two main emerging interface areas namely, one with biology and the other with material science, it was also felt that organic chemists can no longer afford to work in isolation and will have to collaborate with scientists from other disciplines. The lack of adequate vocabulary to appreciate advances in these interface areas must be overcome in order to be a more effective practitioner of organic chemistry in future. To this end, it was refreshing to hear D. Balasubramanian (Centre for Cellular and Molecular Biology, Hyderabad) speak on 'cloning of a gene' and it was felt that lectures of this nature may help bridge the gap between different disciplines. Some participants also expressed the view that natural products chemistry needs to be revived but in a more focused and target oriented manner. Finally, it was also felt that organic chemistry for its own sake will also continue to be practiced, leaving at least a few who will continue to enjoy the pure, simple and *no-strings-attached* excitement of discovery in science.

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Biotechnology in insect control

A week-long workshop in Madras (20-27 January 1992) organized in collaboration with the Centre for Biotechnology, Anna University, Madras, on the theme 'Biotechnological approaches to the biological control of insects' provided a forum for useful interactions between participants and experts drawn from diverse fields such as biotechnology, microbiology, virology, electrophysiology, entomology and natural enemy mass production technology. The programme was aimed at: (i) identification of various phenolics and volatiles that play a role in the nutrition of phytophagous insects, through TLC, HPLC, auto amino acid analyser and GC-MS; (ii) assessment of insecticidal proteins produced by *Bacillus thuringiensis*, (iii) protoplast fusion technique and DNA analysis by restriction mapping, (iv) efficacy of baculoviruses; and (v) demonstration of techniques for mass production of parasitic and predatory insects.

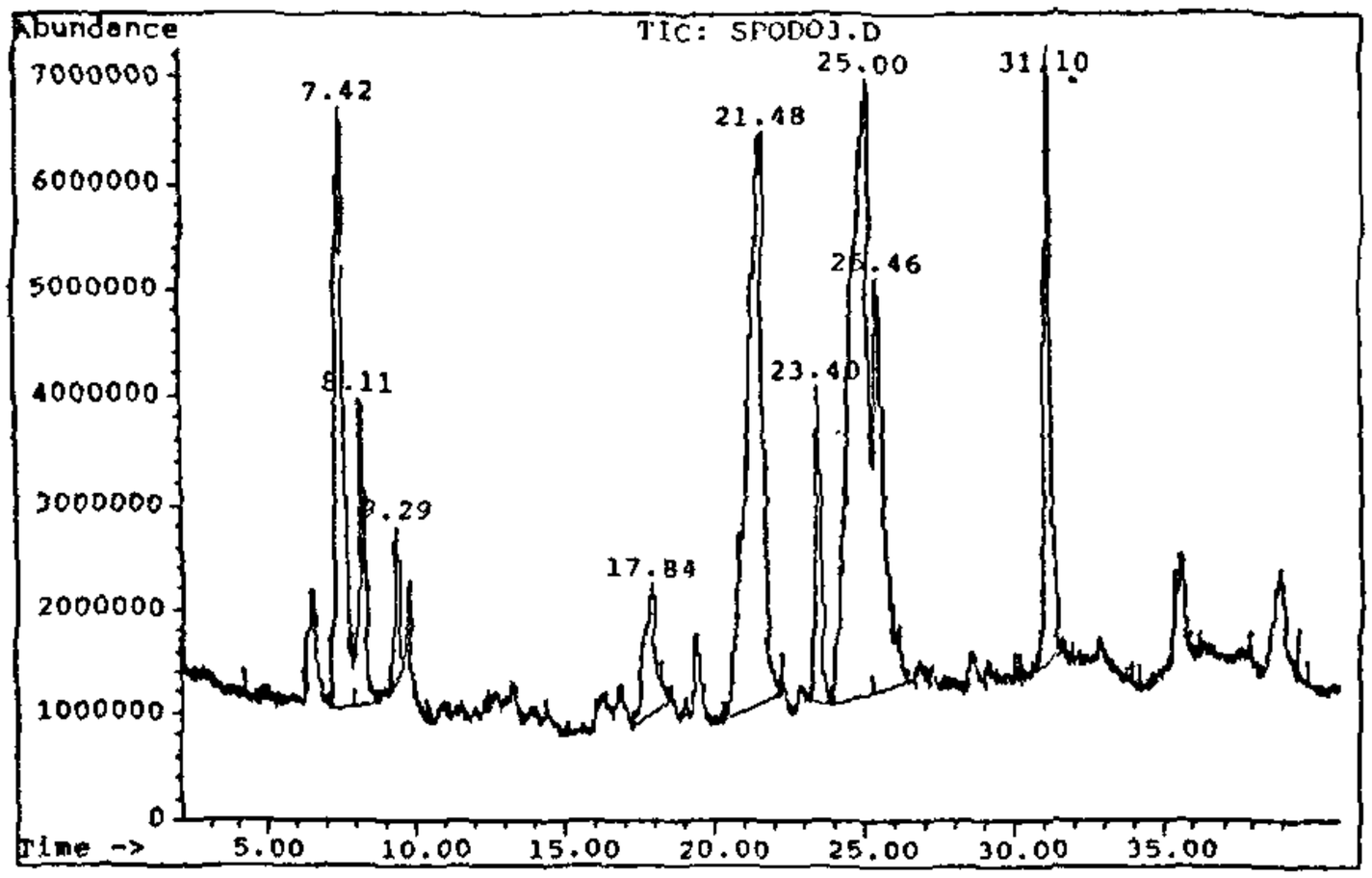
Inaugurating the workshop, M. S. Swaminathan highlighted the need for employment of techniques from recent developments in genetic engineering and biotechnology to enhance genetic resistance of plants to insects, indicating that diverse strategies are available for transferring genetic materials across sexual barriers such as protoplast fusion, direct DNA intake and the like. The scope of biological control of insect pests expands further in the light of continuous advances in biological productivity and consequent changes in the ecology of the field.

