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OF

JAFFNA SCIENCE ASSOCIATION

JAFFNA, SRI LANKA

1994

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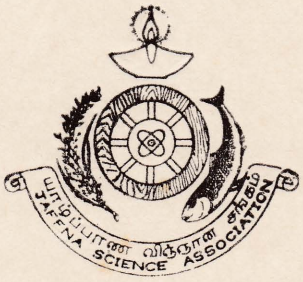

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Presidential address

by

Prof. C. Sivagnanasundram

UNDERGRADUATE RESEARCH IN THE UNIVERSITY OF JAFFNA

Universities, as centres of higher learning have been traditionally associated with research. Research activity and excellence in it is an essential requirement to the University teacher in his academic performance. However, although activities by students, that could be classified as research take place in many University departments, these activities are rarely highlighted as essential fulfilments for his future or national needs. Research as its name implies is a careful search or inquiry into facts, old and new, by scientific methods. It is a course of critical investigation. Hence it is a branch of instruction or learning, the methods of which should be imparted to all undergraduates irrespective of the discipline and whether the course leads to a special or general degree.

The importance of this aspect of training was recognised in this country at the secondary schools level twenty years ago. Diyasena (in Sanyal Ch. 3) states that 'The educational reforms of 1972 brought in curricular changes at the higher secondary schools (grades 10 and 11) and a compulsary component that was introduced in the curriculum was called 'Project Work'. This was introduced with a view to including training, in problem solving, in multi disciplinary approaches to community problems, in data gathering and their use in arriving at decisions. This was basically a community based educational programme. These reforms and activities that came under what was called the HNCE programme were short lived and were hardly given a trial'. At present there is no component in the school curriculum that caters for any project work.

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However it has been said that the radical changes made in formal school system during the decade 1970 – 1980 had considerable influence and impact on some of the curricular changes and development that took place at the University level. (Diasena, in Sanyal)

During this decade efforts were made by some Universities to relate University education to employment. During the 1970s these efforts culminated in the development of the job oriented courses of study in the Arts Faculties. (Bertram Bastiampillai, Ch. 5 in Sanyal)

University education was to be refashioned so that graduates could be profitably employed. There was also an interest in making education meaningful for Sri Lanka's development needs.

Studies were then made to find out the job opportunities of the graduates and also their role in national development. It was found that the public sector i. e. employment by the Government, provided the largest number of employment opportunities, and the teaching service provided the single largest area for the employment of University graduates. During this time Basanayake (1971, preface) observed that there is in Ceylon a wide gap between local research and school teachers. Research goes on in research institutions, Universities, museums and the like. It gets published in reports and journals. Practically none of it gets to the teacher.He suggested that the teachers could be encouraged to do research and thereby activate the habit of reading research reports Local research material would increase the relevance of the content of their courses to the interest of their pupils and to the needs of the country.

The Sri Lanka administrative service (SLAS) is another field of employment open to graduates in this country. (Ch.6 Sanyal) Next come the semi-government sector, which covers all corporations, Boards, Statutary Bodies and National Banks. These provide employment opportunities at specific levels of the hierarchy of employment. The private sector uses comparatively

few graduates. (Ch.6 Sanyal) In the Government and Semi-government Sectors, the executive / administrative level jobs were open to all catagories of graduates in arts and sciences. Although clerical grades generally require secondary level qualifications under the present situation, University graduates especially in the Arts oriented subjects were invariably being absorbed into clerical positions, and they rise to administrative posts in later years.

It is thus seen that the graduates of a University are responsible for teaching children, who would be national leaders of the future or are holding important posts from which they decide the future of this country now. Both these positions need men and women, whether there are graduates in special or general courses, in Arts or Sciences, with a University training that would equip him or her to:

i. identify the rationale behind any action taken in any assignment and solve problems as they arise.

ii. generate new and innovative ideas with a sound base of knowledge of the past.

iii. formulate and construct a fact finding document, for example a questionnaire or record form in order to understand the present position of any situation in which he works.

iv. write a report or circular after any short or long term assignment keeping in mind the person or persons going to read it.

v. make the best use of available resources in terms of men, money and materials.

vi. make a realistic assessment of his own capability, which is an essential qualification for successful work in almost any profession (SRHE).

vii. Face the challenges of professional life by helping him to accept his own limitation and to become aware of when and how to seek advice (SRHE), and finally as Suseendrarajah (Pers.Common) remarked.

viii. make him think logically and to the point in his institution and on public platforms.

The unit in the curriculum that would give him an opportunity to acquire a mind possessing these abilities will be training in research methods. The value of such research, call it projects, exploratory studies, essays, dissertations, reports or whatever, has been acknowledged world wide.

The role of research also varies, the contribution of some disciplines as in the Physical Sciences, is more visible and quantifiable, while others are general and subjective. For example historical research helps in inculcating among the people a sense of national determination, cultural identity and formulation of national ethics. Sociological research gives information for the nation's planning and policy making. Health Systems Research gives immediate information of the working of the Health Systems to the Health administrator and so on.

Research in the Different Faculties

In this address I have attempted to describe and catalogue the research done by undergraduates in the Faculties of Science, Arts and Medicine. The research activities in the Faculty of Medicine have been dealt with in more detail than the work in other Faculties. Comparisons were not always possible as the disciplines vary in their conceptual approach from concreteness to abstraction, for example physics and Mathematics on one hand to Philosophy and Fine Arts on the other.

From the data available I have discussed the programmes and made suggestions that could improve the present status of undergraduate research in this University.

Methodology

Information was collected from the Heads of Departments and Professors in the various disciplines where research is a component and is being evaluated in the curriculum, by using a semi-structured self administered questionnaire. Interviews were also made with the respondents whenever it was necessary to clarify the data provided. There was one hundred percent response. Heads of eleven departments in the Faculty of Arts, five in the Faculty of Science and two in the Faculty of

Medicine supplied information. In addition Professors of Geography, Physics, Chemistry and Biochemistry who are not Heads in their departments gave their views. Three of them are Deans of the three Faculties considered in this study. In the Faculty of Arts, the Department of Sociology which is a new one, has no students who are at a stage for research studies. In Science, Mathematics has no research component. In the Faculty of Medicine, undergraduates do research in the curriculum of Biochemistry and Community Medicine, and they involve all the subjects taught in the whole medical course. For the sake of uniformity and completeness, information from the last batch of students evaluated in the research component was used in this analysis.

Faculty of Science

The faculty has five Departments of study, namely Chemistry, Botany, Zoology, Physics and Mathematics & Statistics. It also has a computer Unit for teaching and research. It provides courses leading to a three year General Degree and a four year Special Degree.

General Degree Course

Students following the general degree take three subjects in different combinations, and according to the subjects are classified Bio-Science students or Physical Science students. In the 1989/90 batch there were 45 students in the Bio-Science and 89 in the Physical Science courses. There is no research component in the general science courses and therefore these 134 students had no opportunity for training in research. Even if they were exposed to activities such as field surveys in Botany or Zoology, there was no formal evaluation so as to give such an investigation any importance.

Special Degree Course

Students who perform well in the first two annual examinations are admitted in the third year to follow the special degree course choosing a main subject in which they obtain their

degree. These students do research, which is compulsory, and is timed to be in the fourth and final year. In the 1989/90 batch there were 34 students in all.

The number of students working for the special degree in each discipline is small, four each in Zoology and Statistics, six in Physics, eight in Botany and twelve in Chemistry. The research done is of an applied nature and the time a student takes in his resarch ranges from 8 – 12 months. Research methodology is taught as a module only in Zoology and Statistics. Department of Statistics devotes 45 hours mainly concentrating on computer soft-ware for statistical techniques. The Department of Zoology teaches the methodology in entomological and Fisheries Biology research for a period of two months. The final presentation of the research is in the form of reports, except in Chemistry where the term dissertation is preferred. The weightage given in the final assessment is as follows:

1/4 of 8 units in Botany, 2/5 of 8 units in Chemistry and 1/2 of 8 units in Physics and Statistics.

Faculty of Arts

The Faculty of Arts has 14 Departments of study. As in the Faculty of Science courses are available for general and special degrees in all disciplines except Siddha Medicine, where there is no differentiation. In the batch taken for study there were 201 students in the special courses. Of these 114(56.7%) are in the Department of Commerce and Management, 79 students in Commerce and 35 in Business Administration. Twenty four (11.9%) are Geography special students and 21(10 4%) are in Economics. Rest of the students i.e. 21% of them are in the other subjects, varying from 11 to 2. There were no students in the special course in Linguistics and English in the batch under study. As stated earlier students doing Sociology have not come up to the year for research.

Special Degree Course

Special degree courses are of four years duration and research component is compulsory. It is conducted in the final year except in Philosophy and Tamil where it is in the third

year. Research in Commerce, Business Administration and Geography was described as applied research, while other departments called it essentially basic in nature.

Table 1 shows how the 54 projects in Commerce and Management could be classified by categories of Management. Of these 22 were in the public secter, 15 in the co-operative and 17 in private sectors. Fifteen projects dealt with industries, nine with banks and the rest were not classified.

Table 1. Projects in Commerce and management, 1991 Batch

Management category	No.	%
Marketing	20	37.0
Production	12	22.2
Organisational	12	22.2
Personal	9	16.7
Financial	1	1.9
All catagories	54	100.0

In most departments the students were given an years time to work on their projects and submit it documented. Commerce, Business Administration, Economics and Political Science however insisted on a more intense work and expected the research to be completed in 4–6 months. However it is not possible to state the number of hours actually spent by the students in their research study.

Course in Methodology

Organised class room teaching in research methodology as a module or unit is done by some departments before the research, while some prefer to give necessary instructions when the students are on the project. Useful inputs for research eg. Statistics are also incorporated in other modules by some departments. The number of hours spent for classroom instruction is defined only when methodology is taught as a module. In others the times vary with the disciplines and are not comparable.

Commerce and Business Administration which has the highest number of students doing research in the Arts Faculty has no organised module in research methodology. In addition to the information imparted in the normal curriculum, individual guidance is given to the students by the superivsors at all stages of their assignment. A student gets on an average 2 hours of guidance per week and this goes on for 2 - 3 months. The student also learns statistics in a course unit, where problem oriented assignments are given.

The Department of Economics gives instructions in research methodology as lectures totalling four hours. Statistics is taught as a separate module.

