investment in emerging industries (including the biotechnology, green energy technologies, and agriculture industries) to ensure long-term sustainability and a high quality of life. Moving forward, the scientific community in Taiwan has recognized the need for a disruptive change that will require the establishment of new industries based on early-stage technologies from discovery research, and technology-based high-value services. With this goal in place, the biotech and pharmaceutical industry has recently become a strong emerging industry with current market capitalization reaching around US$30 billion. More than 20 new pharmaceuticals are currently in phase III clinical trials, including, for example, new drugs and vaccines against infective diseases and cancer. This trend has further stimulated interest in research to support the development of the emerging biotech industry. Overall, Taiwan's contract manufacturing industry has encountered major competition, especially from its neighbors, spurring the government to acknowledge that changes are necessary, and propelling a move toward innovation-based industry.

Fundamental Research in Chemistry

Basic research remains the major focus of the chemistry community. The fundamental research in chemical dynamics, for example, emphasizes the precise study of reaction mechanisms. Various instruments, in particular NMR and mass spectrometers, have been designed to support this kind of basic research at the atomic and molecular level. Understanding the C–H bond stretching related to its cleavage, for example, has been elucidated in the $F+CHD_3$ reaction. In another example, carbonyl oxides, or Criegee intermediates, important transient species in the reaction of unsaturated hydrocarbons with ozone at various humidity levels, were measured and it was found that the effective rate coefficient of the reaction of CH_2OO with the water dimer was $6.5\times 10^{-12}\,cm^3\,s^{-1}$. This discovery is expected to help modelers work more effectively toward constraining the atmospheric concentration of CH_2OO.

Structural and Chemical Biology

The synchrotron facility in Taiwan has just completed the construction of a 3GeV light source, called the Taiwan Photon Source. It is expected that this new facility will help advance materials research and structural biology. Taiwan also has a close collaboration with the SPring-8 facility in Japan, especially in the use of free-electron lasers for the determination of complex biological structures. Academia Sinica, which is home to electron microscopes, high-field NMR and state-of-the-art mass spectrometers, has been actively involved in cutting-edge research in complex systems in biology. One example is the elucidation of the mechanism of bacterial transglycosidase that catalyzes the polymerization of lipid II to form a major part of the cell wall. This work led to the design and development of new antibiotics to tackle drug resistance. In addition, chemists and biologists have been collaborating to study various biological signaling processes and elucidate the role of posttranslational modification in protein structure and function. Among the various research topics, major activities are devoted to phosphorylation and glycosylation and to some extent lipidation and ubiquitylation reactions. Design of molecular probes for use in imaging glycosylation and other signaling processes has enabled identification of new markers as targets for the development of diagnostics and for drug design.

Research in glycoscience is relatively active in Academia Sinica, and, through collaboration between biologists, chemists, and physicists, this scientific field has become a major endeavor and has made important contributions to the understanding of glycosylation in biological systems and development of new drugs. Synthetic carbohydrate chemistry has played an important role in supporting discovery research and clinical development as demonstrated in the synthesis of a carbohydrate-based breast cancer vaccine used in phase II and phase III clinical trials for the treatment of metastatic breast cancer. This vaccine is designed to target the globo-series glycolipids that are exclusively expressed on the surface of breast cancer cells and cancer stem cells, as well as the cell surface of 15 other cancer types, thus suggesting its broad application in cancer therapy and perhaps cancer prevention.

Chemistry in Materials Science and Nanomedicine

Extension of chemistry research to the emerging field of nanoscience is a new initiative. For example, the development of new organic and organometallic materials and polymers for more efficient solar cells has been actively pursued. In another area, fluorescent nanoparticles containing molecular probes have been developed along with single-molecule imaging for live cells in order to understand various biological processes, and to identify new targets for development of early diagnostic methods and new therapeutics. For example, lung and heart stem cells are potentially useful for regenerative therapy. A fluorescent nanodiamond was developed to identify lung stem cells in vivo and track their engraftment and regenerative capabilities with single-cell resolution.

Bridging Discovery Research and Innovation

In order to bridge discovery research and translational innovation to facilitate the development of the biotech industry, Academia Sinica has decided to construct a biotechnology research park next to its current campus to bring together research institutions with strength in translational medicine and disease models. This bioscience park will focus on R&D in infectious diseases, cancer, and regenerative medicine, and is scheduled for completion in 2016. Like other science parks, this bioscience park will need input from chemistry to support this rapidly growing field related to human health and our ageing society.

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