S. Jayaraj (Tamil Nadu Agricultural University, Coimbatore) highlighted the growing relevance of microbial pathogens in the control of insects, touching particularly upon nuclear polyhedrosis viruses (NPVs), *Bacillus thuringiensis* and such fungi as *Verticillium lecanii* and *Metarhizium anisopliae*. Describing the heritable variants of baculoviruses, he indicated the role of restriction endonuclear analysis of viral DNA, enabling altered virulence patterns. He also indicated as to how this technique could be used to manipulate the genomes of known NPVs towards the construction of novel ones. The scope for developing reliable and economic cell culture systems for mass production of insect viruses was also emphasized. Insect cells can be grown in fermenters of the type used for vaccine production, the slack periods of such plants being used for insect virus production.

T. N. Ananthakrishnan (Entomology Research Institute, Madras), speaking on the 'prospects of biotechnology in biological control', laid stress on the specific molecular pathways which regulate host plant resistance and facilitate development of counter adaptations in their respective insect herbivores. These aspects are interlinked with the importance of inducible defenses whose efficiency is compared with other selective agents like biological control agents. While the production of natural and induced-defence chemicals in plants is well known, the interaction between the insect-damaged plants and the third trophic level of insect parasites and predators is not very well known, and there is convincing evidence for the active release of volatile chemicals by insect-interfered plants that attract natural enemies of the insect. Therefore chemical responses evoked in plants by phytophagous insects tend to play an important role in host habitat location by parasitoids. Genes responsible for the production of such substances like farnasene, caryophyllene, polygodial and the like are under investigation (Figure 1).

R. Senrayan (Entomology Research Institute, Madras) indicated that host/prey selection and acceptance mechanism among parasitoids and predators in natural ecosystems are regulated by a combination of factors, viz. nutrition and semiochemical sources of the host. Nutritional quality of hosts and host plants is a prime factor that influences the third trophic level organisms in terms of host selection, acceptance and suitability. Similarly, volatile semiochemicals from plants as well as host sources attract natural enemies and retain them in the microhabitat. Both nutritional and semiochemical sources of insect hosts and host plants have a positive selection value for the crop plants by reducing the herbivore pressure and lowering their fitness. The nutritional and semiochemical interaction between hosts and natural enemies are governed by visual, olfactory, and gustatory signals so that, synchrony in habitat location and host detection can be signalled between hosts and natural enemies. Modern genetic engineering techniques can evoke profound alterations in plant semiochemical sources which are vital for parasite–host interactions.