The Department of Geography has a well organised programme of class room teaching in research methodology, and is spread out as 1-2 hours per week for 2 terms. The theoretical instruction includes all aspects of methodology from problem identification to report writing. Cartographic techniques in Geography, while this form the normal curriculum in the discipline are further emphasised in the programme, in relevance to the assignments given to the students.

The Department of Political Science spends four hours in class room sessions where students are taught the format of writing an essay or dissertation on the subject, together with the use of references. In addition students who need knowledge of statistics are taught basic methods whenever necessary.

Departments of History and Hindu Civilization which have 5 students each, have a similar type of training in research, giving instructions in selection of topic, collection of material, analysis, drafting, marking foot notes and bibliography etc. This takes about 30 hours in both departments.

The Department of Christian and Islamic Civilization has a module on research methodology, and this is done on an average in 7 classes.

The Departmnet of Philosophy teaches scientific methods as applied to philosophy in two short modules, one each in the second and third years.

The three Departments dealing with languages, namely Tamil, Sanskrit and Linguistics together with English have no module for research methodology. Students are taught the methods during their project work.

The Department of Siddha Medicine has no research project, but has a project on Family Health which needs skills of observation, recording, interpretation and documentation Elementary introduction to these skills is given during the lectures given to them by the Department of Community Medicine.

Documentation and Evaluation

The research by students is submitted in the form of dissertation. Departments of Philosophy and Sanskrit call them essays Evaluation of the research goes into the final assessment and the weightage given in all departments is in the region of 1 in 15 or 16 units.

General Degree

Only the Department of Geography has a research component in its course and is evaluated on a dissertation. There were 5 students in the batch, which is small compared with the 24 in the special course.

Departments of philosophy and Tamil insists on a report from the students.

FACULTY OF MEDICINE

The Faculty of Medicine has identified research by students as one of its institutional objectives. It reads thus:

Objective 3.3(e): 'to encourage basic and applied research particularly the identification of regional and national health problems as well as indigenous medicine and therapeutics'. Further in defining the characteristics of the end product of the Jaffna Medical Faculty it states that he should be able to design, implement and submit a report on a research project'. (Hand book, Medical Faculty).

The students undertake two research projects at different stages in their course. First is in the second year course, before the Second MBBS Examination. This research comes within the perview of the Department of Biochemistry. It is largely laboratory based and involves other departments, especially Physiology in terms of content identity and for it supervision. The second research is done in the Fourth Year before he takes the Third MBBS Part II examination. By this time he has passed Anatomy, Physiology, Biochemistry, Microbiology, Parasitology, Pharmacology and Forensic Medicine. He has almost completed his course in Pathology and Community Medicine and done 1½ years of clinical work in the hospital. He is at a level of maturity comparable to that of a young post-graduate student in the Arts and Science Faculties. This research is undertaken as a requirement in the curriculum of Community Medicine and the studies are based in the Community and the Hospital. I wish to give in some detail information about these courses.

Research under the Department of Biochemistry

The Department of Biochemistry has integrated planned research projects with their modified practical classes in biochemistry at various periods of time. This strategy in the curriculum was adopted to enable the students to see the relevance of biochemistry in their medical career and was seen as a motivating factor. It was found necessary to change the format of the traditional biochemistry practicals, so that time was available for research projects of the students. The students, from the first term itself, was given a training in calorimetric estimations and the use of chromatography and electrophoresis instead of their qualitative studies. By the third term in his course, the students were familiar with most of the routine clinical biochemistry practicals and general methodologies that could be applied in basic and clinical research. About this time, physiology practicals in the cardio vascular and respiratory systems have been completed, a requirement for the students to choose research projects in a wider clinical context. The students have also had a series of lessons in basic statistics given by the teachers in Community Medicine, accomodated in the physiology time table

The Department of Biochemistry has had the research project for six batches of students so far. It carries 10% of the marks in biochemistry which is one of the three subjects in the 2nd MBBS examination. The areas for research are suggested by the department, but the students carry out individual projects. The projects cover a wide range of subjects. In the earlier batches the spread was more, for example it covered fields embracing genetics, nutrition, hypoglycaemic drugs, allergy, exercise transcendental meditation etc. In later batches, as the topic areas were grouped the projects seemed to be more manageable for supervision. A grouping of the recent batch is shown in Table 2. Of these 87 projects 8 were supervised by the teachers in physiology, and the others by the biochemistry teachers. Supervision and help during the students projects consume a considerable amount of time of not only the teachers in biochemistry but also of the technicians, as an accademic member and the two technicians are always available in the laboratory right through the week including Saturdays.

Table 2. Biochemistry Student Projects

Subject Groups	No. of Projects	%
Effect of Smoking (Includes cigar, beedi) Effect of tobacco chew	27	31.0%
Effect of dietary fibre and soya bean	16	18.4%
Effect of hormonal Contraceptives	14	16.1%
Effect of drugs, tea, coffee	10	11.5%
Effect of other substances	06	6.9%
Disease related biochemical changes	07	8.0%
Others	07	8.0%
	87	99.9%

The effect of the research component in the biochemistry curriculum was discussed by the curriculum committee of the Faculty at the end of the projects of the first batch, that carried out research. The committee had a favourable view of this trial and recommended that the weightage given to the research project in evaluation be increased (Balasubramaniam, 1992). It considered the project work to be a motivating factor for the learning of biochemistry, as it provided exposure to information retrieval and developing their innate ability to judge case and research reports.

The motivational factor was also studied by the Dept. of Biochemistry by getting the opinion of students by means of a structured questionnaire administered to the first research batch (Balasubramaniam, 1992). All the 69 respondents said that they liked doing the projects. The reasons given for their liking the project work is worth consideration, 40.5% said that it helps them to gather and accumulate knowledge and 24 6% said that it helps in analysis and deductive thinking. 21.7% believed that they were contributing to medical knowledge. 3% said that they liked it because they could meet people. 10% wanted the projects to earn marks. To a question whether the projects should be compulsory, 58 students, ie 55% said that although made compulsory, it should not be included for marks in the examination. The major difficulties experienced by the students in carrying out the projects were identifying and approaching people (37.7%) and getting specimen and other data (34.8%), which means 72.5% of the students considered getting the required specimen from selected people to be their major hurdle. An important information worth the Faculty's consideration was that 23 of the 69 respondents ie. 33.3% recommended that there be one research project for the entire medical course. The rest wanted several projects at different stages in their course. However it should be added that it was too early for the students to form a definite opinion on this issue. The marks obtained by the students for the research batch out of 100 was 73.5 and the 2nd batch was 70.1, the standard deviation being 11.6 and 12.1 respectively.

Some of the students have been successful in getting their findings published in journals or reading them in meetings of scientific associations. Upto now 3 students projects have been published together with their supervisors names, two in the Jaffna Medical Journal and one in the Journal of Natural Science Council. Eight research papers have been read; five of them at the annual scientific sessions of the Jaffna Medical Association, and 3 at the present sessions of the J. S. A. Recognition of student research has high motivating value to future batches of students for maintaining quality of their studies.

Research under the Department of Community Medicine

TEACHING FOR RESEARCH

Some of the subjects taught in Community Medicine, like epidemiology, statistics and sociology provide the elements of knowledge and skill that is fundamental for research in the medical field. In addition the students are given a 7 hours course of lectures in research methodology before they embark on their research projects in the fourth year. This course covers all stages, from identifying a problem for study, getting permission to do the study from various authorities including the ethical committee, to writing and reading a report. The main topics dealt with are : Formulation of general and specific objectives, construction of a hypothesis, identification of variables, research design including sampling, construction of appropriate instrument (Eg.questionnaire) pilot study, collection of data, analysis and interpretation.

This course enables the students to identify projects that could use descriptive, analytic or experimental and quasi-experimental methods in various situations in the hospital and community. Methods of interviewing and training on data collection are emphasised during the teaching. Health System Research concepts are also clarified, so that he could recognize the applied nature of this type of research for timely decisions for the Health administrator.

At a later stage in the Community Medicine course, the students are given a class on critiquing a research paper, as one of the objectives of the research component in the curriculum is that the student should be able to read a research article critically and evaluate it for his own development.

RESEARCH ACTIVITIES

The batch evaluated in 1990 was the first to do the research project in Community Medicine, as stipulated at present. The earlier batches from the 1st batch had a component known as the 'Family Study' which they followed up for 1 year and wrote a report at the end. It carried 10% of the marks in Community Medicine.

This Family study project had several sub-studies in it, such as knowledge, attitude and practice of the family on health matters and also a full nutritional assessment and follow up of their health status for 1 year. The one year family study therefore had the elements of observation, recording and interpretation in its own context.

However the present research project carried out by the last 3 batches has defined qualities of a Research Project.

Selection of the Topic is of considerable importance because a difficult unmanagable topic would, along the way, fatigue the student and the supervisor, and the end would be hard to achieve. By the time the course in Research Methodology is over, the student is capable of identifying the problem area or discipline in which he is interested. He is full of enthusiasm, which is very gratifying to the teacher, but the teacher finds it difficult to narrow down his enthusiasm to a well defined topic with clear objectives or simple hypothesis so that the study is relevant, feasible, practical and can be done in a short time with little cost.

The research projects selected cover a wide range of topics, as expected because of the multidisciplinary nature of

the Health Care, which is emphasised in the various components of the curriculum in Community Medicine itself - mother and child care, prevention of diseases, occupational health, nutrition, sociological and psychological components of health, management for care etc. A broad grouping of the research subjects by category is given in Table 3. Quarter of projects deal with general diseases, communicable and non-communicable in all age groups, 16% with diseases of women and childbirth, 14% with childrens' diseases and care, 7% with psychiatry and 5% with drugs and poisons. One third are projects related to behaviour of the patient and care by the provider.

Table 3. Subjects of Research by Batches

Subjects	Batches			Total	%
	1992	1991	1990		
General Diseases	05	07	25	37	25 2
Gyn & Obs	03	05	16	24	16.3
Paediatrics	09	04	08	21	14 3
Psychiatry	01	06	03	10	6.8
Drugs & Poisons	03	01	03	24	4.8
Others	12	12	24	48	32.7
Total	33	35	79	147	100.1

Table 4. shows the major types of research into which these projects could be classified. Almost half use the epidemiological methods of study and of these almost all of them use descriptive epidemiology. A quarter of the projects inquired into the knowledge, attitude and practice (KAP studies) of well and ill people and used sociological methods of inquiry. About 20% have a high clinical component where student actively collect information by examining the patients. These are classified as clinical. The rest 7% deal with simple studies on the working of the Health System.

