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IMPLAD

Institute of Medicinal Plant Development

BEIJING, CHINA



EXCELLENCE IN SCIENCE

Profiles of Research Institutions in Developing Countries

PUBLISHED WITH THE SUPPORT OF
the David and Lucile Packard Foundation

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Foreword

Founded in 1983 and officially launched in 1985 in Trieste, Italy, by the secretary general of the United Nations, TWAS, the academy of sciences for the developing world, is dedicated to the promotion of scientific excellence and research capacity in developing countries.

With an initial membership of 42 'Founding Fellows', TWAS now counts 880 eminent scientists in 90 countries among its members. More than 85 percent of these scientists live and work in developing countries. This membership not only gives the Academy insight into the state of science in developing countries, but also provides a unique network of individuals and institutions through which the Academy can coordinate its activities.

Among these activities are annual TWAS Prizes designed to honour scientists in the South for their outstanding work in the fields of agriculture, biology, chemistry, earth sciences, engineering sciences, mathematics, medical sciences and physics. TWAS Prizes help bring the achievements of scientists working in the South to the attention of their national governments, providing them with a rare opportunity for recognition in their home countries. TWAS also offers research grants to individual scientists working in developing countries, as well as to research groups based in the world's least developed countries (LDCs) and other science- and technology-lagging countries. In addition, in

collaboration with the governments of Brazil, China, India and Pakistan, TWAS oversees the world's largest South-South fellowship programme. Under this scheme, young scientists from one developing country visit participating institutions in another developing country – particularly those mentioned above – to further their research, often by having access to equipment and materials not available at their home institution.

Institutions of scientific exellence in the developing world are included in a unique resource book, *Profiles of Institutions for Scientific Exchange and Training in the South*, produced jointly by TWAS and the Commission of Science and Technology for Sustainable Development in the South (COMSATS), based in Islamabad, Pakistan. The fourth edition of this book, published in 2007, lists 485 such institutions located in 65 different countries in the South and outlines their main scientific achievements, facilities and future plans.

Despite the perception that science in the South is lagging behind science being carried out in laboratories in the North, these 485 institutions provide evidence that top-quality research can be carried out in developing countries. And with a growing consensus that indigenous capacity in science and technology drives sustainable economic development, there is a need for more countries in the South to build their own scientific infrastructure – in terms of both human and institutional resources.

The purpose of this series of TWAS publications, which has been generously funded by the Packard Foundation, is to provide details about individual 'centres of excellence', including how they developed, how their research programmes are organized, their achievements, their strengths and weaknesses, and – most important – how they can

act as a model that other governments and organizations can follow when considering building scientific capacity. In this way, we hope the series will form a 'blueprint for a centre of excellence' that can be used by policy-makers and those involved in the administration of national science policies.

The choice of which institutions to include in the series was difficult. However, it was felt that if the selected institutions all focused on a similar research area, then comparisons between institutions and countries would be simplified, making it easier to draw valid conclusions once several institutions have been studied. We have therefore taken advantage of the existence of a network of institutions created thanks to a programme originally operated by the Third World Network of Scientific Organizations (TWNSO), a TWAS-affiliated organization also based in Trieste and recently transformed into the Consortium on Science, Technology and Conservation for the South (COSTIS), which focuses on indigenous and medicinal plants and the conservation and sustainable use of biodiversity. Despite the common theme, the institutions profiled in this series cover a wide range of activities, from the scientific validation of traditional medicines to the use of modern biotechnology. Taken together, however, these institutions are representative of a cross-section of countries in the South. They have also been instrumental in taking indigenous resources – in terms of local biodiversity – and transforming them into profitable commercial products available on local and international markets. In this way, these institutions are excellent examples of how capacity in science and technology can lead to innovation and socio-economic development.

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Introduction and History

Some 4,600 years ago, Huang Di, known as the 'Yellow Emperor', wrote what is believed to be the earliest text describing Chinese medicine. In his 'Canon of Internal Medicine', the emperor introduced the concepts of yin and yang (or a body in balance) and the five elements (earth, fire, metal, water and wood), which remain at the core of traditional Chinese medicine (TCM) to this day.

Although such concepts may not stand up to modern scientific scrutiny, many TCMs – including many species of medicinal plants – are being adopted and adapted by other medicinal philosophies, including modern allopathic medicine, as practiced in developed countries. Ginkgo biloba, which is used to improve blood flow and shows potential use in the treatment of Alzheimer's disease, and ginseng, reputed to help the body cope with stress, are just two examples.

While many traditional medical systems have become extinct, TCM continues to be an important component of the Chinese national healthcare system. One reason for this has been the support of the Chinese government, which, in 1957, established the Institute of Materia Medica, to study the resources, properties and preparations of TCMs.

In 1983, the Chinese government restructured a medicinal plant cultivation station of the Institute of Materia Medica to create the Institute of Medicinal Plant Development (IMPLAD), established under the auspices of the Chinese Academy of Medical Sciences (CAMS) and the Peking Union Medical College (PUMC).

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Visitors to IMPLAD are greeted by a statue of Li Shizhen (1518–1593), another of the great father-figures of traditional Chinese medicine. In 1578, Li published a 52-volume 'Compendium of Materia Medica' *(Ben Cao Gang Mu)* describing nearly 2,000 plants, animals and minerals believed to possess medicinal properties (see *Snaphots* box).

IMPLAD's remit is to help ensure the continued existence of the valuable heritage of TCM by applying the tools of modern science to ancient tradition. "The principal aims of the institute," explains Shi-lin Chen, IMPLAD's director, "are to protect, develop and utilize medicinal plant resources using modern scientific techniques."

In addition to its wide use in China, TCM has been steadily growing in appeal around the world. Its holistic approach to treatment provides people in many developed countries with an alternative to Western allopathic medicine.

This increasing demand for TCMs raises several issues. First, many medicines are collected from wild sources without any regulation. As a result, many populations of wild medicinal plants are now under severe pressure and are becoming endangered (see *Snaphots* box). Second, because the raw materials are often collected from a variety of sources, the active compounds within the medicines may vary in quantity, causing the medicines to vary in quality and effectiveness. Finally, and increasingly, there is a need to convince a global market of the effectiveness and safety of such traditional remedies using scientific principles.

CHINA'S GREATEST NATURALIST

• *Li Shizhen (1518–1593), a renowned pharmacist of the Ming Dynasty, is considered to be China's greatest naturalist. Li's 52-volume pharmacological work* Ben Cao Gang Mu *(Compendium of Materia Medica), published in 1578, describes 1,892 herbs, animals and minerals, offering detailed information about their appearance and medical uses.*

The work was the product of a lifetime of research, both in the field and in sorting through the existing literature. Though used as a pharmacopoeia, the compendium is also a treatise on botany, metallurgy, mineralogy and zoology. Regarded as the most comprehensive work ever written on TCM, it lists all the plants, animals, minerals and other objects believed at the time to possess medicinal properties. Li arranged these in 16 categories: earth, fire, water, metal and stone, grass, cereal, vegetable, fruit, wood, utensil, worm, scale, shell, bird, beast and man.