V. D. Padmanabhan (Department of Animal Biotechnology, Tamil Nadu Veterinary and Animal Sciences University, Madras) speaking on 'cell lines' indicated that *in vitro* culture of cell types has come to stay as a vital source of conservation of the genomic identity. This technique, involving embryos, single cells, tissues and organs, has grown today into an effective source for several genetic engineering/molecular biological



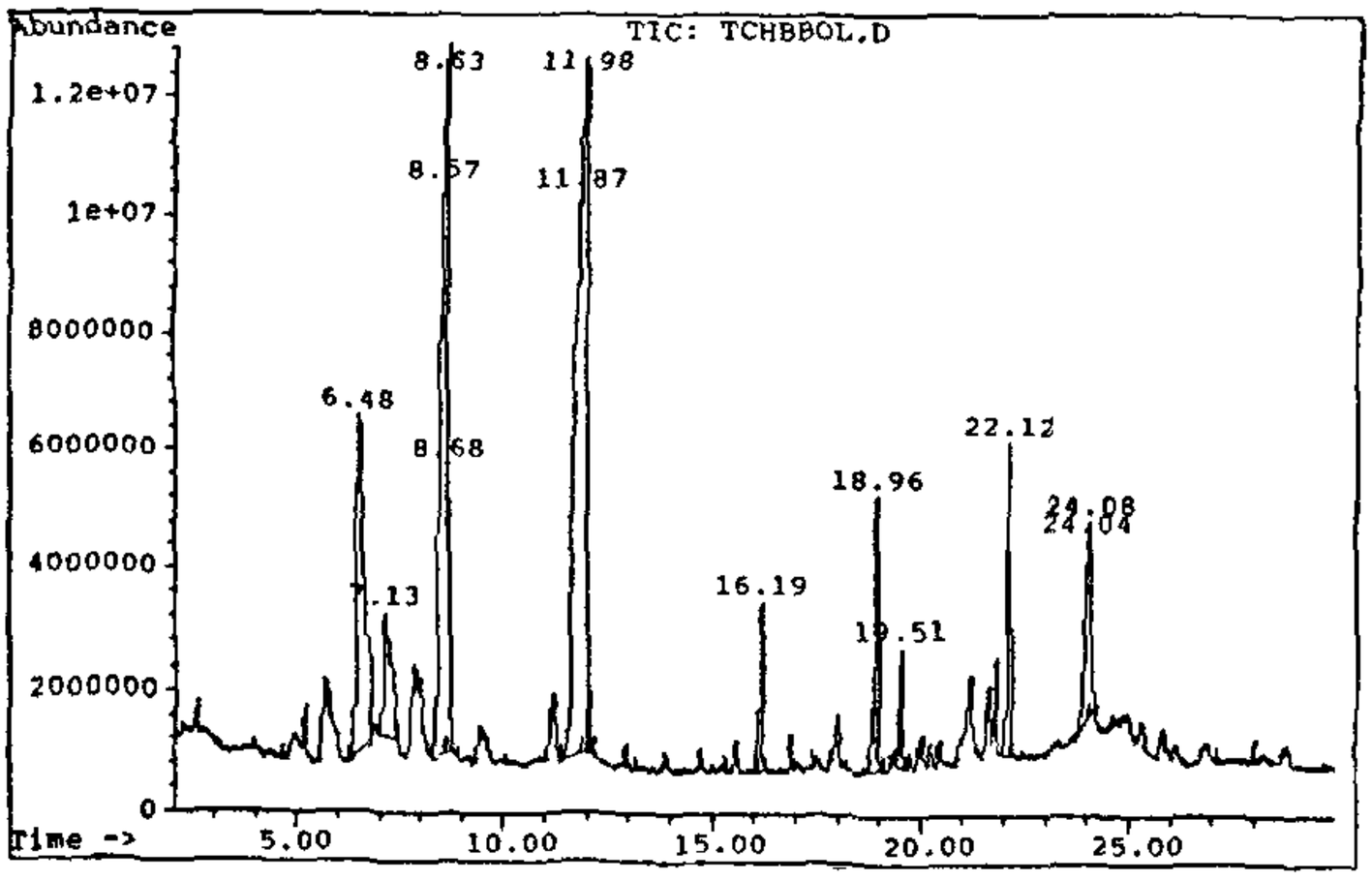


Figure 1. Volatile profiles of *Spodoptera litura* (*top*) and of cotton boll (*bottom*) to show caryophyllene peaks at 7.42 and 6.48 respectively.

methods, offering profound scope for replications and manipulations. Cell lines provide great opportunities because they have shorter doubling time and withstand long subculturing; they remain uninhibited through contact and are anchorage independent. Establishment of cell lines has come in handy in hybridoma technology, raising of monoclonal antibodies and development of cell culture products.

