grappling with. This was then followed by an equally informative lecture by Acharya on detector technology, how it is built, and what we measure using it. There could not be any doubt that the inquisitiveness of the teachers was aroused by these two talks.

Next the teachers were asked to explore the QuarkNet URL at Fermi National Laboratory. This was a good learning experience for all the participants. They were allowed to access some of the data collected by students elsewhere, as also see some of the posters prepared by them. Many of them were creatively thought-out problems. This provided an inkling into the nature of work that could be carried out using the detectors. They were helped in this by Bardeen and Peterson and also by Acharya and Raghava Varma. Later, in the evening the teachers were divided into four groups. One group was assigned the task of assembling the detectors, the other three were assigned the task of choosing one set of data to be analysed (the URL contains a number of options).

The next day the detector group started fabricating the detector, while each of the other groups tried to converge on what analysis they should do. After the morning tea session, the groups that were engaged in data analysis presented what they were going to look for, while the detector group started assembling the detector. All the resource persons were actively involved in assisting the groups while assembling. The participants were not just piecing together the equipment, but also simultaneously getting insight into the various aspects of the principles of physics involved. Often one had to sit with the teachers and explain the limitations. Each of the groups was first allowed to find the right path or suitable hints were given by the resource persons to help them come back on track. Similar methodology was adopted with the assembly team. In the afternoon, it was a moment of joy for the assembly team to see its detector detecting cosmic rays. With every count on the display unit of the data card, the smiles and surprises on the participants' faces got bigger! However, due to slow bandwidth of the Internet, it was not possible to store the data on the Fermi National Laboratory Grid. Team by team, participants were given a short time to present what they learnt from their efforts. Judging by the response of the participants, the meet was a big success.

The entire hardware kit used in the workshop was gifted to the participants for follow-up action by the QuarkNet team from USA. The detector is now set up at the Jawaharlal Nehru Planetarium, Bangalore by H. R. Madhusudana. It was felt that it would be useful to repeat such workshops in a few places around the country.

Rohini M. Godbole, Centre for High Energy Physics, Indian Institute of Science, Bangalore 560 012, India; **Raghava Verma,** Department of Physics, Indian Institute of Technology, Mumbai 400 076, India; **B. N. Chandrika,** Department of Physics, VVS First Grade College for Women, Bangalore 560 079, India; **H. R. Madhusudana,** Bangalore Association for Science Education, J. N. Planetarium, Bangalore 560 001, India
*e-mail: godbolerm@gmail.com

MEETING REPORT

Conservation of cycads in India*

Cycads are the most primitive seed plants characterized by a large crown of compound leaves and a stout trunk. They originated 300 million years ago and are often termed 'living fossils' as they have undergone little change compared to their Mesozoic ancestors. The gymnosperm order Cycadales comprises about 300 extant species in three families, viz. Cycadaceae, Stangeriaceae and Zamiaceae. *Cycas* is the only genus represented in India within cycads. Six species namely *C. rumphii*, *C. sphaerica*, *C. circinalis*, *C. beddomei*, *C. pectinata* and *C. annaikalensis* occur in India of which the last four are endemic. *C. beddomei*, endemic to the Cuddapah hills of Eastern Ghats is considered highly endangered. The exotic species *C. revoluta* is widely cultivated as an ornamental plant. Emergence of the Asian cycad scale, *Aulacaspis yasumatsui* (Hemiptera: Diaspididae) as an invasive pest of international importance that kills cycads, is threatening with the extermination of the endemic species in countries of its invasion. A native of the region between Thailand and China, the Asian cycad scale has recently spread to the Pacific, Caribbean, USA and Taiwan. It is quite possible that this scale may gain entry into India through infested planting material leading to the extinction of endemic cycads. In the backdrop of the threat of introduction of the Asian cycad scale, a workshop on conservation of cycads in India was held at Thiruvananthapuram. Incidentally, Kerala (erstwhile Malabar coast) happens to be the type locality of *C. circinalis*, the first known cycad described by Linnaeus in 1753. Papers dealing with every aspect of cycad study were presented and discussed in five sessions, viz. morphology and systematics; ecology, regeneration and ethnobiology; pests and diseases; distribution and documentation, and threats and conservation.

Cycads are characterized by many interesting morphological and physiological features that are distinct from other phanerogams. Long living leaves as well as stems with persistent pith and cortex comprising living parenchyma and concentric vascular cylinders have critically contributed towards the survival of cycads. The cycad–cyanobiont symbiosis that affords access to fixed nitrogen is yet another reason for their survival throughout tens of millions of years. All

Cycascircinalis – megasporophyll.

*A report on the Workshop on Conservation of Cycads in India held at Thiruvananthapuram during 17 to 20 July 2006, funded by the Indo-US Technology Forum, New Delhi.

cycads possess a suite of secondary metabolites which are toxic to consumers. These morphological and physiological features impart considerable phenotypic plasticity in response to the environment.

Cycad systematists reject the biological species concept, as clearly defined cycad species can interbreed and produce fertile offspring. Species are generally recognized based on the combined effects of geographical isolation and morphological disparity. Currently, 305 species belonging to 10–12 genera are recognized. Cycadophytes survived the great end-Permian extinction. The class flourished from middle Triassic to the middle Cretaceous and was a prominent element of the flora worldwide.