The compendium had a considerable influence, and not only in China. In 1607, it was introduced to Japan. By the 18th century, it had made its way to Europe, where it captured the interest of such naturalists as Carl von Linné and Charles Darwin, who both referred to it in their work. Parts of Ben Cao Gang Mu *would eventually be translated into Latin, French, German, Japanese, Korean and Russian.*

SNAPSHOTS

> *"The principal aims of the institute are to protect, develop and utilize medicinal plant resources using modern scientific techniques."*

CONSERVING MEDICINAL PLANT BIODIVERSITY

• *Since its foundation, one of IMPLAD's priorities has been finding ways to conserve and cultivate China's wild medical plants. Its first priority has been to rescue plants on the verge of extinction. Among these is the plant used in 'bulbus fritillariae cirrhosae', a popular traditional Chinese medicine for relieving coughs and eliminating phlegm that has been in use for more than 1,000 years. Scientific tests have demonstrated the plant's efficacy. In the Chinese pharmacopoeia, 'bulbus fritillariae cirrhosae' refers to the bulbs of four related species, of which the most widely used is the tendril leaf fritillary (*Fritillaria cirrhosa*).*

F. cirrhosa *grows in the Tibetan plateau region, where severe weather and high altitude limit its reproduction. Most fritillary bulbs are collected from the wild to supply the roughly 400 companies in China that make fritillary-based products, which account for an estimated US$400 million in annual sales. Not surprisingly, supplies cannot keep up with the ever-growing demand, and the plant is in danger of extinction.*

IMPLAD researchers devised a two-part plan for assuring the plant's conservation. First, they developed a system of cultivating F. cirrhosa *in its natural environment. This marked the first large-scale 'natural fostering' project for the sustainable use of a medicinal plant. Second, they looked for alternative sources for the popular remedy. Researchers identified five related species of fritillary having similar chemical compositions to the tendril leaf fritillary. All have the advantage of being easier to cultivate. Natural fostering of* F. cirrhosa*, combined with the cultivation of alternative species, should help ensure a sustainable supply of this ancient and effective remedy.*

SNAPSHOTS

Then and now

"In 1983, when IMPLAD was inaugurated, there was a staff of just 60 people," notes Chen. "We now have more than 600 staff, including 150 professors and associate professors, 120 postgraduate students and one member of the Chinese Academy of Engineering. Yet, we are still a very young institution, with more than 80 percent of our project investigators under 45 years old. These young scientists have a high level of education and are energetic researchers."

PEI-GEN XIAO, honorary director of IMPLAD

• Pei-gen Xiao is a recognized leader in the field of traditional Chinese medicine, as well as a world-renowned ethnopharmacologist. He has been called a 'living dictionary' of TCM.

Xiao graduated in 1953 from Amoy University, China, with a degree in biology. After graduation, he served at the Chinese Academy of Medical Sciences' Institute of Materia Medica.

When this institution was transformed into IMPLAD in 1983, Xiao was named director of the new institution. In 1996, he became its honorary director and head of its Key Laboratory on Resource Utilization and Conservation of Chinese Materia Medica.

Xiao specializes in the integration of the traditional experience and modern scientific knowledge of TCM, as well as ethnopharmacology, a field to which he has made great contributions both at home and abroad.

He played a leading role in the establishment of the systematic investigation and scientific studies on TCM resources. In the early 1950s, for example, he organized and conducted a nationwide survey on Chinese materia medica, travelling throughout China. During the survey, Xiao investigated the botanical origins of many plants used in TCM, discovering one new genus, 32 new species and 11 new varieties.

He has published more than 500 scientific papers and 20 books. In honour of his outstanding scientific achievements, Xiao was elected a member of the Chinese Academy of Engineering in 1994. In the same year, he was elected president of the International Society on Ethnopharmacology.

In the context of international calls for the conservation and sustainable use of natural resources, the Chinese government renewed its commitment to the institution in 1996, funding a major research programme aimed at the conservation of the country's wild medicinal plants.

The growing global market for TCMs meant that many threatened species were under increasing pressure. It also meant that China's medicinal plants were an increasingly valuable economic resource, which, to be fully exploited, would require improved quality-control standards and scientific validation. The government's 2002 report 'Outline of

KEY PERSONNEL

SHI-LIN CHEN, director of IMPLAD, and director of the Research Centre of Resources and Conservation

• Shi-lin Chen was named director of IMPLAD in 2004, and director of IMPLAD's Resources and Conservation Research Centre in the same year.

His research interests include studies on medicinal plant resources and cultivation, the authentication of medicinal plants by DNA bar-coding, functional genomics of medicinal plants, tissue culture and the production of active components.

He has published more than 100 papers in scientific journals, as well as seven books. He is currently editor of the *China Journal of Chinese Materia Medica, Chinese Traditional and Herbal Drugs* and *World Sciences and Technology*. He is the recipient of the Chinese government's Special Subsidy and the Second Prize Project of the National Sci-Tech Advance Award.

Chen is a research fellow and visiting professor in the department of applied biology and chemical technology of Hong Kong Polytechnic University, a visiting professor at the Hainan Institute of Medicinal Plant Development, secretary of the GAP Association of Chinese Medicinal Material, and deputy secretary of the International Association of Chinese Medicine.

Chen has visited a number of countries, including Germany, Italy and Japan, for research and to advance the modernization of traditional Chinese medicine.

Chen received his BSc from Hubei College of Traditional Chinese Medicine in 1982, and his MSc and PhD from Chengdu University of Traditional Chinese Medicine, in 1988 and 2001, respectively. Chen has also received training from the Royal Botanic Garden, Kew, UK.

Modernized Development of Chinese Medicine (2002–2010)' addressed both concerns, calling for continued development of the traditional medicine industry, while identifying as a 'key task' the sustainable use of herbal medicinal resources.

For the past decade, therefore, IMPLAD has benefited from the Chinese government's realization that the institute is ideally suited to handle both challenges: scientifically validating TCMs and improving quality control so as to exploit international markets. At the same time it works to ensure the conservation and sustainable use of the country's medicinal plant resources.

IMPLAD's research focuses on evaluating Chinese herbal products, medicinal plants and fungi, chiefly in the areas of neuropharmacy, immunology and cardiovascular health. TCMs for gastrointestinal, bacterial and inflammatory conditions, as well as cancer, are also tested. In addition, the institution is seeking to develop new methodologies and technologies for pharmacology and toxicology.

The institute's research typically begins with taxonomy: identifying a plant used in TCM to study. Next, chemistry comes into play, as researchers isolate, extract and identify any active components. Quality-control follows, in which herbal components are standardized and checks on other attributes, such as shelf life, are made. Finally, pharmacology and toxicology studies are carried out to determine standard formulae and doses and to test for positive effects as well as any undesired side-effects. IMPLAD is currently investigating about 20 Chinese herbs. Two have shown potential medicinal properties, including one that seems to enhance learning and memory.



The institute's researchers work either with extracts of TCM or pure compounds. The ideal in Western medicine is to use single compounds. But, if TCM works, why, they ask, should money be spent to further refine it? Moreover, in many cases, it is not known if a single compound will work by itself. In China, most medicinal products are based on selected fractions of whole plant extracts. For this reason, the pharmacology is more difficult because, instead of dealing with a single compound, the scientists must contend with interactions between five to ten compounds.