N. Ramakrishnan (Division of Entomology, Indian Agricultural Research Institute, New Delhi), speaking on 'baculoviruses and improvement of their efficacy', indicated that the baculoviruses being generally host-specific and pathogenic to several insects, make them a useful tool in biological control. He also stressed that inoculative releases and augmentation of baculoviruses have controlled several lepidopteran pests, besides *Oryctes rhinoceros*. A number of vector constructs have been devised which consist of a prokaryotic plasmid, the polyhedrin with variable lengths of upstream sequences, an insertion site for the foreign gene and a stretch of the polyhedrin gene proper. The growing role of baculoviruses as helper independent viral vectors for the high level expression of foreign genes in eukaryotes is becoming very significant. Insect cells infected with recombinant virus are polyhedra-negative plaques, that could be isolated, purified and also amplified. With cloned DNA as probe, hybridization could be done. It is preferable, if the virus vectors express polyhedrin gene also if it is to be used as a viral insecticide. This polyhedrin gene codes for inclusion bodies that help in persistence of virus in nature. The property of expression by baculoviruses needs to be improved, by incorporating the crystal protein gene of *Bacillus thuringiensis* (Figure 2).

E. Sivamani (Centre for Biotechnology, Anna University, Madras), speaking on 'bacterial protoplast fusion', indicated that integration of DNA substrates of two bacteria, *Bacillus thuringiensis* (gram-positive) and *Pseudomonas fluorescens* (gram-negative), has been accomplished, and with UV radiation the chromosomal DNA of *B. thuringiensis* can be eliminated, enabling a better recombination frequency, since, generally, the gene coding for insecticidal protein crystal is located in coiled plasmids. Protoplast fusion is a very simple and economical technique to obtain recombinant strains that are transgenic in nature. Molecular probes (antigen or DNA) are an added advantage for easy screening of the fusants. Stability of the fusants is another important criterion in protoplast-fusion studies. Fusion between species are more stable than between genera. Still one can achieve a stable mutant if screening and stability tests are performed rigorously and carefully.

Speaking on the 'relevance of recombinant-DNA technology in pest control', P. Balakrishna (Entomology Research Institute, Madras) indicated that recombinant-DNA technology is equally effective both in insect and plant genomes to engineer resistance of plants to insects. Presently *B. thuringiensis* toxin is generally used to confer resistance. Also during insect feeding, the wounded plants tend to produce proteinase inhibitor inducing factor (PIIF) which actively synthesizes proteinase inhibitors. These proteinase inhibitors are generally specific against insect and microbial proteins. This strategy is effective against a wide range of insects. Insect-resistant plants can be developed only when (a) resistance is inherited stably through successive generations and (b) the engineered plant is safe for human and animal consumption.

In his talk on 'biological control from lab to land — role of commercial insectaries', T. M. Manjunath (Commercial Insectary Unit, Pest Control India, Bangalore) observed that in developed