Table 4. Category of Research by Batches in Community Medicine

Category	Batches			Total	%
	1992	1991	1990		
Epidemiological	08*	18	42*	68	46.3
Sociological	15	05	17	37	25.2
Clinical	07	08	17	32	21.8
Health Care analysis	03	04	03	10	6.8
Total	33	35	79	147	100.1

* 1 Lab Based

SUPERVISION

Supervision in the early stages of the project is vital for the success of the students research. The importance of the selection of the topic has been already mentioned. In the department of Community Medicine the average number of consultations with the teacher for selection of the topic and formation of the general objectives or hypothesis is about two, which we consider is a reasonable contact time.

The students in our projects usually make their first contact with a teacher in Community Medicine. as the project has to be approved by the Head of the Department of Community Medicine, and sent to the ethical committee. They usually select their immediate supervisor in consultation with the teachers of Community Medicine. Taking all the three batches together, 50% of the projects have been supervised by the clinicians at the teaching hospital, Jaffna, 40% by the teachers in Community Medicine and 10% by the other departments in the Medical Faculty. In addition all students make it a point to have some contact with the teachers in Community Medicine whether it is necessary or not, because they are aware that the evaluation of their projects is done by them.

It was pointed out that only 40% of the supervision is from the Dept. of Community Medicine, so that a clear understanding of the purpose and format of this project work

was necessary among the other supervisors, chiefly consultants in the Teaching Hospital. In Feb. 1987 when the first batch of students (1984 batch) started their research a circular was sent by the Dean, Faculty of Medicine to the prospective supervisors, clincians and teachers in other departments explaining the objectives of the research project. It gave the elements of a project proposal and the format of the final project report. Supervision of these projects by the clinical teachers, not just helped to ease the load of work of teachers in Community Medicine but gave much credibility to the projects relating to the discipline, which was their speciality.

EVALUATION

The research project is given 15 of the 100 marks in Community Medicine which is one of the 6 subjects in the 3rd MBBS examination. In the batch evaluated in 1990 each student carried out a project and evaluation was on the report submitted and on a viva, both carrying equal marks. However later, projects were allowed to be done by 2 or 3 students as some projects were large for a single student. Further monitoring large number of single projects, reading the reports and having viva were beyond the scope of the teachers with a limited time. When more than one student did a project same marks were given to the report, but the marks varied in the viva depending on the students performance. In the last batch time restrictions and shortage of one member of the staff forced us to mark only on the report. No students gets less than 40% of the marks in the research project, as projects are returned to the students for correction and if necessary re-writing if the standard of the report falls below this mark. If he does not come up to this mark before the examination, he is not allowed to sit the examination. So far this happened to one student only.

EVALUATION BY STUDENTS

Students evaluation of the research projects was obtained by means of a questionnaire which was answered anonymously. For the batch 1990 it was done just before the evaluation,

61 out of 79 responded, ie 77%. As we thought that there might be a tendency to please us before the examination even annonymously for 1992 batch the questionare was administered just after the results were published. Many students had left the peninsula and were not available. We asked the students how confident they feel for the future in doing the various stages in research. Answers were given on a 5 point scale ranging from very poor to very good, point 3 was average. All students scored more than 3 in each of the 12 stages identified. The first 5 stages where highest number scored 5 points were in order of numbers-collection of data, selection of sample, selection of topic, selection of method and literature search. In the other stages their response was average. Least number of 'very confident' responses was for writing objective and hypothesis. A feed back from the students was found to be very useful and we were conscious of our defects in teaching, and attempts were made to correct them both in the lecture and during student contact times. The students' satisfaction regards supervision of their projects certainly improved by our efforts to have more contact times.

When the opinion of students on some selected items or issues were inquired into, only 46% of the 1991 batch said that the degree of help they received from the supervisors was more than their average expectation. In the 1992 batch 70% said so, as regards usefulness of the project for their doing research in their future carier 87% of the 1990 batch and 85% of the 1991 batch said that their usefulness was more than average. In fact 60% thought it was very useful. Again 92% in the 1991 batch and 80% in the 1992 batch said that the project exercise was more than average help in reading articles in scientific journals. However 20% in both batches said that they did not enjoy doing the research project.

Facilities and Limitations

Library

The opinion regarding library facilities for undergraduate research varied among the respondents. In the Science Faculty of the six respondents four said it was good or satisfactory. In

the Arts Faculty similar response was 8 out of 11 respondents. Hence 70 per cent of the Heads of departments were satisfied with the library facilities. However in both Faculties majority of the teachers said that the current publications came late as is expected under the present situation. It was also pointed out that the reference books in Tamil were limited and the Tamil periodicals very inadequate. The library facilities in the Faculty of Medicine is good, especially because of the books and publications sent very regularly by the WHO as donations. This Faculty also gives priority to the purchase of books suitable for reference by students in using the WHO and other grants.

Only the Department of Geography mentioned the lack of microfilm reading facilities as a limitation. It appears that the Departments have taken the present adversity in life in general as a matter of course and not considered as a limitation the lack of facilities usually found in modern libraries.

Laboratory

The Head of the Department of Chemistry is of opinion that the facilities in the laboratory are poor for research by students. Chemicals are in very short supply and basic apparatus Eg. spectroscopic instruments and instruments for chromatographic seperation are not available. S. Maheswaran said that inadequate equipment hinders monitoring of research. Hence projects are limited to certain types. Similar views regarding lack of chemicals were expressed by the Heads of Zoology and Biochemistry. Both the Head and Professor of Physics remarked that the lack of equipment and material affects the flexibility of the research work. (Often the students were forced to adopt techniques which can be implemented using standard equipments and materials if available). It was also difficult to find standard projects for students with the facilities available in the laboratory. Only the Department of Botany was satisfied with the available facilities.

Computer

The Departments in science and arts that reported the dearth of computer facilities are Chemistry, Geography, and Commerce and Management. The Head of the last department

remarked that the computer unit is not in a position to accomodate large number of students from his department. In the Faculty of Medicine, the Department of Biochemistry does not have sufficient computers for use of undergraduates. Some students working on research projects of the Department of Community Medicine use the Computer unit of the University.

Travel

Student research in almost all departments is affected by the present difficulties in transport. The departments most affected are Geography, History, Hindu Civilisation, Economics and Commerce and Management. Balakrishnan remarks that ideally professional courses like Commerce and Buisness administration should relate to work place experience including research. Under the present constraints, this is not possible.

Funds

There are no funds available for undergraduate research n their curriculum. Most of the respondents identified lack of funds as a substantial limitation for research by students.

Others

Other limitations identified were lack of supervisors, time, paucity of projects and the inadequate English proficiency. Several Departments especially Physics, Commerce and Management and Community Medicine pointed out that the supervisors lacked the time to give sufficient guidance to the student projects due to their committments to teaching, administration and field work. Kunaratnam was of opinion that 'when large number of students get involved in research, it becomes difficult in the course of time, to find suitable projects which are different from the ones given in previous years.' The same opinion was expressed by Balakrishnan regarding projects in Commerce and Buisness Administration. S.K.S. Nathan observed that the references in economics and political sciences were in English and the students' proficiency in English was inadequate to make the best use of these references. This observation is likely to be true for other disciplines as well.

Observations of the Heads of Departments on undergraduate research

All the Heads and Professors of the Dapartments interviewed were of opinion that research at the undergraduate level was a useful component in the curriculum. Kunaratnam summarises this usefulness by saying "that research enables the student to apply the knowledge to real problems. It makes them think independently and critically and exposes them to the limitations of models used in lectures. In our context, classroom teaching only encourages passive learning while research results in active learning, as the student himself explores."

V. K. Ganeshalingam, K. Kandasamy, K. Balasubramaniam and S. Krishnarajah express similar opinions when they remark that research:

(1) Gives primary strength to the undergraduate ie Confidence (V. K. G. & K. K.)

(2) Motivates and promotes better understanding of the subject (K. B. and S. K.)

(3) Stimulates intellectual, independent, and analytic thinking (V. K. G., K. B. and S. K.)

(4) Improves communicative skills (V. K. G.) and

(5) Prepares for continued education (K. B.)

Maheswaran, Professor of organic chemistry indicated that the research is useful to students doing postgraduate studies and those seeking jobs in the industry. Balachandran dealing with research in geography states that this training helps in all future jobs by the graduates in private and public sectors. Five heads of departments in the Faculty of Arts stated that research in the undergraduate course enables the student to do post-graduate degrees eg: M. Phil in their disciplines. A comment made by Kunaratnam is worthy of quotation here. He states that 'if all teachers are able to engage in active research (real research, and not preudo-research!) a better alternative to research projects would be to

get students to assist the teachers in various aspects of their research, but unfortunately, in our context, this seems to be a remote possibility'.

Discussion and Suggestion

The emphasis given to the research component in the courses leading to special degrees in Sciences and Arts and that of Medicine is gratifying. Sufficient analysis was not attempted in this study, which is of an exploratory nature, to determine either the degree of sophistication reached by individual research or the usefulness of the research to the country. A cursory inspection of the titles of projects in geography, economics, commerce and management showed that many of them have relevance to national needs and demands. Some of the projects in Community Medicine and Biochemistry are good enough to be pilot projects for more intensive research by teachers.

Suggestion No. 1 : The teachers of all disciplines should identify the research contribution by students for further research and publicise short abstracts of the studies already done by students for use by others.

The total absence of a research component in the general degrees, except geography, deserves thought and timely action. Students in the general courses form a formidable number in a batch, in the one studied 134 in Science and 104 in Arts. They will also be our future administrators, Bankers, Businessman, policy makers and above all teachers of our children. All the good qualities of research discussed in this paper should be their forte as well. In fact I see no reason for not training a 'general' graduate in research. It has been omitted by tradition, as one of the professors (Nathan, S.S.K.) told me.

Suggestion No. 2 : Students following the general course should be given a training in research methodology and directed to projects relevant to their future jobs and to the country.

Many departments do not have a class room teaching module for research methodology. In some departments the training appears inadequate. All disciplines have their own methodologies and those have to be imparted before projects are given. Recently Joseph E. Stiglitz (1991) writing in the Economic Journal described the methodological innovation in economics as the triumph of 20th Century economics. This is equally true for many other disciplines; the development of Health Systems Research in recent years could be cited as another example, Research into the working of the Health System, apart from using epidemiological methods depends heavily on the techniques used by Sociologists, as many studies are based in a society setting. Similarly all disciplines in the Faculty of Arts have a direct link with the society. They produce graduates special or 'ordinary' who are thrust among people with their problems - cultural, occupational, socio-economic and political in various settings. Work in these settings need humanistic approach, a mode of inquiry andtraining linked with anthropology and social psychology. In short social research teaches a student, methods which are part and parcel of every day administration.