Despite being a relatively young institution – both in terms of its staff and the fact that it was established just 25 years ago – IMPLAD has achieved a series of notable successes. These include research on the cultivation of *Gastrodia elata* (an endangered medicinal plant of the orchid family), new drug development from *Fagopyrum dibotrys* (perennial buckwheat), comprehensive research on the utilization and development of *Hippophae rhamnoides* (seaberry), and research and development on *Ganoderma lucidum* (Reishi, known as the 'mushroom of immortality').

In the past five years, the institute has made significant progress in the wild-breeding of rare and endangered species of medicinal plants; research on mycorrhizal biology (the relation between beneficial fungi and root systems); new drug development from medicinal plants; research on developing standards for TCM; establishing a National Medicinal Plant Gene Bank; and selecting seeds of new species of medicinal plants.

Institutional Structure

The headquarters of IMPLAD are located in the Zhongguancun Scientific and Technical Zone of Beijing, a 100-square kilometre science park known as China's Silicon Valley, which hosts 138 top research institutions and 56 higher-education institutions, including the Chinese Academy of Sciences, Peking University and Tsinghua University, as well as some 6,000 high-tech companies. IMPLAD lies within an area of 65 hectares that houses the laboratories and administrative offices, an ornamental garden featuring many examples of plants used in TCM, production facilities for spin-off companies, glasshouses, and fields for plant propagation and horticultural trials.

In addition, IMPLAD has established three branches in the subtropical zone of southern China, where climatic conditions allow a different range of medicinal plant species – some 3,000 in total – to be grown. These centres are located on the island of Hainan and in the provinces of Guangxi and Yunnan, both of which border Vietnam. Indeed, the medicinal plant garden at IMPLAD's Guangxi branch is the largest in Asia and among the largest in the world.

XIAO-BO SUN, deputy director of IMPLAD

• Xiao-bo Sun became the deputy director of IMPLAD in 2007. In addition to being a PhD supervisor at the TCM University of Heilongjiang, Sun has served as an evaluation expert for China's national-level new drugs, basic drugs and progress in science and technology policies and for China's National Science Foundation, which awards research grants to scientists throughout the country.

Sun has received numerous national and regional awards for his scientific research, including the national Innovation Prize in Science and Technology. He has received funding for 40 national and provincial projects, including his research into the herbal remedy 'long ya guanxin', which received the equivalent of US$800,000 from the National Development and Reform Commission as part of the special fund to reinvigorate the industrial base in northeast China.

He has published more than 100 academic papers, edited two monographs and co-edited another seven. Sun is actively involved in international exchange and cooperation, having studied in Japan and carried out collaborative research in Singapore, South Korea, Thailand and the United States.

At the Beijing site, research is divided into five departments, focusing on the following scientific disciplines:

- medicinal plant cultivation;
- resources and conservation (a National Key Laboratory);
- natural medicine chemistry;
- pharmacology and toxicology; and
- biotechnology.

Research Centre of Medicinal Plant Cultivation

Established in 2004, the Research Centre of Medicinal Plant Cultivation is the most recent addition to IMPLAD's focus areas. The department consists of three sections: cultivation technology, plant conservation and seeds. Its research focuses on:

- identification and characterization of new species of medicinal plants and basic genetic studies;
- standardization and quality control of seeds;
- development of standardized cultivation techniques for medicinal plants;
- prevention and elimination of diseases and insect pests;
- determination of the influence of environmental factors on the quality of medicinal plants; and
- cultivation of medicinal plants in wild conditions.

Quality seeds

The success of any commercial crop begins with quality planting material, and a major IMPLAD programme is dedicated to the improvement of seed quality.

"Whereas most crops are available as well-characterized varieties," explains Xianen Li, head of the Research Centre of Medicinal Plant Cultivation, "medicinal plants are usually sown as heterogeneous mixtures by farmers using what they have saved from their previous crop." As well as potentially increasing the risk of carrying over pests and diseases from the previous season, such mixtures often have poor agronomic qualities. For example, germination rates might be low and not all seeds will germinate at the

IMPLAD REGIONAL BRANCHES

• *IMPLAD's three regional branches are all in southern China, a region that enjoys a subtropical climate, allowing the cultivation of a different range of plant species.*

The 22-hectare Yunnan branch, in Jinghong, focuses on the introduction, cultivation and conservation of germplasm resources of tropical and subtropical medicinal plants, as well as the classification and utilization of ethnomedicine. More than 1,500 species of tropical and subtropical medicinal plants, brought in both from other parts of China and abroad, are cultivated here.

Located in Xinglong, the 14-hectare Hainan branch also focuses on the introduction and cultivation of tropical and subtropical medicinal plants. The branch, which is responsible for propagating 600 species of medicinal plants, has successfully introduced 16 foreign species, such as clove and nutmeg.

The Guangxi branch – Guangxi Botanical Garden of Medicinal Plants – in Nanning, is spread over 220 hectares. Its main objectives are to introduce, collect, conserve, develop and utilize authentic species of traditional Chinese medicine; to research the standardization of cultivation technologies for medicinal plants; and to set up a manufacturing demonstration base. Nearly 3,000 species of medicinal plants have been introduced and cultivated. As the largest botanic garden of medicinal plants in China, it is also a major tourist attraction, drawing more than 100,000 visitors a year.

SNAPSHOTS

> *"The success of any commercial crop begins with quality planting material."*

XIANEN LI, director, Research Centre of Medicinal Plant Cultivation

• Xianen Li was appointed director of IMPLAD's Research Centre of Medicinal Plant Cultivation in 2004.

His research interests include cultivation, resource collection and conservation, breeding, seed standardization and quality examination of medicinal plants. He is the author of more than 40 scientific papers and three books. Li received his BSc from Nanjing Agricultural University in 1985.

same time. This leads to crops that do not mature evenly and a final product with variable quality.

To address these challenges, IMPLAD scientists have collected germplasm of many medicinal crops from farmers' fields and have begun to identify the best breeding lines in order to develop standard varieties.

"These varieties will have greater uniformity, improved properties in terms of their active medicinal ingredients, and higher yields," states Li. "One species that we are working on," says Jian-he Wei, a professor focusing on the breeding of medicinal plants, "is *Platycodon grandiflorum* (jie geng or balloon flower)." This species is used widely in Chinese medicine to treat lung and throat conditions, by inhibiting coughs and reducing phlegm. "We are trying to breed new varieties by developing hybrids through cross-fertilization."

Allied to the use of molecular markers for breeding purposes and chromatography methods to identify and measure the concentrations of active ingredients, such research can also help to distinguish between factors that are genetically determined and qualities of the plant that are affected more by environmental conditions.

"Once we have obtained seeds of a standard variety, it is also important that we can guarantee how those seeds will grow," says Li. IMPLAD is therefore developing a quality profile for each variety that includes the germination rate, thousand grain weight (a measure of how much stored 'energy' is contained in a batch of seeds), varietal purity, and cleanliness (i.e., the absence of soil debris, weed seeds or other potential contaminants).

"Our aim is to produce seeds of guaranteed quality for a number of medicinal plants for distribution to farmers throughout China," states Li.

Good Agricultural Practices

"China is the world's largest producer of medicinal plants," observes Li, "cultivating more than 200 species on around one million hectares of land."