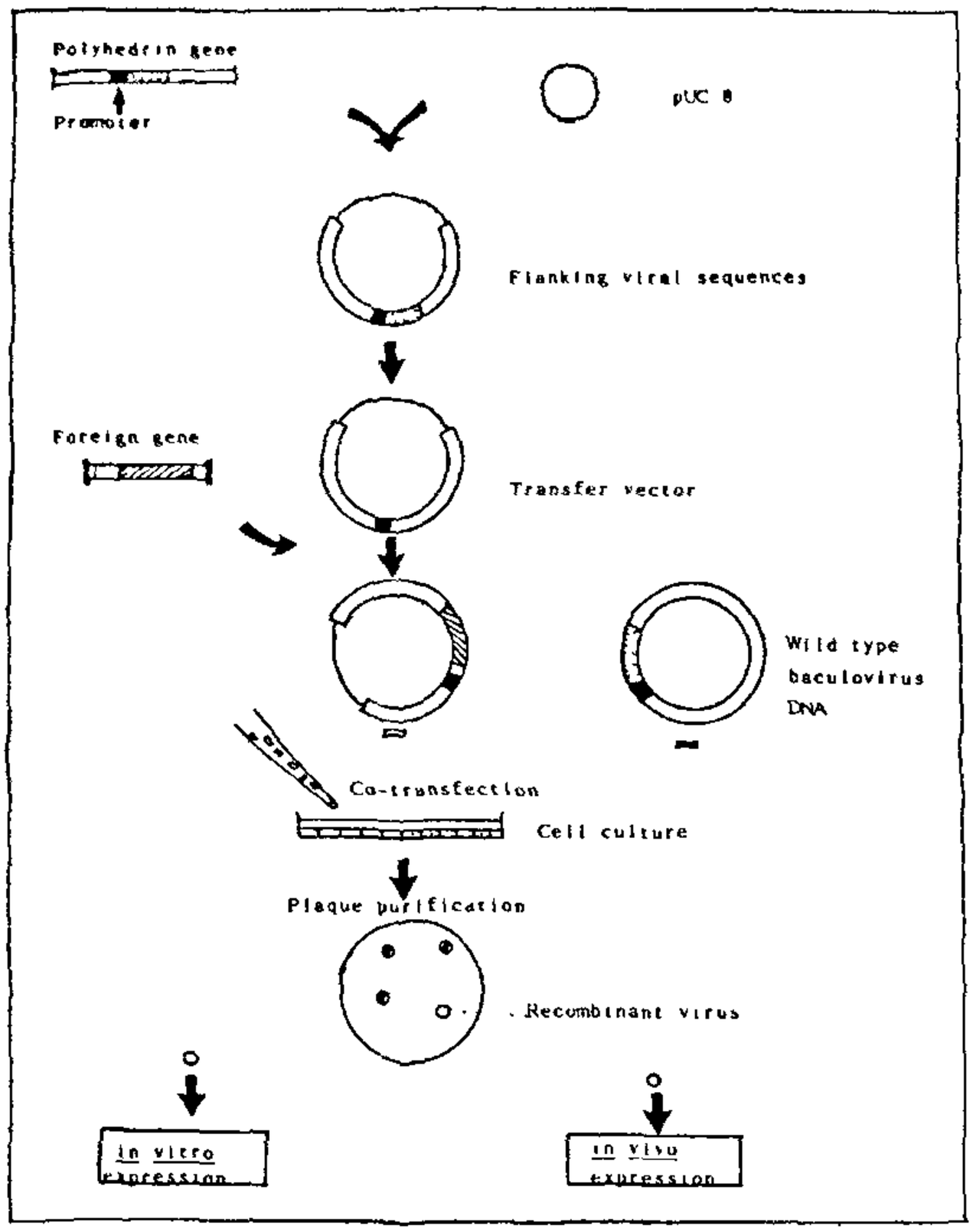


Figure 2. Construction of baculovirus expression vectors

countries, annual production of parasites is generally more than several millions of individuals, which effectively control highly diverse crop pests. Considering India's agricultural pest problems, only commercial insectaries appear to be a viable solution. This calls for effective production of natural enemies. Special packing processes and the sufficient know-how for handling these biological resources are equally important.

Delivering the valedictory address on 'wide hybridization—a new strategy in developing insect-resistant rice varieties', S. Chelliah (Tamil Nadu Agricultural University, Coimbatore) emphasized that several barriers like failure of pollen germination, slow pollen tube growth, elimination of chromosomes, hybrid inviability and hybrid sterility operate at various levels, hampering successful gene transfer from wild to cultivated species of rice.

In recent years, biotechnological techniques have been used to overcome barriers. While several techniques like using bridging species, use of exogenous growth substances and immunosuppressants, *in vivo/in vitro* embryo culture, *in vitro* fertilization and ovule culture and somatic cell hybridization have been used in several crops, embryo rescue and culture in special media have been successfully carried out in wide hybridization in rice. This achievement, coupled with other attempts currently being made to transfer resistant gene(s) from wild rices to cultivated rice, would hopefully help us in achieving durable resistance to major insect pests in the years to come.

In conclusion, the workshop served to highlight diverse approaches to biotechnological aspects relevant to the biological control of insects, emphasizing the role of microorganisms like Bt and NPV, which could be genetically improved for greater virulence, persistence and desired host range. In particular, NPV could be genetically improved by selecting for desired traits or by using genetic engineering techniques. Interestingly enough, recent researchers have also indicated that genetic manipulation of baculoviruses to produce neuropeptides inside the pest organism would substantially disrupt its normal body function. The genetically engineered techniques also lead the way to the production of crops with a variety of resistance factors.

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