Certain disciplines for example those dealing with languages, philosophy, civilisation and political Science should get away from their 'purist' attitude and come in terms with reality if their under graduates are to fit into society. Kim and colleagues (1980) state that modern thought is to broaden the curricula and "liberate" it from the "purist" tradition. This is not easy. They state that at the Chulalonkon University of Thailand "the advent of the behavioural approach has split social scientists in Thailand into two opposing groups.

To the traditionalists, the correct tactics for social sciences is the introspective study of the mind rather than observations of external behaviour. Advocates of the new approach, on the other hand, find it a great stimulus for research". Again, "with the rapid development of sociology and anthropology excessive formalism in political science has been toned down by approaches through political sociology." (Kim et al 1980)

Suggestion No. 3: A course in appropriate research methodology is essential for all disciplines.

Students in the Faculty of Arts, related to humanities – History, Languages, Political Science, Economics and those dealing with Hindu, Christian and Islamic civilisations – would benefit by training in sociological methodology. Data collecting techniques, such as Focus Group Discussion, Nominal Group Techniques, Delphi technique, case studies and participatory research give a wide range of possibilities for gathering information on the economic, social, political and cultural aspects of national life.

Tamil, as a language of modern thought and communication needs research on its usage by different sections of the people in every day life - education, administration, law, aesthetics etc. Readability and relevance of modern prose for fiction and non-fiction, readership of Tamil literature and other books in Tamil could be assessed by these methods.

Suggestion No. 4: A common methodology course in the social sciences, conducted as lectures, seminars or workshops should be organised for the disciplines dealing with humanities ie those that come under Section D of this Association. The Department of Sociology is best suited for the formation and execution of this common curriculum.

This arrangement also provides for inter-departmental co-operation in research, for example a student in Tamil could have as his supervisor a lecturer from Sociology.

Suggestion No. 5: Inter-departmental or even inter-faculty collaboration should be encouraged in student research.

A notable absence in the Arts and Science Faculties is academic orientation to the library. In the Faculty of Medicine, every new batch is introduced, by groups, to the use of the library. This includes organisation of the library resources, classification and shelving of books and the use of catalogue for location of the books. In addition special instruction is given by the Senior Assistant Librarian on the use of Medical Index, before the research projects.

Suggestion No. 6: A common course on the usage of library should be organised for the students at entry to the University. This should be supplemented by additional instructions on the library for research.

Various limitations were identified by the teachers in the execution of student projects. The following three suggestions are put forward in order to make the best use of the materials, time and the supervisor.

Suggestion No. 7: As far as possible group research involving 2 – 3 students should be encouraged, and appropriate methods for marking individual student be devised, as done by Community Medicine.

Suggestion No. 8: Get students to participate in the research projects of the teacher wherever possible.

This gives opportunity to the students to see a lecturer not only as a teacher but as a research scientist.

Suggestion No. 9: The Computer Unit of the University be enlarged and re-organised so as to enable students to get their research material analysed by appointment.

Students must be encouraged to produce research of quality, without which the whole excercise would be meaningless, infact counter productive.

Suggestion No. 10: Selected student research should be

i. kept for reference in the library, even in abstract form.

ii. given a chance of appearing in local Scientific or Medical journals.

iii. presented at the meeting of the JSA and JMA.

Further opinion of students on their research activities will supply the departments methods of improvement of this component in the curriculum.

Suggestion No. 11: Students evaluation of the research activity must be obtained for each batch by using an anonymous questionnaire.

Finally, regular monitoring of the students research activities is important in order to find out the many issues related to it.

Suggestion No. 12: Each Faculty should have its curriculum committee that regularly monitor the execution of the student research. In the case of the Faculty of Arts the Department of Education should take an active role in co-ordinating the activities related to undergraduate research.

Ladies and gentlemen, I have chosen a subject which is important and worthwhile. My study has been of an exploratory nature. The comments made by the Heads and Professors have been very useful. I have studied them before making my suggestions. I hope my simple study would give rise to better thought and action so that we produce graduates who are capable of reasoning for truth, and live up to the motto of this University.

எப்பொருள் எத்தன்மைத்தாயினும் —
எப்பொருள் யார்யார் வாய்க்கேட்பினும் —
அப்பொருள் மெய்ப்பொருள் காண்பது அறிவு

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OUR OPTIONS IN TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

Professor V. Navaratnarajah, Chairman, Section B.

1.0 INTRODUCTION

Our countries have been classified as less developed countries (LDCs), third world countries or as belonging to the 'South' in the North / South divide of the countries of the world based on the level of development in the country. When one talks of development, the yardstick used is that of the West which is supposed to be modern, the concept being that what is modern is good and what is traditional is bad !

Development today seems to imply to be developed in an industrial sense. Hence the yearning to become a newly industriaised country (NIC) on the premise that once a country reaches a certain level of industrialisation, it has reached a satisfactory level of economic development ! Perhaps this is understandable when one perceives that some of the new NICs in the Asian continent, the so-called "Tigers" in South-East Asia and Far-East Asia have been able to improve the standard of living of their population through selected industrialisation.

In choosing technology for development, one has to be mindful of the effects of such developmental technology on the ecological systems - what is now being increasingly referred to as sustainable development i. e. development that satisfies present needs without risking the future generation's needs and thereby ensuring humanity's long term future. Consequently, the model of development would take account of each country's specific culture and ecological conditions – the model has to be adaptable to the culture, potential resources and ecology. In choosing models of development and the related technology, cognisance

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has to be taken of two aspects. Firstly, model developed in one historical context under specific sociocultural conditions cannot be applied directly or en-bloc to other societies without considerable social costs. Secondly, using highly sophisticated advanced technology means 'leap-frogging' one or more of the socioeconomic stages through which the highly industrial countries had passed through in arriving at the point where they are at present – this involves the developing country crossing various technological gaps much to the disadvantage and psycho-sociological dependence on the industrialised countries.

In this context, it is useful to be reminded of the call by a Costa Rican philosopher Ramirez [1] that:

> "it is important to forge a new concept of development in order not to confuse it with modernisation and because it is preferable to decide things for ourselves than to have others decide them for us."

2.0 FRAMEWORK FOR SUSTAINABLE DEVELOPMENT

Any model of sustainable development must satisfy at least two criteria amongst others, namely:

1. The objective of any development approach must be satisfied by human needs and not the maximisation of abstract growth and productivity indicators.
2. The development must draw on people's initiatives and self-organisation, be self-reliant and ecologically sound. Ecologically sound development conserves existing ecosystems, preferentially exploits replenishable resources and applies gentle or appropriate technologies.

Considering the second aspect, it is implied that satisfactory development should be based on an appropriate technology. There are different perceptions of what is considered appropriate technology. However, Ramirez [2] proposes an ethical criteria for deciding it as follows:

"What is *not* appropriate technology? A technology excessively contaminating, expensive and difficult to repair, one that deepens dependency, consumes much fuel and is capital intensive. On the other hand, appropriate technology is one that is friendly to the user and the environment, that is appropriate in not damaging to the human and non-human environment, one which does not require the payment of large sums for patents and pre-requisites, one with low consumption of energy and fuel, one that helps resolve some of our problems and that, by not submerging the country in greater dependence, stimulates independence and confidence in ourselves as a people."

The familiar "Nothern" model of development has been on the basis of equating development with quantitative economic growth and rapid industrialisation. The assumption was that with time the benefits of economic growth would automatically spread to the poorer regions and population groups–the so-called 'trickle-down' effect. The hoped for trickle-down of economic growth has proved illusory and generally failed to alleviate the problems of the developing countries, but seems to have engendered specific social and economic ills. These models also considered 'rural' and 'urban' as separate entities, thus creating social problems arising from migration from rural areas to urban areas, such as reduced housing and health facilities besides the difficulties in finding sufficient labour for employment in the rural and agricultural industries.

The concept of maximising abstract growth has to be rejected in our context in favour of a development approach geared towards the satisfaction of basic human needs. The concept of basic needs is not new as it is stated in all religions and is an old and humanistic idea, but people have lost sight of its economic application. However, the basic differences in approaches between the basic needs concept and the conventional growth concept is stated by Braun [3] as follows:

Growth and Industrialisation Concept	Basic Needs Concept
UNDERDEVELOPMENT	
(the condition of) material poverty	(the process of) dependence/inequality
INDICATOR	
gross national product (per capita GNP below US$ 500/- per annum = developing country)	absolute poverty/inequality in living couditions political = oppression economic = exploitation cultural = alienation
DEVELOPMENT	
growth in GNP industrialisation world market in integration	satisfaction of basic needs; abolition of absolute poverty; cultural identity; social participation.

2.1 Sustainable development targets

In order to identify suitable technology for development, we have to be mindful of our present level of technological competence, Hence, priorities for development targets have to be identified and categorised based on the concept of progressive advancement of technology use with time. The priorities may be set up us follows:

1. Basic needs
2. Small development projects
3. Low technology projects
4. High technology projects

2.1.1 Basic needs

These have been known through the ages as food, clothing and shelter. However, to this must be added another, namely health and living environment. In order to have a healthy population, the proposed development must provide sufficient nutritionally balanced food, good drinking water, environmentally

suitable waste disposal systems and comfortable housing. The provision of nutritionally balanced food includes improvement of productivity in agriculture, and food contributing animal proteins such as fish or poultry or vegetable protein such as dahl or soya. These measures would necessitate expanding the amount of land under cultivation, introducing high-yielding indigenous cereals, expanding the fisheries industry and increasing productivity of food related egg and poultry industries. This would also involve designing the ecological use of land and promoting comprehensive land reform.

Besides designing and implementing new patterns of land use, greater emphasis has to be paid to the provision of human settlements with healthy environment. This would necessitate provision of low-cost but comfortable and safe housing units together with clean drinking water and healthy waste disposal systems.