"The government pays a great deal of attention to agricultural practices," he says, "and, since 1998, has issued a series of standards to which the cultivation of crops must comply. These standards are similar to the 'Good Agricultural Practices' (GAP) followed in many developed countries."

To date, IMPLAD scientists have developed GAP protocols for some 150 species of medicinal plants, including one for the production of *Artemisia annua*, the source of an anti-malarial compound, which has been published by the World Health Organization (WHO). IMPLAD scientists are currently working on GAP protocols for an additional 15 medicinal plant species.

To develop these protocols, field trials are carried out at either the Beijing headquarters or at one of the three field stations in the south of the country, depending on

> *China is the world's largest producer of medicinal plants.*

the climatic conditions required. Current research in the department focuses on several common Chinese medicinal plants, including huang-chin (*Scutellaria baicalensis*), which has antibacterial properties, chaihu (*Bupleurum chinense*), used to reduce fevers, and Asian ginseng (*Panax ginseng*).

IMPLAD scientists are also attempting to develop biological control procedures for the main pests and diseases of medicinal plants so that the use of pesticides, which may leave potentially toxic residues in the medicinal products, can be minimized or avoided all together.

"For example, probably the most important disease affecting medicinal plants is root rot, which can seriously affect ginseng," explains Jian-he. At IMPLAD, three senior researchers are engaged in tackling this issue and aiming to develop suitable biological control procedures.

Research Centre of Resources and Conservation

The Research Centre of Resources and Conservation has been designated a 'National Key Laboratory', meaning that its facilities and expertise are among the best in the country in its subject area, and thus the laboratory is considered a national asset.

As well as being responsible for overseeing the maintenance of the 3,000 species of living plants distributed between IMPLAD's headquarters in Beijing and the three branches in the south of the country, the Research Centre of Resources and Conservation also oversees the institute's collection of preserved plants, animals and minerals with medicinal properties.

"The herbarium collection is 40 years old and is derived from the collection of the original Institute of Materia Medica," says Baoli Li, the curator of the museum. "At IMPLAD, we have some 90,000 samples of more than 7,000 plant species." These specimens are preserved between sheets of paper in a specially designed room to prevent them from becoming damp and deteriorating. In many cases, species in the collection are represented by more than one specimen as they have been collected from different regions of the country and therefore their medicinal properties may differ, Baoli explains.

Also under Baoli's stewardship are some 13,000 pickled or dried samples of plants – mostly preserved in antique-looking jars – as well as animals and minerals.

"Nearly everything in the Chinese pharmacopoeia is present in this collection," continues Baoli, "including the 500 or so medicines in common use in China today."

The impression of a dusty and dated museum, however, is somewhat misleading, as IMPLAD, like many other organizations that traverse the boundaries between traditional knowledge and modern science, has created a searchable database of its collection that is available on CD. This is important, as under the 1992 International Convention on Biological Diversity (CBD), sovereign states own their indigenous biodiversity and, if this biodiversity is exploited in any way, the nations are entitled to share in the profits. By documenting traditional knowledge about China's medicinal plants, IMPLAD is helping to protect its nation's natural heritage from exploitation by so-called 'bio-pirates' that may develop commercial products based on this knowledge and claim that their patent is 'novel', whereas it is actually based on centuries-old information.

As a National Key Laboratory, the research centre and its herbarium and other collections are an invaluable resource, not only for the institute's own scientists, but also for researchers from across China and elsewhere who wish to compare specimens that they are working on with well-characterized specimens in this unique reference collection.

The department is especially valuable in that it is equipped to do DNA bar-coding, a digital authentication system in which a short fragment of the genome is used to identify a specimen. "DNA bar-coding technology will significantly promote traditional taxonomy," Yong Peng, associate professor in the research centre, predicts.

One of the main contributions of the department is its survey of the country's medicinal plants. The centre's researchers use modern techniques – including remote sensing, geographical information systems (GIS) and global positioning systems (GPS) – to investigate the natural distribution of medicinal plants. The centre also runs the National Medicinal Plant Gene Bank, for which they have collected more than 20,000 viable seed specimens.

> *"Whereas allopathic medicine targets specific receptors, TCM aims to bring the whole body into balance."*

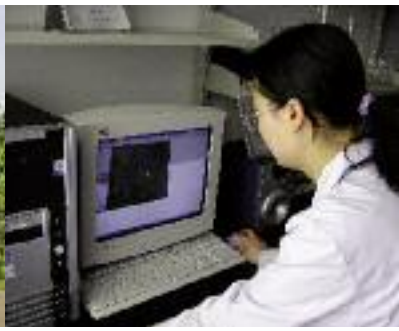
Research Centre of Natural Medicine Chemistry

What may be termed the 'drug development pipeline' begins in the Research Centre of Natural Medicine Chemistry, which consists of four sections: phytochemistry, natural products chemistry, analytical chemistry and pharmaceutics.

IMPLAD is fortunate to be able to rely on the expertise of professor emeritus Yang Junshan. The institute's former director of research can call on more than 40-years' experience and the publication of more than 200 papers in phytochemistry to provide a guiding hand to the department's relatively young scientific staff.

The research centre itself is currently headed by Jian-min Chen, one of 10 professors teaching at the centre, which also has 10 associate professors and 13 support staff.

"Our aim is to isolate and identify active compounds from natural products," says Chen. "Chinese traditional medicine has also combined different plants into compound formulae, so we are also interested in identifying the effective fractions from these mixtures and developing compound-formula medicines ourselves."



Whereas allopathic medicine targets specific receptors, TCM aims to bring the whole body into balance. "Preliminary studies suggest that, although the mode of action of TCMs differs from Western medicines," says Chen, "they do work. We are now trying to find specific evidence for this 'balance' within the body."

To date, thousands of chemical entities have been isolated from natural products, and many have been subjected to pharmacological screening. "From these, we have

ZHONG-MEI ZOU, director, Research Centre of Natural Medicine Chemistry

• Zhong-mei Zou was named director of the Research Centre of Natural Medicine Chemistry in March 2005, taking over from former director Jian-min Chen. Prior to this, she had served as the department's deputy director.

Zou has worked in the field of natural products chemistry for more than 24 years. Her primary research interests are purification and structural identification of naturally occurring compounds that may have potential in treating cancer, age-related conditions and infectious diseases. She has authored or co-authored 80 peer-reviewed publications and seven books.

She also works on the research and development of TCM products, including the identification of active constituents, quality control, and efficacy and safety evaluation. Since 1999, she has collaborated with the Mount Sinai Medical School, New York, USA, on TCMs for allergic diseases. Zou received her master's degree in pharmacognosy and PhD in medicinal chemistry from Peking Union Medical College, in 1990 and 1998, respectively.

identified some interesting lead compounds," adds Chen. "We hope to develop some of these into actual medicines."

IMPLAD scientists, for example, have identified a new chemical entity in celery (*Apium graveolens*) for treating stroke that has been approved by the SFDA (the Chinese national drug agency, the standards of which are adapted from the European Union and US Food and Drug Administration models). An effective fraction and an active compound isolated from *Pueraria lobata* (also known as kudzu) are also showing promise in the treatment of blood circulation problems.