Until the mid-1980s, it was generally believed that cycads, like most gymnosperms, are wind-pollinated; but now it has been proven that insects, especially highly host-specific beetles, are the exclusive pollinators of several species of *Zamia* in North America. Among the non-beetle pollinators, the primitive thrips *Cycadothrips* are highly specialized pollinators of *Macrozamia* in Australia. It is presumed that the beetles colonized cycads recently from angiosperms. Hence cycads are alleged to have copied entomophily from angiosperms stealing their pollinators. Cycad–pollinator associations have evolved independently in each continent. Studies on interactions between the pollinators and their host cones have indicated that cone volatiles and thermogenesis act as the primary cues attracting pollinators to their specific host cones. Understanding the mechanisms of pollination in cycads is important in the context of conservation and management of cycads, as their regeneration is crippled by slow growth and dioecious mode of reproduction.

Cycads are propagated through seeds as well as vegetative means offering scope for artificial cultivation and replenishment of dwindling populations in their natural habitats. Current research reveals that successful propagation of cycads through *in vitro* techniques is also possible.

Cycads in their natural habitat constitute an important component of the forests of the Western and Eastern Ghats and northeastern states of India. Information on their uses – both traditional and modern – is vital for their protection and sustainable management. Indigenous people harvest the leaves, seeds and bark for medicinal purposes. Collection of male cones before pollen shed for use in traditional medicine prevents pollen flow from male to female. Besides being used in traditional food and medicine, cycads are now also being used in proprietary drugs available in the market. Large-scale harvesting of leaves for the urban floriculture industry in south India is a matter of concern.

Cycads attract a number of phytophagous insects, some causing considerable damage. In India, the scale insect *Ceroplastes rubens* (Coccidae) on *C. revoluta* and the plain cupid butterfly *Chilades pandava pandava* (Lycaenidae) on *C. revoluta* and *C. circinalis* are serious pests. The stem borer *Dihammus marianarum* (Cerambycidae) is a serious pest of *C. micronesica* in Guam. Most of the insects feeding on vegetative parts of cycads are polyphagous, utilizing cycads as alternate resources to their angiosperm hosts, but none of them are as serious as the Asian cycad scale. In Florida, *C. revoluta* and *C. rumphii* proved to be highly susceptible to this insect. In Guam and Taiwan, the endemic species *C. micronesica* and *C. taitungensis* respectively, are threatened. Control of the scale with chemical pesticides, especially in the natural habitats of endemic cycads, is practically impossible. Biological control through introduction and augmentation of natural enemies is the only means of its control in the event of its entry into India. The predators *Cybocephalus nipponicus* (Cybocephalidae), *Rhizobius lophanthae* (Coccinellidae) and the parasitoid *Coccobius fulvus* (Aphelinidae) are promising candidates against the scale.

Cycads are prone to infection by several fungal pathogens causing leaf spot, blight, ovule rot and tuber rot diseases. Cycas Necrotic Stunt Virus, a NEPO virus causing chlorotic and necrotic spots on the foliage in Japan, is the only viral disease known to affect cycads. Though not fatal, fungal leaf spot diseases reduce the aesthetic value of leaves. Root rot caused by *Fusarium equiseti* on *C. beddomei* and a foliar disease by *Asperisporium* sp. on *C. circinalis* are potentially serious in south India.

Cycads are found on five of the seven continents between latitudes 31°N and 37°S. Their distribution corresponds well with the patterns of isolation imposed by the continental drift, but seed dispersal by ocean currents has resulted in changes to the usual pattern. Ecological niche modelling has been suggested as a powerful tool to predict areas of distribution, locate viable populations and identify suitable habitats for cultivation and conservation. This also would suggest localities with suitable environmental conditions for the domestication of hitherto unexplored cycads. Predictions regarding the fate of existing populations can also be made using niche modelling tools.

Experience of a conservation project in China on *C. debaoensis* was shared in the workshop. The focus was at the village level as people living near wild populations of plants have the most immediate impact on that population. Emphasis was placed on education on the scientific and cultural importance of the plant. Village-based nurseries were developed for the sustained production and sale of seeds and seedlings. This was presented as a model in conservation that can be used in conjunction with traditional approaches like National Parks. Efforts of Mysore Amateur Naturalists, a voluntary group, to conserve *C. circinalis* in the Melkote Temple Wildlife Sanctuary, Karnataka was another inspiring example. This programme began with training of teachers and village forest committees to reach out to students and the community at large to create awareness against harvesting of cycad leaves for the urban floricultural market and cutting of trees for pith, reputed to have medicinal properties. The Tropical Botanical Garden and Research Institute (TBGRI), Palode was identified as an alternate centre for *ex situ* conservation of cycads. The collection at TBGRI which comprises of 16 species in seven genera, is one of the largest in the country.

The workshop highlighted the need to coordinate research efforts to survey for cycads, their pollinators, seed dispersers, pests and diseases in India, identification of critical areas for protection of cycads, development of cycad gardens/cycad sections in botanic gardens, use of biochemical and molecular tools in resolving cycad taxonomy and early detection of sexes, documentation and digitization of cycads and associated indigenous/traditional knowledge.

K. D. Prathapan, Department of Entomology, Kerala Agricultural University, Vellayani P.O., Thiruvananthapuram 695 522, India
e-mail: prathapankd@gmail.com