2.1.2 Small development projects

These would be related to the basic needs of food, human settlements and health mentioned above. In relation to food, this would involve experimentation in different types of food that would provide the necessary nutrition to the people and the related infrastructure in terms of men, materials and methods towards that objective. For example, one could design intergrated projects which could include the farming of the food cereals; designing the irrigation facilities and rehabilitation of existing water resource facilities such as lakes and ponds for conservation of rain water for agricultural purposes; providing sufficient irrigation for grasslands which could provide the necessary fodder for a dairy farm from which the requirements of milk and other dairy products for the improved nutrition and health of the people could be obtained; the waste from the dairy farm may be used as bio-fertilizers in the fields and for producing biogas from which energy may be obtained directly for cooking or converted into electrical energy for use in food related industries. The

food cereals and the milk could be further processed and value-added to provide readily marketable and even exportable baby foods. Similar examples can be given in other fields such as fisheries and poultry production. The important criteria in the development of such small projects is that it can be carried out by the people at the rural or village level with resources readily available to them.

2.1.3 Low technology projects

One of the serious problems faced by developing countries is the lack of sufficient trained technical manpower at the technician and technologist level to support and service development projects although efforts taken in providing higher level manpower has been moderately successful in the training of this manpower in the local universities. This has been partly due to a lack of a technological culture amongst our people and a desire to produce more and more manpower at the professional level attracted by the monetary returns of employment at that level. Even the educational system that we inherited from the colonial powers which was mainly geared towards the running of an efficient state machinery to export the primary products produced in this country, has not been changed towards promoting more technological emphasis in the curriculum. Countries like Singapore which became independent much later have developed technological and service oriented skills which have helped them to project their manpower as technologically advanced and thereby attracting foreign investment into them.

However, even with the level of technology obtaining at the present time, it is possible to carry out projects to improve the lot of the people. These can be geared to the food industries such as those involving low-level biotechnology in improving production in agriculture and fisheries, and in suitably processing them ready for marketing, first locally and later for export. Weaving of cloth from imported yarn (till such time as yarn is made locally from materials such as banana tree stems), industries related to the coconut fibre industry, palmyrah industries, leather

industries and similar cottage type of industries can be grouped under this category. Another group of industries that would be of use is the category of light-metal industries and industries involved in the making of spares for machinery used in the agriculture and small scale industries. It is important to note that these activities have existed in the past in our region and it is only necessary to rehabilitate and revamp these industries with a new vigour.

2.1.4 High technology projects

In view of our lagging behind in the availability of technical manpower, it is not possible to be involved in all types of high technology projects which involve design and manufacture. However, there are technologies grouped under this category which may involve using borrowed technology and training our manpower for the specific purpose of carrying out this technology. Examples are the assembly of air-conditioners or refrigerators or even hi-fi equipment including TV and video equipment for local consumption and export. Such projects would help us to develop our technology and also increase our foreign exchange earnings which could be used to further other projects.

One of the useful fall-outs of co-operation in high technology projects with developed countries is the gradual transfer of technology and development of technical skills related to the industries, not to understate the market outlets of these countries, for our manufactured products.

In my address last year [4], I discussed the ways in which co-operation in technology with industrialised countries could be beneficial to us. I gave examples of how Germany helped India in projects related to meteriology, land and forestry, water resources and worked with Indonesia in the mapping of land use for human settlements, desalination plant for purification of drinking water and generation of electricity with wood-fired generators. The adaption of the imported technology to local conditions, simplification of the technology towards making it

more robust and reliable and making its operation, maintenance and repair work easier are essential aspects in the field of successful technological co-operation.

3.0 CHOICE OF TECHNOLOGY

The appropriate technology, for it to be meaningful, has to be necessarily related to the basic needs mentioned earlier. In this respect, looking back on our indigenous ways of life before we started imitating the West may indicate the most suitable technology which with proper modernisation could be adapted to our present situations.

3.1 Technology related to food production

Farming in a broad sense includes agriculture, animal rearing (cattle and goat), poultry rearing and even fish farming (aquaculture). Even in earlier times, when one mentioned farmsteads, these described a scene of extents of land growing cereals for food, farm animals which included animals used for tilling the soil besides those used for providing milk and products such as butter, ghee and the farm birds such as poultry providing supplementary food in the form of eggs and meat. Besides helping to provide a balanced diet which maintained a healthy life on these farms, the different groups provided an integrated system of farming. For example, the waste from the animals and poultry served as good manure for the land in the production of the cereals. The natural manure helped to renew the bio-nitrogen content of the soil without the necessity for the use of expensive artificial petro-chemical fertilizers which are known to deplete the nutrients in the soil over an extended period of use. In other words, biodiversity and its conservation was very much in practice in the earlier times.

In the last four or five decades, third world countries have borrowed and practised the mechanised farming methods of the West which depended heavily on the import of fossil-fuels (diesel and kerosene) for operating the farm tractors and pumps for

irrigation. They also adopted high-yielding varieties of rice (the main cereal grown in our countries) which has conquered Asia and in some places such as Philippines, Indonesia and Vietnam, a single variety may account for as much as 60 percent of all rice production. In doing so, it has swept aside hundreds of locally adopted varieties which had been tested and found to be resistant to pests. The high yielding varieties fulfil their potential only as part of a package that includes irrigation, pesticides, herbicides and top grade soil. If any of these components is missing, the so-called high-yield variety performs more poorly than those it displaced. The exchange of herbicide tolerant genes between the domesticated crops and weedy relatives could ultimately result in the need for more herbicides to control herbicide-resistant weeds [5]. Furthermore, it has been estimated that less than 1% of the pesticides, including herbicides, applied actually reach the targets. Consequently, more than 99% of herbicides applied may contaminate land, water, air, humans, other animals and wildlife habitat. Moreover, herbicides account for approximately 31% of the estimated oncogenic risk of pesticides residue in fresh foods and approximately 12% of the pesticide residue risk in processed food [5]. It would not be very wrong to conjecture that the increased occurence of cancer amongst the population in the Jaffna Peninsula may be a direct consequence of the increased dependance of our farmers and vegetable growers on herbicides and pesticides.

The increased irrigation required for the high-yielding varieties has prompted the farmers in the Northern regions to pump water stored in the underground aquifers using kerosene operated pumps from open wells and tube wells. The water found underground in the peninsula and the northern parts of the main land is found as fresh water floating in lens formation over brackish or saline water. Increased and uncontrolled rate of pumping of this water has resulted in the exhaustion of this limited supply of fresh water and conversion of fresh water wells to saline wells, no more useful for irrigation purposes.

Hence, it would seem that modern mechanised farming methods which were originally designed to be applied to extensive areas of farming land in the West may not be ideally suited to our farming where the plots of land belonging to individual farmers are small and manageable by the individual family groups. We also had an indigenous technology in the earlier times that was suitable to produce food to the point of self-sufficiency and it would seem that farming should go back to its roots! Without chemical fertilizers and pesticides, local crop seeds can outperform the introduced varieties.

In 1986, Salazar, along with scientists from the University of Philippines at Los Banos, established a programme called MASIPAG, which collected more than 200 older varieties from around the country. The scientists worked with farmers to screen the samples for their ability to resist disease and yield well without expensive chemical inputs. After just three years, MASIPAG has come up with traditional varieties that had proved to be more than a match to the high-yield varieties. On a level field, without chemical fertilizers and pesticides, the traditional varieties yielded 3.98 tonnes per hectare while the high yield varieties gave 3.87 tonnes per hectare [6].

One of the precious resources we have, is water stored in underground aquifers. In the past, this water was used mostly drawn from open wells for domestic use as the lakes and tanks used to conserve excess rain water during the rainly season became useful for the supply of water for irrigation purposes. However, with the neglect of lakes and ponds and the discharge of the excess rain water direct to the sea, besides depriving the recharge to the underground storage from the water in the lakes and ponds, increased water had been pumped from wells for irrigation purposes. It is necessary to rehabilitate the system of lakes and ponds for irrigation purposes in the peninsula while improving the system of lakes and small dams for storage in the mainland northern region which lies in the Dry Zone of Sri Lanka. Efficient water management practice must be

adopted to improve the gains since the tradional water management practice observed in these dry zone villages are based on common property access to minimise social conflict over water rights. They are acceptably efficient in economic terms, given the water demands of the traditional rice production technology. Adoption of high-yielding variety (HYV) rice technology to increase rice output makes the water-management practices less efficient.

In the traditional interseasonal allocation process, the rice crops of the two seasons are not treated by villagers as competing bidders for the water stored in the dam/tank. The Dry Season's cultivation is often relegated to secondary importance and receives only the residual storage. More recently, Sri Lankan sources have recognised the possibility of significantly increased inefficiency arising out of the greater demands of the HYV technology. The source of this increased inefficiency is that HYV adaption raises the opportunity cost of water applied in the wet season Mahendrarajah and Warr [7] have discussed the salient features of the water allocation problem which can be demonstrated with the aid of Fig. 1, where the two vertical axes represent the net

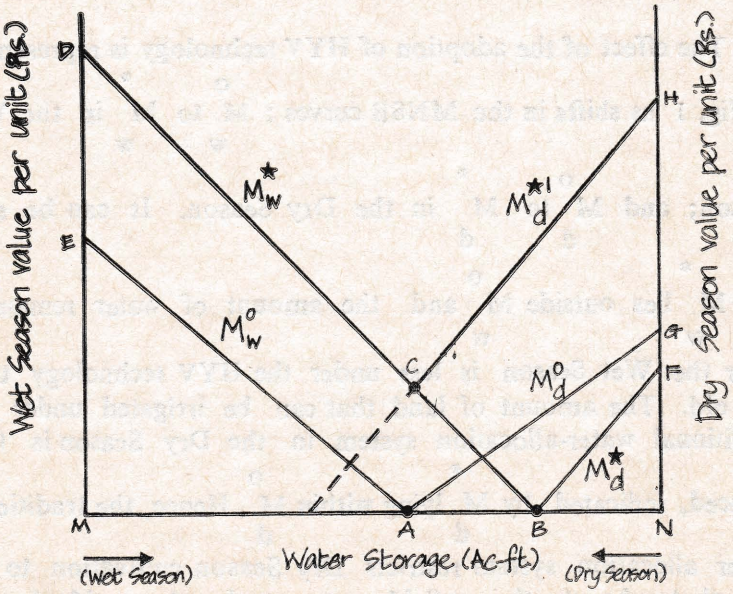

Fig. 1. Traditional & Efficient Interseasonal Allocation of water

benefit per unit of water use in each of the two seasons, while the horizontal axis measures the stock of water. Water allocation for the Wet Season is measured from left to right and that of the Dry Season from right to left. The marginal net social benefit (MNSB) curve for the Wet Season, using the old technology, M_w^o, cuts the horizontal axis at the point A. The residual storage is allocated to an appropriate area of rice in the Dry season. The area of land both cultivated and irrigated in the Dry Zone is chosen to be just sufficient to exhaust the stock of water remaining after the Wet Season. The Dry Season-old technology MNSB curve M_d^o corresponding to this restricted amount of land thus intersects the horizontal axis also at A. The areas bounded by the two MNSB curves and the horizontal axis measure the total net social benefit accuring to villages: the areas EAM plus AGN.