Scientists in the Research Centre of Natural Medicine Chemistry have also been given the responsibility for establishing quality control systems for TCM. "Because the composition of the key botanical ingredients can vary significantly between batches," admits Chen, "it is notoriously difficult to control the quality, efficacy and safety of many TCMs."

The final task of the centre is drug formulation and delivery. Rather than relying on traditional methods, IMPLAD scientists are investigating modern drug delivery systems such as the inhalation of aerosols or the ingestion of slow-release capsules to improve the efficacy of the active compound.

PESTS OR PRODUCTS?

• *The Research Centre of Natural Medicine Chemistry is examining ways to control alien invasive plant species – plants which, after being introduced into a country, grow out of control. Such invasive species can create imbalances in ecological systems and also cause allergies and other health problems. Solutions for controlling them, says department head Jian-min Chen, are to be sought not only in an understanding of their growth mechanisms, but also in finding profitable uses for the plants.*

For instance, in the 1970s, Pueraria lobata *(or kudzu) began to spread out of control in the USA, its fast-growing vines invading valuable crop land, and even climbing up abandoned houses and utility poles. Yet, in China, far from being a nuisance weed,* Pueraria *is harvested in the wild and cultivated as a medicinal plant used to treat headaches, tinnitus and dizziness. Indeed, it is considered one of TCM's 50 'fundamental herbs'.*

*"If there are profits to be made from a plant," Chen points out, "its growth will be controlled automatically through harvesting and utilizing it." The issue is an important one for China, as invasive species have caused as much as US$6 billion a year in damages. One example is the water hyacinth (*Eichhornia crassipes*), a floating plant that grows in rivers, blocking their flow: One region has spent nearly US$2 million in an effort to control these weeds.*

"*The Research Centre of Natural Medicine Chemistry is examining ways to control alien invasive plant species.*"

"Typically, we use injections, but, because of cost and safety concerns, we are looking for ways to replace these," adds Chen.

Research Centre of Pharmacology and Toxicology

The Research Centre for Pharmacology and Toxicology consists of four sections: pharmacology, molecular pharmacology, pharmacokinetics and toxicology. Its 20-member staff includes eight professors and associate professors.

"Our centre uses both *in vitro* and *in vivo* techniques in pharmacological and pharmakinetic research," says department director Xin-min Liu. "We are responsible for evaluating the safety of natural products and TCMs, and especially their effects on neurology and psychiatry, as well as the digestive, endocrine and immune systems, and the blood vessels that serve the brain."

"In the past decade," Liu says, "in collaboration with the Chinese Cosmonaut Training Centre, we have developed important computer-aided control and image-analysing systems for pharmacological research." Such systems as the water maze allow researchers to observe the behaviour of laboratory animals under the influence of various drugs. Using these analysis tools, says Liu, researchers can "combine the advantages of bioinformatics, pharmacology, molecular biology and electro-engineering, with the specialized knowledge of traditional Chinese medicine."



"To date, we have screened over 50 Chinese herbs for their efficacy in treating cognitive deficiencies, depression and insomnia, cardiovascular complaints, hypertension and stroke, as well as for anti-cancer properties (against ovarian and cervical cancer and leukaemia)," adds Liu.

Pharmacokinetics

Pharmacokinetics refers to the study of the human body's absorption, distribution, metabolism and excretion of drugs. In seeking to develop quality-control standards and determining dosages, drug absorption (how pharmaceuticals are absorbed by the body after their administration) and metabolism (any changes in the chemicals once

XIN-MIN LIU, director of Research Centre of Pharmacology and Toxicology

• Xin-min Liu was appointed director of IMPLAD's Research Centre of Pharmacology and Toxicology in March 2005. Prior to this, he served as vice-director of the institute's Research Centre for Natural Medicine (2003–2005).

Liu received his BSc degree in 1984 from Hunan Medical University, Changsha, and came to IMPLAD as a research assistant in the same year. He later obtained his master's and MD degrees from Peking Union Medical College (PUMC), in 1991 and 1996, respectively.

He has been an executive member of the World Federation of Chinese Medicine Association's Committee of Chinese Material Medica, since 2004, and of its Committee of Clinical Trials for TCM, since 2006.

Liu has published more than 30 scientific papers, and has edited the books *Modernization and Globalization of Traditional Chinese Medicine* and *Modernization of Chinese Material Medica*. He serves as editor for the journals *World Science and Technology*, and *Basic Science and Engineering*.

His research interests include developing new techniques and methods for evaluating the efficiency of TCM, and neuro-pharmacological research with Chinese herbs, including treatments for improving learning and memory deficiencies. Liu has developed computer-analysis systems for learning and memory and for depression, making use of advances in bio-medical sciences, information technology, electronic engineering and computer technology.

absorbed) are crucial factors. And it is on these factors that the department's pharmacokinetics research focuses.

The research centre uses liquid chromatography-mass spectrometry (LC-MS), a technique that couples the physical separation capabilities of liquid chromatography with the chemical analysis capabilities of mass spectrometry. LC-MS allows researchers to separate the chemical compounds of plants, identify them and measure their concentrations. Since the spectra of plants are complex, researchers also use the approach known as 'metabolite fingerprinting', which provides information from spectra of the total compositions of metabolites.

As one of the principle experts responsible for drafting and designing national policy on the modernization and internationalization of TCM for the Chinese Ministry of Science and Technology, Liu says, "The scientists in the department could also become a bridge between Chinese government agencies and foreign scientists in international cooperation efforts in TCM research. Currently, we actively cooperate with Canada, Luxembourg, Pakistan, Peru and the UK, especially on the pharmacology of nerve cells and anticancer agents, which receive strong support from the government."

To assist with this work, the department has access to a state-of-the-art controlled-environment animal house, where researches can conduct behavioural experiments under optimal conditions (see *Snapshots* box).

Research Centre of Biotechnology

The Research Centre of Biotechnology consists of four sections: molecular biotechnology, fermentation biotechnology, mycorrhizal biology and molecular ecology. Its 12-member staff, currently headed by Shun-xing Guo, focus their research on:

- molecular biotechnology of medicinal plants;
- medicinal microorganisms;
- fermentation biotechnology of medicinal microorganisms;
- tissue culture and cytobiology of medicinal plants;
- mycorrhizal biology of medicinal plants; and
- molecular ecology of medicinal plants.

ANIMAL HOUSE FACILITY

• The facilities of the Research Centre for Pharmacology and Toxicology include a 600-square-metre SPF (specific pathogen free) animal house for experiments requiring the use of rats and mice, and a 300-square-metre ordinary animal house for guinea pigs and rabbits.

Unlike similar facilities at Western institutes – which, due to the controversy surrounding animal testing, tend to be hidden away – the one-storey brick building that houses these sits in the centre of the IMPLAD campus.

Animals are brought in and out through one doorway, while scientists and technicians enter and leave through a special service door and corridor. Practices such as the wearing of special protective clothing and shoes ensure good hygiene and minimal contact between humans and animals. All rooms are controlled for temperature, humidity, ventilation and lighting.

As well as facilities for rearing animals, there are five experimental labs in the animal house. The animal houses are certified under national quality standards that, in China, are increasingly being brought into line with those of the European Union and the United States.

“Over 80 percent of the world’s population depend on traditional plant-derived medicines for their health needs.”