The effect of the adoption of HYV technology is represented in Fig. 1 as shifts in the MNSB curves : M_w^o to M_w^* in the Wet Season; and M_d^o to M_d^* in the Dry Season. It can be seen that M_w^* lies outside M_w^o and the amount of water remaining after the Wet Season is less under the HYV technology than the old. The amount of land that can be irrigated under the traditional water-allocation system in the Dry Season is thus reduced, indicated by M_d^* lying within M_d^o. Hence, the traditional water allocation system restricts Dry Season cultivation to an area that exhausts the available water stock - the residual after Wet Season use – at the zero Value of Marginal Product (VMP).

In order to obtain an efficient interseasonal allocation, the VMPs for water in the two seasons are equated and occurs corresponding to the point C with a positive VMP. The gain attributable to the adoption of HYV technology, but retaining the water allocation system, is equivalent to the area ABDE less area ABFG. This difference must be positive, or the new technology would not be adopted. The further gain attributable to the efficient allocation of water under HYV technology corresponds to the area BCHF. The total gain from both, corresponding to the movement from A to C, is given by the area DEAGHC.

One of the areas of concern is that a great portion of fertile land in the peninsula is used for the cultivation of cash crops such as tobacco which does not meet the immediate basic needs of the population. A part of the area is also used for growing vegetables, chillies and onions, a greater portion of the latter two again being cultivated in excess of local requirements for export to southern Sri Lanka for cash. The types of vegetables cultivated in the region also have changed in the last 2 or 3 decades and one wonders if it is really necessary to grow carrots, beetroots and cabbage which require fair amount of pesticides to obtain an economic crop, in preference to the vegetables such as brinjals, bitter-gourd, ladies finger or pumpkins which have been grown in our region for over a century. Perhaps our people believe that it is more civilised to eat western type of vegetables rather than the locally available vegetables. There have been no studies to report that our people are healthier because they are eating carrots, beetroots and cabage! However, studies elsewhere have shown that people eat locally produced vegetables because they are better than the imported type. For example, in Kenya The Indigenous Food Plants Project of KENGO had found that *Gnandropsis gynandra* or *dek* in the language of the Luo people has three times the Vitamin A, five times the Vitamin C and three times the protein of an introduced vegetable such as cabbage [6]. It is necessary for our bioscientists to carry out research to find out the portent of our local vegetables instead of planting imported varieties of vegetables which need a high dose of pesticides and irrigation.

One must not lose sight of the fact that the local farmer has over a period of time learnt to grow crops that are resistant to pests and therefore do not need pesticides. In fact he has learnt that growing other plants near his crops helps to keep away the pests! A typical example where the modern scientists have learnt from the local farmers was when the International Institute of Tropical Agriculture found under cultivation in nothern Nigeria a strain of cowpea that was usually resistant to weevils, which often eat a large part of the cowpea harvest. The Institute employed researchers from the University of Durham, England to isolate the source of this resistance, which turned out to be a molecule called trypsin inhibitor that interferes with the metabolism of the weevil. The University took out a patent on the gene and began licensing seed companies to incorporate it in a number of different crops[7].

It is also necessary to use technology to improve the productivity of our arid and saline lands. Parthasarathy[9] has reported how "life-saving irrigation" in the form of a single light dose of water can increase land productivity by sizeable amounts. The recent advance with the greatest impact on furrow irrigation is surge irrigation. This constitutes the intermittent application of water to alternating blocks of furrows[10]. It reduces the infiltration rate on most soils so that water advances down the field more quickly and less water is required to wet the furrows along their entire length. The presence of an excessive amount of salts in irrigation or soil water has been considered a major threat to the permanence of irrigated agriculture throught the world. Worldwide, aproximately one-third to one half of all irrigated lands have salt problems; the majority of these lands are in lesser-developed arid regions. On the positive side, agricultural engineers have developed carefully calculated drainage systems that, when properly managed, will keep the salts out of the root zone. There has also been success in identifying salt-resistant crops or creating salt-tolerant crop by selection, hybridization, back crossing and other such methods, using conventional crops. Decades of work have resulted in crops that do indeed have an increased

tolerance of salty conditions. A few of the notable crops are barley, tomato, wheat, asparagus, rice, corn, cotton and alfalfa[11]. Agricultural engineering, biotechnology, the development of salt-loving glycophytes and halophytes have the potential for reclaiming salt-ruined land, stabilizing soil from wind and water erosion, providing pasturage, and helping people feed themselves.

Fish production at the present time is limited to coastal and near coastal areas of our region. There is a necessity to venture into deep-sea or ocean fishing in order to increase our fish production. Our technology, which has not developed very much should be given a push and developed to that used in Japan and the Scandinavian countries. Adoption of such technologies would pave the way for increased production of sea food and even lead to export of the excess over home needs to earn much needed foreign exchange. Besides fishing in sea-waters, aquacutlure could be developed in the coastal areas around the nothern regions of the peninsula.

People are knowledgeable with poultry and cattle rearing, the former for the supply of eggs and meat and the latter for milk and milk products. However, the method of marketing these products and managing these activities on a scientific and industrial basis is found lacking in our region, although the supporting services in the form of veterinary laboratories and food and health inspectorates are available to be tapped

3.2 Technology related to food processing

One of the problems in our food probuction is that it is seasonal and periodic. Hence, there are periods when food is abundantly available alternating with periods when it is scarce. This is partly due to our climate in which food stored over long periods become unfit for consumption. Certain types of food such as cereals could be stored over short periods, whereas other types such as some vegetables, milk and fish become unfit for consumption even over a day! Hence, these periods of plenty and scarcity have to be evened out so that a steady supply is available for marketing.

Foods that become spoilt over a day need to be stored in refrigerators for which the high cost of electricity has to be reckoned with. However, several countries including Sri Lanka have experimented using absorption cooling cycles and most of these are aimed at house - hold scale food coolers or small scale ice manufacture [12]. There are many possible refrigeration cycles and systems such as intermittent absorption cycles that can be considered for solar-powered refrigeration. However, the basic question as to the best scale on which to operate solar refrigeration has yet to be established. Although there are a number of open questions regarding solar refrigeration, its application has the attractive possibility of increased utlli-zation of available foodstuffs.

Another area of solar power technology that may be used in food processing is crop-drying. Grains, fruits and vegetables could be dried in the open in direct exposure to the sun in the conventional manner. In recent years, solar drying has come to mean the process whereby agricultural products are dried not by direct exposure to the sun, but by means of solar-heated air in protected surroundings. A large portion of the world's supply of dried fruits and vegetables continues to be prepared by sun-drying as this is the cheapest and simplest way to dry crops in regions having abundant sunshine and where the post-harvest season is characterised by low humidity and little or no rainfall[12]. The dried vegetables and other food items may be kept in storage before marketing or processed for export.

Milk produced in dairy farms could be processed into butter, cheese and ghee or as dried milk powder. A further innovation would be the production of baby milk foods and cereals, combining the milk powder and cereals and thereby producing a value-added product which can be made available for local consumption (in lieu of imported similar products) or exported. One of the requirements for such low-technology industry would be the necessary energy - in this case the electric energy to motivate the processing plant. An integrated

approach of obtaining electricity from biogas generated from the animal waste products from a dairy or from a producer gas plant operating on waste products such as hay or wood-waste is worthy of consideration.

3.3 The Biotechnology Option

Coventional factories are large establishments operating on the basis of economics of scale. Biotechnology based factories, on the other hand, can be small establishments suitable for villages. Several biotechnologies are labour intensive and economy of scale is not as important as in chemical industries. Biotechnologies are as a rule less pollutive and the cost of maintenance of biofactories would be much lower.

Biotechnologies could increase industrial productivity while maintaining involvement in agriculture or agriculture related industries. A judicious use of biotechnologies could lead to a situation where a large proportion of the population while continuing to be engaged in agricultural activities may derive a large portion of its income from non-agricultural activities, as found in Japan. Biotechnologies could thus bridge the gap between industry and agriculture, and this interaction is beneficial to the agro-based industry.

Biotechnology offers a powerful new capacity for science-based rural industrialisation. The potential of this development is illustrated in Figure 2 [13]. Opportunities are offered by the fact that we are situated in the tropical belt, often rich in natural resources which biotechnologies can convert into high value-added products. These opportunities can only be taken advantage of successfully if accompanied by increased capability in the technologies. This is dependent on the skilled scientists and engineers and the development of an indigenous scientific and technological base. Thailand initiated steps to improve its technology base when its rural development projects were started in the early 80s to alleviate rural hardship and increase agricultural production through

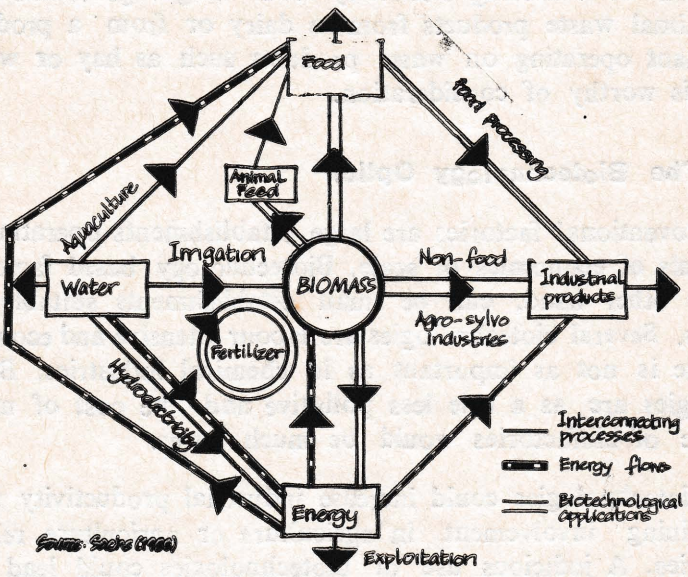

Fig. 2 A systems approach to rural development (Simplified)

diversification. It has since benefited from an active biotechnology involvement due to the reasons that it is a fertile country with a vast pool of unused natural reasources, a large number of qualified research personnel and a fairly sound economic status which would ensure returns in judiciously chosen biotechnology investments[14]. The interests of Thai industries in relation to biotechnologies include the areas of amino-acid production for foodstuffs, cassava starch modification, hybrid seed production, commercial plant propagation through tissue culture, secondary production of antibiotics, animal vaccines, beverages and foodstuffs. These are all industries which could be developed by us with profit and benefit to our area. One factor that helped to strengthen biotechnologies in Thailand was the establishment of the National Centre for Genetic Engineering and Biotechnology (NCGEB). This Centre has affiliated laboratories with emphasis on the development, transfer and utilization of biotechnologies, including genetic engineering, in industry, agriculture, public

health, energy and environment. In areas where there is a shortage of trained manpower, Thailand has benefited from co-operation with other countries. For example, the NCGEB has tapped the expertise of British university researchers, funded by the British Council and the Royal Society, to develop a local starch industry using cassava[8]. We could learn from the experiences of Thailand.