The research centre's biochemistry, histotechnique and molecular genetics laboratories are packed with sophisticated equipment. For example, its electron microscopy suite can carry out histochemistry research (which combines biochemistry and histology techniques to study the chemical constitution of cells and tissues), with an automatic microtome for making sequential sections of tissue preparations, a fluorescence microscope and a transmission electron microscope. The molecular laboratories contain equipment for doing polymerase chain reaction (PCR) amplification of target DNA sequences and electrophoresis to help separate and identify them, a centrifuge and an ultra-low-temperature freezer. The biochemistry laboratory is equipped with a UV-visible

KEY PERSONNEL

SHUN-XING GUO, director, Research Centre of Biotechnology

• Shun-xing Guo was named director of IMPLAD's Research Centre of Biotechnology in 2004.

Since 1986, he has focused on the research of medicinal fungi, especially on medicinal molecular ecology and the activity of plant secondary metabolites. He has published more than 200 scientific papers and three books. He was awarded the Excellent Doctoral Graduate Student prize by the Chinese Education Ministry in 1999.

Guo received his MSc and PhD from Peking Union Medical College (PUMC) and the Chinese Academy of Medical Sciences (CAMS), in 1989 and 1995, respectively, where his research focused on medicinal fungi and cell biology.

spectrophotometer and high-performance liquid chromatography (HPLC) apparatus. A high-pressure steam sterilizer, fermenter, freeze drying equipment and various incubators are also available.

To date, the centre has collected and carried out research on several thousand samples of medicinal fungi. Notable achievements include its research on endangered species of medicinal fungi (including *Grifola umbellata*, *Cordyceps sinensis* and *Ganoderma lucidum*) and recent work on endophytic fungi (fungi that live asymptomatically inside plant tissues) from medicinal plants.

In its studies on developing anti-tumour drugs, the department has isolated several hundred endophytic fungi from medicinal plants (including *Anoectochilus roxburghii*, *Dendrobium candidum* and *Ganoderma lucidum*). Several have been tested for their anti-tumour activities, both *in vitro* and *in vivo*. Other studies have focused on identifying and developing potential anti-HIV drugs from fungi. One bioactive strain found to be effective against the HIV-1 virus was identified after screening dozens of endophytic fungi from medicinal plants harvested from the wild. An advantage of such fungal products is that they could be produced on an industrial scale by bio-fermentation, which also means their quality can be closely controlled.

Scientific support services

Library

The IMPLAD library subscribes to 130 monthly journals and periodicals, most of which are Chinese. Topics covered include: agriculture, entomology, organic chemistry, natural product chemistry, pharmacology, toxicology and the conservation of medicinal plants.

English-language journals are available to IMPLAD students at the nearby Chinese Agricultural University, which boasts one of the country's finest collections of relevant scientific literature. The university is a fifteen-minute walk away, or just five minutes by bicycle. All IMPLAD staff and students have access to the university library's current periodicals and extensive archives.

Computer centre

The computer centre houses ten computers for undergraduate and postdoctoral students. An additional ten computers are housed in various laboratories. Using these terminals, students can search the databases of all Chinese journals from 1989 to the present. The centre staff also 'data mine' news stories and produce a monthly 30- to 40-page document called 'Medical and Medicinal Information' for department heads and research leaders, which allows them to keep in touch with developments in the field.

Greenhouse

IMPLAD recently opened a new greenhouse. The new structure, which features modern humidity and temperature regulation, displays nearly 1,000 species of medicinal plants, mostly introduced from tropical regions.

From Research to Commercialization

IMPLAD has a joint venture with the Beijing Kangerfu Pharmaceutical Industry Company Ltd., which was established in 1992, providing the company with technical support, primarily on quality control. In 1999, the pharmaceutical company expanded to a site on the newly developed outskirts of Beijing. It has four working plants and produces medicines in six different forms: capsules, soft capsules, drop pills, tablets, liquids and soluble powders.

Kangerfu employs 76 people, making it a mid- to large-sized operation. There are 40 professional staff in management and research and development, and 36 others who work on the production lines. The company has five departments: manufacturing, marketing, finance, supply and research and development. Because it is located in a technology park dedicated to promoting science- and technology-related enterprises, the company benefits from economic incentives such as reduced taxes.

Its major products include:

- niu huang jiedu jiaonang (main ingredients: bezoar and rheum), in a soft capsule, for colds and flu;
- niu huang shedan chuanbei wan (main ingredients: bezoar, snake gall and fritillary), in drop pill form, to reduce fever and flu symptoms;
- naoxuekang (main ingredient: leech), drop pills that improve brain function, for example, after a stroke.

The company also manufactures two so-called 'health foods', or dietary supplements. These are distinguished from pharmaceutical products in that they have not undergone the rigorous scientific and clinical trials required for medical use. However, their production still requires the use of good manufacturing practices with regard to hygiene, standardization and quality assurance. One of the products is claimed to protect against cancer, while the other aids digestion.

Kangerfu ensures that all its products receive State Food and Drug Administration (SFDA) approval and meet national Good Manufacturing Process (GMP) standards. In fact, the company's quality-control personnel check and maintain standards at each stage of production. Its suppliers of raw materials must meet Good Agricultural Practices (GAP), for example, and the company itself follows good manufacturing practices and Good Sales Practices (GSP).

China's GMP standards are less rigorous than certain international standards, but the country is making efforts to close the gap. Its goal is to bring them up to GMP standards enforced in the European Union. Yet researchers point out that it is difficult to compare Western and Chinese standards because the latter are based on the more intrinsically varied products of TCM.

This disparity in standards makes Chinese medicines difficult to export. International standards require each component of a pharmaceutical product to be identified, but many TCMs are mixtures, sometimes including extracts from as many as 10 plants. Thus, to break into international markets, manufacturers need to develop more advanced techniques of product characterization.

Kangerfu buys the raw plant materials it requires from suppliers in either dried or semi-dried forms. It then purifies the active fractions. Though its products are based on

traditional knowledge, the company uses advanced manufacturing technology to improve and add value to them. For instance, its laboratories for analytical assays are equipped with gas chromatography and high-pressure liquid chromatography separation and analysis equipment. All staff in Kangerfu's quality control department have at least bachelor's degrees.

Dried raw material is cleaned and then ground to powder. The powder is then made into capsules on the production line, where, for hygiene purposes, workers are required to change clothes twice a day.

Research and development is done by Kangerfu to identify active ingredients, in view of eventually meeting international standards. The incentive to reach an international market is not always there, however, because the market within China is so large. It is easier to produce 'health foods' to less stringent requirements than pharmaceuticals for the export markets.

The research and development carried out by Kangerfu also has its quality-control practices in place. In moves to bridge the gap between scientific research and the commercial market, the company is provided with technical support and expert advice from IMPLAD. The agreement with Kangerfu is one of a few such agreements that IMPLAD has with companies producing TCMs.

Close to the imposing main gates of the IMPLAD campus is a pharmacy that provides medicinal herbs and remedies direct to the public. All the products on sale have been certified by IMPLAD, which also provides the pharmacists with the best scientific advice for their use.

> *"IMPLAD scientists provide technical support and expert advice to private pharmaceutical companies."*

Measures of Success

Since its creation in 1983, more than 280 young scientists have received post-graduate training at IMPLAD. The majority of these were trained to the MSc level, yet nearly half have received PhD degrees.