There are also other sources of help available for small countries trying to develop capabilities in biotechnology. The Rockerfeller Foundation currently provides about US$ 7.0 Million annually for a comprehensive programme of rice biotechnology research designed to meet the needs of the developing world[15]. In the period 1985–90, the Foundation spent US$ 33.85 Million on Rice Biotechnology towards direct capacity building, applications in breeding, genetic engineering and programme administration. Potential applications of biotechnology for agricultural improvement are found in plant improvement (disease free plant improvement, biological nitrogen fixation and transgenic plants for pest resistance), animal embryo manipulation and animal disease control.

Biotechnology research requires materials and equipment far more sophisticated and costly than most crop and animal breeders use. There are of course a range which are simpler and require less costly investment than others. Some, such as tissue culture, can be used to achieve near-term goals like disease-free planting for perennial crops.

4.0 EDUCATION IN TECHNOLOGY DEVELOPMENT

We have discussed how Thailand identified very early that one of its needs to institute vigorous rural development using biotechnology related agricultural methods was to increase its scientific and technological manpower. We have been producing yearly graduates in the scientific and technical fields but have been unable to use them efficiently in furthering an aggressive

development. It would seem that our educational policies have not been formulated to produce the relevant technologically oriented graduates.

There is a need to make our students aware of the development and progress of the various technologies used in the outside world and educate them how they could be implanted with profit in our developmental efforts. We do not have to repeat the research done in the developed world, but study the findings of such research and how it may be suitably adapted to the local situation and climate. Therefore, we need to produce scientists, applied scientists and technologists who would be able to initiate and carry out research on local resources and ways of exploiting them. It is the incumbent duty of our tertiary institutions to model their methods of instruction so as to inculcate a desire in the minds of our youngsters to be innovative and think of new ideas in which the local resources can be exploited without too much help from outside – as outside help always carries a price with it!

Hence, there is an immediate need to orientate our instruction in the tertiary institutions through a curriculum that will produce graduates who are capeable of contributing to development in a positive way and not serve a bureaucracy that was evolved to serve the needs of a colonial administration. Our graduates should be development oriented in their thinking and be entrepreneurial in their approach to development. They should be able to develop strategies and methods not only to increase productivity but produce value-added goods from the resources available. Investment in the bio-science graduates of today with their proper orientation towards development of a local brand of biotechnology may reap bountiful benefits tomorrow. A few of the developing countries, notably Brazil, China, India and Thailand currently enjoy a capacity to develop and export biotechnologies, largely because of concerted efforts by their policy makers and scientists to develop national biotechnology policies[16].

5.0 CONCLUDING REMARKS

In conclusion, we could summarize as follows :

1. We should develop a framework for sustainable development towards achieving the basic needs of our population. It should include the participation of the people and draw on people's initiative and self organisation and be self-reliant and ecologically sound.

2. Low technology and high technology projects shall be mixed and chosen according to the needs and available resources, not forgetting the maximum involvement of the people – be they rural or urban.

3. Agriculture and fisheries related technology offers immediate benefits to our need oriented development.

4. Biotechnology in agriculture related industries and others should be given priority and developed to use efficiently our available resources.

5. Education should be oriented towards a technologically oriented society.

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TAMILS IN EARLY SRI LANKA
A HISTORICAL PERSPECTIVE

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1. ANTIQUITY OF THE FORM TAMIL

The aim of this paper is to analyse the history of the Tamils in Sri Lanka during the Pre-Christian era from the middle of the 3rd century BC (250 BC) in a historical perspective. As a corollary to the subject it is pertinent to dwell on the form Tamil. The earliest reference to this is found in Tolkāppiyam, the earliest extant grammar in Tamil.[1] However, it is opined that the word Tamil occurs nearly in fifteen instances in the Sangam classics like Puranānūru, Akanānūru, Patirruppattu and Cirupānārruppatai, as a reference to the land, language and finally to the people.[2] It is also argued that the form Tak – i r and Tamir gave way to Damil, Damila, Dravida as m/v alteration is a common phenomenon in Dravidian phonology.[3] Apparently, the form Dravida/Dravidian today is used to denote a group of languages of which Tamil is one amongst them. In the Buddhist sources the Tamil country is referred to as Damila, Damilaratta and its language as Damilabhasa.[4] While the Tamil country is referred to as Damila in Jaina sources, its script is mentioned as Damili.[5] The Greek forms such as Damirike, and Lymirike are in fact the adaptations of Damila.[6]

Now turning to our Sri Lankan sources it may be recounted that the forms 'Damila' and 'Dameda' occur in both Pali[7] and epigraphical sources[8], as a reference to the Tamil country and its people. Incidentally it may be noted that the form 'Damila'

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is the earliest morphological derivation from Tamir as we have mentioned earlier. Hence the occurrence of this form in Sri Lankan sources indicates its early presence here co-eval with that of Tamil Nadu. While the form 'Dameda' occurs with reference to Tamil traders, the latter (Damila) is used in the Pali Chronicles with reference to invasions from the Tamil country. Perhaps it may be noted here that the context in which these forms Dameda / Damila occur in both epigraphs and literature does not in anyway warrant any conclusion that at this time ethnicity was ever attributed to these forms. Instead, these forms denoted the country, language and its people who inhabited it.

2. PERCEPTIONS OF THE TAMILIAN PAST

Rasanayagam writing in the twenties of the present century identified Tamils with the Nagas mentioned in the Pali Chronicles and the Tamil sources and took back the origin of the Tamil settlements in Sri Lanka to the 15th century BC.[9] Gnanaprakasar, a contemporary of Rasanayagam, published several articles in which he claimed that Sri Lanka was originally the land of the Dravidians.[10] The late forties witnessed the publication of the book entitled 'The early history of Ceylon' by the pioneer historian of Sri Lanka, Mendis. Writing on Sri Lankan history, he assigned a third place to the Dravidians after the Stone Age and the Aryan settlements.[11]

At the close of the fifties when Paranavitana edited the University of Ceylon's publication on the History of Ceylon, he remarked that 'There is also no evidence to establish that a people of Dravidian stock who in historic times occupied the neighbouring mainland and on many occasions fought with the Sinhalese for the sovereignty over the Island were present there at the time of the first Aryan settlement. Early Tamil literature contains nothing to indicate that Ceylon was a region in which that language was spoken by a

considerable proportion of the people." However, he further commented that 'The higher culture, including the languages brought to these regions by the Sinhalese as well as the Tamils was adopted in varying degrees by the people of Stone Age culture who were there before their arrival. Thus the vast majority of the people who today speak Sinhalese or Tamil must ultimately be descended from those autochthonous people of whom we know next to nothing.[12]

Arasaratnam, writing in the mid sixties while discussing the antiquity of the early Tamil settlements and acknowledging the fact that the Megalithic culture paved the way for the flowering of the Dravidian civilization in South India, observed that 'Could this Megalithic parent of the later Dravidian civilization have spread to Ceylon and could this have been the culture that existed in Ceylon when the Aryans landed there? Whether this be so or not, there is no doubt that at the time of Aryan Colonisation of Ceylon the inhabitants of the Tamil country played an important role in the establishment of this civilization'.[13]

Paranavitana published a book entitled 'Sinhalayo' in 1967, where he stated that 'These Megalithic sites and urn fields are found throughout the regions inhabited by Dravidian speaking people. The burial customs to which they bear witness are referred to in early Tamil literature It is therefore egitimate to infer that the people who buried their dead in dolmens and cists as well as in large earthenware jars were Dravidians. The Megalithic monuments and urn burials discovered in Ceylon are obviously an overflow from South India. The archaeological evidence is supported by literary sources. The Dravidian people influenced the course of the Island's history about the same time they gained mastery over the South Indian Kingdoms.[14]

At this juncture it is relevant to quote Indrapala who gave a public lecture on the early Tamil settlements in Sri Lanka at the Royal Asiatic Society of Sri Lanka in the latter

half of the sixties.[15] While referring to constraints encountered in this study he remarked that 'the study of the early Tamil settlements in Ceylon has been rendered difficult due to a variety of reasons. As in the case of all students of ancient history we are confronted in the first place with the problem of inadequate sources. While the Pali and the Sinhalese Chronicles provide very reliable, fairly adequate and surprisingly continuous information regarding the political and to an extent the religious history of the Island, their contribution to our inquiry is very little. The activities of the Tamils in Ceylon find mention in the Chronicles only when these affected the political or religious affairs of the Sinhalese Kingdom. On the Tamil side the Chronicles that are extant are those written nearly three centuries after the foundation of the Tamil Kingdom in the Island in the thirteenth century. The sections of these works dealing with the period prior to the thirteenth century. i. e. the period during which the earliest Tamil settlements were established are full of legendary material and are wholly unreliable. The Tamil works of South India have no notable allusions to the activities of Tamils in Ceylon. The evidence of the archaeological materials is far more encouraging in this respect but by no means adequate. But excavation is still an undeveloped branch of archaeological research in our country. As long as excavation work remains undone, much that is relevant to our study will be wanting.

K. M. de Silva in his book published in 1980, after discussing the Aryan colonisation and the introduction of Buddhism into the Island observed that 'the Dravidian influence was the third major ingredient in the Island's development in Proto-historic times. There is no firm evidence as to when the Dravidians first came to the Island, but come they did from very early times either as invaders or as peaceful immigrants. Tamil and other literary sources, however, point to substantial urban and trading centres in South India in the third century BC. Very probably these trade relation between them and Sri Lanka

and very probably too the Island's trade with the Mediterranean was through these South Indian ports. By the third century BC, the Dravidian intrusion into the affairs of Sri Lanka became very marked.[16]

However the excavations conducted at the Proto-historic sites which too are spoken of as the early centres of Aryan settlements in the Chronicles have not only added fresh data regarding the dawn of civilization in Sri Lanka but also have helped us to test the accuracy of the Chronicles with regard to the beginning of civilization in the Island.[17] Hence today one could move from the arena of speculation and probabilities to concrete archaeological data the lack of which Indrapala lamented a quarter of century ago and Rasanayagam and Gnanaprakasar were unaware of half a century ago. This in turn helps us to analyse even the legends of early colonisation and put them in a historical perspective.