Scientists at IMPLAD have also overseen the work of several students receiving PhD and MSc degrees in pharmacognosy (the study of natural medicine), granted by the State Council Degree Committee.

Other IMPLAD achievements include:

- research on quality-control and standardization of 65 of the most commonly used Chinese medicinal plants and their equivalents;
- a database of Chinese medicinal plant material and prescriptions;
- studies on the key technologies of prevention and control of pests and diseases of organic Chinese crude drugs; and
- research on the effects and safety of (the ordinarily toxic mineral) cinnabar in the TCM remedy known as 'zhu sha an shen wan' (which translates as 'cinnabar pill to calm the spirit'), used for anxiety, irritability and insomnia.

Recognition of IMPLAD's growing importance can be seen in terms of the funding it receives, which has increased tenfold from US$600,000 in 1996 to US$6 million in 2007.

Patents

Since 2005, IMPLAD has applied for 17 national patents, of which the following four were obtained:

- a method for the preparation and quality-control of a sustained-release remedy for cardiovascular disease;
- a herbal treatment for osteoporosis;
- a method for determining traces of *Panax notoginseng* saponins; and
- a method of preparing a double-layer sustained-release tablet of *Panax notoginseng* saponins.

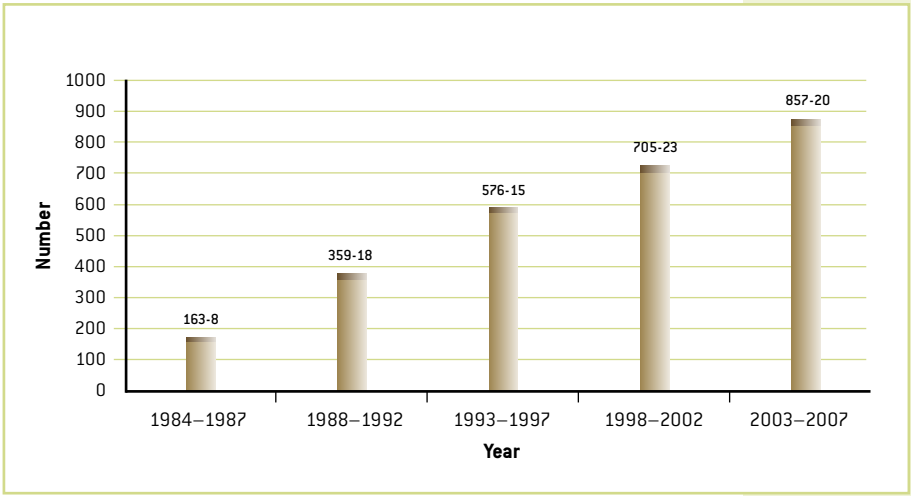
IMPLAD has been actively involved in international academic exchange and cooperation with more than 50 countries.

Publications

Researchers at the institute have published more than 2,500 papers in Chinese and international journals. Among the 100 monographs published are: *An Introduction to Chinese Materia Medica*, *The Cultivation of Medicinal Plants in China*, *Chinese Medicinal Mycology*, *The Application of Mass Spectrometry in Natural Product Chemistry* and *A Pictorial Encyclopaedia of Chinese Medicinal Herbs*. The most recent publications include: *Modern Chinese Materia Medica* (in four volumes) and *Introduction to the Sustainable Utilization of Chinese Medicinal Herb Resources*.

IMPLAD also provided major input to the World Health Organization (WHO) 'Good Agricultural Practice' (GAP) monograph on *Artemisia annua* (used for the treatment of malaria). This was the first monograph in China for a medicinal crop, rather than a food crop.

Fig. 1: Publications



Awards

Scientists at IMPLAD have won more than 70 scientific research awards from the Chinese Ministry of Health and other state authorities. The most recent awards include:

- Chinese National Science and Technology Progress Award (2006), for 'Systematic Studies on the Three-Dimensional Quantity Authentification of Chinese Medicinal Materials and their Cultivation Adaptability'; and
- Chinese Medical Science and Technology Award (2006), for 'Studies on the Key Technologies of Prevention and Control of Pests and Diseases of Organic Chinese Crude Drugs'.



Creating new research centres

Given the growing importance of TCM in China and the government's realization of its value – both in terms of its use in healthcare in the country and as a potential export commodity – IMPLAD expertise has been called upon to advise on the creation of a number of new research and development centres in the country. Six such centres have been established since 1996, including the:

- Centre for the Utilization and Conservation of Chinese Medicinal Herb Resources (a key research laboratory established by the State Administration of Traditional Chinese Medicine in 1996);
- Beijing Municipal Department of Pharmacognosy (a key research department established in 2002);

- Chinese Medicinal Herb Resource Conservation and Phytochemistry Laboratory (a key research laboratory established by the State Administration of Traditional Chinese Medicine in 2003);
- Laboratory for Investigation into the Chemical Basis and Resource Utilization of Chinese Medicinal Herbs (a key research laboratory established by the Ministry of Education in 2004);
- National Medicinal Plant Seed Resource Bank (2005).

Such reliance on the input of IMPLAD experts by the Chinese government is testimony to the high regard in which the institute is held by policy-makers in China.



International cooperation

Another measure of IMPLAD's increasing impact in the world of medicinal plant research is that the institute has been actively involved in international academic exchange and cooperation with more than 50 countries. To date, it has sent more than 30 researchers abroad – for example, to France, Germany, Japan, North Korea, South Korea, the United Kingdom (UK) and the USA – for training, study and collaborative research. In addition, IMPLAD researchers have participated in nearly 100 international conferences and academic exchanges.

The institute has also collaborated with a number of prestigious organizations and academic institutions, including Harvard University (USA), the University of British Columbia Brain Research Centre (Canada), Hong Kong Baptist University (China),

Karachi University (Pakistan), Cayetano Heredia University (Peru) and the Institute of Materia Medica (Vietnam).

Among its more active collaborations are those with the Royal Botanic Gardens, Kew (UK) and the UN World Health Organization (WHO).

WHO Collaborating Centre for Traditional Medicine in China

IMPLAD has been designated a WHO Collaborating Centre for Traditional Medicine since 1986. In this capacity, its goals are to:

- develop training programmes within the framework of IMPLAD projects for developing countries;
- undertake the exchange of personnel between China and other countries to facilitate mutual progress in relevant areas of science and technology;
- pursue cooperative research projects in which IMPLAD participates as a partner;
- exchange information concerning specific fields of medicinal plants; and
- engage in activities entrusted to it under the traditional medicine programme of the WHO regional office for the Western Pacific.

As the WHO Collaborating Centre in China, IMPLAD has welcomed more than 300 overseas delegations, involving more than 1,000 scientists, to participate in academic exchange. It has also hosted the training of 20 foreign scientists from such countries as Canada, India, Japan, Nepal, North Korea, Peru, South Korea, the UK and Vietnam.

Chinese Medicinal Plants Authentication Centre

In 1998, IMPLAD and the Royal Botanic Gardens, Kew, UK, collaborated to establish the Chinese Medicinal Plants Authentication Centre (CMPAC). The centre's chief aim is to provide scientific expertise for the authentication and, when possible, quality assessment of Chinese medicinal plants available on the UK market. (The UK holds the largest share of the TCM market in Europe, with more than 2,000 TCM clinics and 20 importing companies.)

The centre benefits from ready access to Kew Garden's extensive botanical libraries, plant collections and expertise in plant taxonomy and natural product research. The centre's activities include:

- developing a botanical reference collection of authentic TCMs representative of those sold in Europe (to date, 350 herbal drug samples have been collected from 16 Chinese provinces);

- creating 'fingerprint' libraries (anatomical, chemical and molecular) of Chinese medicinal plants;
- validating existing laboratory authentication and quality-control methods, and ensuring their compliance with UK and European Union regulatory systems;
- researching new authentication and quality-control methods; and
- providing an authoritative authentication service for Chinese herbal medicines sold on the international market.

The centre also encourages the conservation and sustainable use of Chinese medicinal plants by, for example, monitoring the use of those plants that are wild-harvested rather than cultivated, as excessive harvesting has resulted in many plants becoming endangered in their natural habitats.

"Despite its success, IMPLAD is not content to rest on its laurels."

Future Plans

Despite its progress over the past 10 years, IMPLAD, like any other successful venture, is not content to rest on its laurels. In fact, the institute has set out an ambitious plan for its future development that includes:

- establishing a demonstration centre for the cultivation of medicinal plants according to GAP standards;
- establishing a test centre for so-called 'green crude drugs' (cultivated without the use of chemical pesticides) to promote the standardization of TCM and medicinal raw materials;
- continuing research in new cultivation techniques so that wild plants do not need to be harvested;
- establishing quality standards, quality testing and market supervision for seeds and seedlings;
- advancing research in medicinal plant germplasm resources and the breeding of improved varieties; and
- increasing the use of biotechnology in medicinal plant cultivation.

To achieve these aims and solidify its position as a world leader in medicinal plant research, IMPLAD is actively seeking research partners in other developing countries. The institute's researchers believe that, with their experience in preparing traditional medicines for the modern market, they can help other developing countries develop their own traditional medicines to scientific standards.

The reason for this, explains Xin-guo Zhang, IMPLAD's Head of Foreign Affairs, is that "many developing countries rely on the use of traditional medicines. Just as the Chinese government has invested heavily in the research and development and promotion of TCM, especially in rural areas, so there is great potential for economic benefits for developing countries if they were to follow the same policy." To utilize such biological resources effectively, however, requires investment in scientific research so that the quality and efficacy of the medicines developed can be assured.

It is estimated that over 80 percent of the world's population depend on traditional plant-derived medicines for their health needs, and that its use is even higher in some developing countries. It could thus be said that the utilization of plants for medicinal purposes represents the largest use of biodiversity in the world.

Public Information

IMPLAD also takes seriously its obligations to the public – especially the younger generation – when it comes to informing them about the science it is carrying out. This is achieved mainly through opening up its 20-hectare medicinal herb garden, one of the most important of its kind in China.

With its impressive range of medicinal plants – currently some 1,200 species are represented – the garden serves not only to protect plant resources, but also to popularize traditional Chinese medicine and educate the public about this precious heritage.

Visitors, who pay an entrance fee of 15 Yuan (about US$2), are able to admire up close the impressive collection of plants, many of which are clearly labelled with both Chinese and scientific names, as well as information on their uses in TCM. Indeed, some 45,000 visitors – mostly children – visit the gardens every year.

Within the gardens is also a restaurant and tea room, the management of which is contracted out by IMPLAD, providing another source of revenue for the institute's research budget.

Conclusion

Traditional Chinese medicine represents a rich heritage dating back more than 4,000 years. As a government-supported institution, IMPLAD is, in effect, the official guardian of this invaluable cultural inheritance. This means that, in addition to government support, the institute benefits from its access to enviable resources. These include its herbarium, which, with its 90,000 samples, contains nearly everything in the traditional Chinese pharmacopoeia. It also includes the extensive knowledge and expertise of individuals such as IMPLAD's honorary director, Pei-gen Xiao.

At the same time, IMPLAD is a young, dynamic institution with a research staff well trained in the most advanced techniques. Indeed, this combination of hoary tradition with modern science is what defines the institute and sets it apart from many other research centres in the developing world.

Traditional Chinese medicine represents a rich heritage dating back more than 4,000 years.

The institute's three branches in southern China extend the range of biodiversity available for its researchers to study. Also, IMPLAD benefits from its international connections, for example with WHO and Kew Gardens.

IMPLAD's principal challenge is to make further progress in translating its research into commercial products. "IMPLAD is a national institution, the principle task of which is undertaking basic research for national research projects," explains Zhang. Although it has great strengths in researching medicinal plants, continues Zhang, IMPLAD "has yet to realize its advantages in the area of innovation and intellectual property development. The challenge it faces is how to couple research with the development of new commercial applications."

The growing global market for TCMs means that they represent a potentially valuable economic resource for China. Thanks to many years of government support and a young and committed workforce, IMPLAD is well placed to play a key role in scientifically validating, standardizing, and ensuring quality control of TCMs. By doing so, it will not only help build China's export market for herbal remedies, and assist in maintaining – and, hopefully, improving – the health of the Chinese people, but also help to ensure the continued survival of this ancient heritage.

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TWAS

TWAS, the academy of sciences for the developing world, is an autonomous international organization that promotes scientific capacity and excellence in the South. Founded in 1983 by a group of eminent scientists under the leadership of the late Nobel Laureate Abdus Salam, TWAS was officially launched in Trieste, Italy, in 1985, by the secretary general of the United Nations.

TWAS has 880 members from 90 countries, over 85 percent of whom live and work in developing countries. A Council of 13 members is responsible for supervising the Academy affairs. TWAS is assisted in the administration and coordination of programmes by a secretariat, headed by the executive director. The secretariat is located on the premises of the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. UNESCO is responsible for the administration of TWAS funds and staff. A major portion of TWAS funding is provided by the Ministry of Foreign Affairs of the government of Italy.

The main objectives of TWAS are to:

- recognize, support and promote excellence in scientific research in the South;
- provide promising scientists in the South with research facilities necessary for the advancement of their work;
- facilitate contacts between individual scientists and institutions in the South;
- encourage South-North cooperation between individuals and centres of scholarship.

To achieve these objectives, TWAS is involved in various activities and collaborates with a number of organizations, especially UNESCO, ICTP and the International Council for Science (ICSU).

For additional information, see www.twas.org.

THE DAVID AND LUCILE PACKARD FOUNDATION

The David and Lucile Packard Foundation was created in 1964 by David Packard (1912–1996), co-founder of the Hewlett-Packard Company, and his wife, Lucile Salter Packard (1914–1987). Throughout their lives in business and philanthropy, the Packards sought to use private funds for public good.

Guided by the founders' values, the David and Lucile Packard Foundation supports both people and organizations with the aim of enabling the creative pursuit of science; conserving and restoring the Earth's natural systems; improving the lives of children; and advancing reproductive health.

For additional information, see www.packard.org.

EXCELLENCE IN SCIENCE

This series of booklets – published by TWAS, the academy of sciences for the developing world – highlights successful scientific institutions in the South and explains how their research has both been sustained over a number of years and is helping their host nations achieve sustainable economic development.

twas