3. THE LEGENDARY PHASE

Evidence regarding the early Tamil settlements is found in the Pali Chronicles such as Dipavamsa and Mahavamsa in two phases, namely Proto-historic and Historic, while the earlier reference is found in the legends of the Proto-historic period and the latter in relation to the early political history of the Island. Now coming to the legendary phase Mahavamsa speaks of Vijaya, the hero of the Sinhalese race marrying the daughter of King Pāndu of Southern Madurai (Dakkinam Madhuram Puram) although this information is not found in the earlier Chronicle Dipavamsa.[18]. According to this Chronicle Mahavamsa accompanying the Princes from Madurai were other maidens and a thousand families belonging to the eighteen guilds. These maidens were married to Vijaya's ministers and retainers according to social status. Scholars who have studied the Vijaya legend while admitting its legendary nature, however saw a kernel of historical truth in it, that is the people of Tamil Nadu helped the Sinhalese race in the founding of civilization in the Island.[19] Thus Basham who made a study

of this legend contended that the Dravidian infiltration into Sri Lanka must have been going on from the earliest historical times and probably before and concluded that the story of the Princess of Madurai arose from the need to account for the presence of Tamils in Sri Lanka and to provide them with a place in the social and ethnic structure.[20]

Paranavitana, on the other hand, while endorsing the view that the 'Original home of the Pandyan Princess as Southern Madhura (Dakkhinam Madhuram Puram) as specifically stated in the Mahavamsa, contended that the qualifying word meaning 'Southern' attached to the name of the capital of the Pāndya country was, no doubt meant to distinguish it from the present Madhurā which had been the seat of Pāndya royalty from about the beginning of the Christian era. The city however, acquired that position after earlier Kapāta (Kapāta-puram in Tamil) which is referred to in the Ramayana as well as in the Mahābhārata, as the chief city of the Southern Kingdom was submerged in the sea. Kapātapura itself supplanted an earlier Madhurā at which according to Tamil tradition, the first college of Tamil poets called the Sangam was held and which too was swallowed by the sea. The earlier Madhurā is referred to in Tamil literature as Southern Madhurā and it was that city to which the author of the Mahāvamsa referred as the capital of Pāndya Kingdom at the time of the first Aryan settlement of the Island'.[21] However regarding the origin of these Pāndyas Paranavitana has a different tale to tell; he concluded that 'the assumption that the Pandyas, with whom the first Aryan settlers in Ceylon allied themselves, were Dravidians is not a necessary one, for the names of their capital and dynasty are of Aryan origin.[22]

The geographical proximity of Pandyan country to Sri Lanka and other recently accumulated archaeological data about

which we shall dwell in sequel however necessitates the linking up of the element Pāndu with the Pandyas of Tamil Nadu. The Tamil Nadu region has often been spoken of in these Pali Chronicles as the closest region to Sri Lanka. For, it is referred to as 'opposite coast' and 'further coast' [23]. The close link between the two regions is also reflected in the common flood tradition or deluge between the two regions as mentioned in Tamil and the Sinhalese sources[24]. The geological study has further confirmed the literary tradition of these two regions.[25]

In the light of the geographical proximity mentioned above it is plausible to link the Pāndus of the Pāli Chronicles with the Pandyas of Tamil Nadu. In the word Pandyar, Pandu is its chief component. Pandu, means old, the addition of respectable suffix ar with this would become Pandyar[26]. However, the occurrence of this early form 'Pandu' in the legends of the Proto-historic phase as the names of the successors of Vijaya such as Panduvāsudeva, Pandukabhaya (Pakundaka), Pandula, as well as the presence of Pandyan capital Kapātapuram as Dvaramandala in the legends of Pandukabhaya like the other early forms such as Damila / Dameda establishes the Dravidian presence during the Proto-historic phase itself. Therefore the Dravidian form Pāndyar cannot be linked with the Indo Aryan 'Pandu' of North India. Besides this, there is little connection between Madhura of North India and Maturai of the Pandyas. The two are independent in origin. Even if one takes Maturai and Madhura as variant forms, yet there is no evidence for the presence of Southern Madhura in North India or of its becoming a seat of political authority in North India at the time of these legends. The existence of Southern Maturai at an earlier date around the seventh century is confirmed by the recent study of Romila Thapar who has

identified Qdal of the cuneiform texts with the early Pandyan capital which too bore the name Kūdal.[27] Southern Maturai and the second capital, Kapāṭapuram lay on the Tāmraparni delta of the Pandyan country.

It is also equally important to note that the Sanskrit form Tāmraparnī reminds us of its Pali equivalent Tambapanni, the ancient name of Sri Lanka which gave way for its Greek adoption Taprobane. It has been argued on the basis of Tamil literary and epigraphical evidences that the original form of Sanskrit Tāmraparni is Tan Porunai which became Sanskritised as Tāmraparni and Prakritised as Tambapanni.[28] If this is so, it is very likely that in the early colonisation of the island the people of Tan Porunai delta played a vital role and as a memory of this the island was so named. The probability is further enhanced by the fact that Tambapanni the first landing place of Vijaya and later his capital where he is supposed to have reigned for thirty eight years has been identified on the coast of Mannar, on the opposite coast of the Pandya country near Kadamba nadi or Malwattu oya.[29] The discovery of urn burials at Pomparippu which also means copper coloured region along Kala Oya on the same coast and its genetical similarity with that of the burials from Ādichchanallur, in the region of Tāmraparni delta further confirm the above supposition.[30]

The close link between the Pandyas and early Sri Lanka is also further confirmed by the tradition of Tamil Sangams and the Sri Lankan poets participating in the deliberations of these Sangams. Although the three Sangams or Academies were located in the Pandyan country, the first and the last were located in Maturai. A poet named Pūtantevanār figures in the Sangam classics as Ilattup Pūtantevanār and Maturai ilattup Pūtantevanār. It is opined that both the names refer to one and the same person and the

Maturai Ilattup Putantevannar may be explained as Putantevanar from Ilam settled in Maturai.[31] He has seven poems to his credit, three in Akananuru,[32] three in Kuruntokai [33] one in Narrinai.[34] Finally the prevalence of Sangam words in the vocabulary of the Jaffna Tamil further reinforces the link that Sri Lanka had once with Tamil Nadu.[35] Perhaps the Pandyan - Sri Lankan linkage is also confirmed by the discovery of early coins in Sri Lanka, namely punch - marked and copper coins which betray their Pandyan ancestry.[36] The Pandyan lineage of the early Brahmi script of Sri Lanka is further corroborated by the study of Brahmi inscriptions of both the regions.[37]

Thus occurrence of this form Pandu as a name for the Pandyas, could be explained as part of the historical memories of the people who were culturally knit with the Pandyas before they adopted Buddhism. With the coming of Buddhism when the legends of Vijaya developed with Jataka tales and North Indian connection as a base, the forms Pandu and Maturai lost their original connections and probably began to be identified with North India on account of the cultural differences that existed between Tamil Nadu and Sri Lanka at the time of the development of these legends.

4. PERCEPTIONS OF THE PALI CHRONICLERS

The earliest reference to the Tamil presence in the Pali Chronicles is narrated in relation to the capture of political power in the ancient Anuradhapura Kingdom by the Damilas of Tamil Nadu. These Chronicles mention only the number of years they have successfully ruled from Anurahapura, the whole of Sri Lanka. It is very likely that their rule would have paved the way for more and more Tamil settlements not only in Anuradhapura but also in other regions as well. In dealing with the Tamil rule, one could see at least two views of the chroniclers: one is that their rule was just and the other is that Buddhism suffered

under their rule. Both these ideas are linked up in their description of the Tamil rule here. The first Tamils (Damilas) to capture power were Sena and Guttaka. They are said to be the sons of a mariner trading in horses (Assanāvika). They wrested power from Sura Tissa, one of the brothers of Devanampiya Tissa and jointly ruled righteously (rājjam dhammena kārayum) for twenty - two years (177-155 BC).[38]

Asela, another younger brother of Devanampiya Tissa is said to have wrested power from Sena and Guttaka and ruled for ten years. However, he was ousted by Elāra, a Tamil from the Cola country who also reigned righteously for forty four years (145-101 BC) till he was slain in an open battle by Dutthagāmani. While Dipavamsa simply calls him by name, the Mahavamsa calls him as Damila from the Cola country.[39]

Dutthagāmani had two other problems before he assumed the over - lordship of Sri Lanka, according to the Mahavamsa. The author of Mahavamsa says that by killing thirty two Damila kings Dutthagāmani became the sovereign ruler of Lanka.[40] As no other details are furnished in Mahavamsa about them, we are unable to say anything further. However, in the light of evidence from the Brahmi inscriptions which testify to the existence of the rule of minor kings all over the island, it is very likely that these thirty two Tamil kings ruled in various parts of the Island when Elara reigned at Anuradhapura. Whether they were ruling independently or as sub-kings of Elāra we are unable to say anything at the moment. Most probably they would have acknowledged the hegemony of Elāra. The other hurdle which lay before Dutthagāmani was his battle with Bhalluka. Bhalluka is mentioned in Mahavamsa as a nephew of

Elāra.[41] He came with a force of sixty thousand men to help Elāra in his battle against Dutthagāmani. Neverthless he arrived only on the seventh day after the last rites of Elara were over and Dutthagāmani had killed not only Bhalluka but also his men.

Again during the rule of Vattagāmani five Damilas are mentioned in the Pali Chronicles as having captured power from him and ruled for fourteen years and seven months.[42] They are Pulahattha, Bāhiya, Panayamāra, Pilayamāraka and Dāthika (43 - 29 BC). Two Tamils again figure during the reign of queen Anula (48 - 44 BC).[43] They are described as paramours of this queen. One was Damila Vatuka, described as a foreigner (annadesika) who ruled for one year and two months.[44] The other was Damila Niliya, who as a palace priest (Brahmin) ruled for six months. Thus if we calculate the rule of Tamil kings at Anuradhapura in terms of years they have ruled nearly eighty two years, thus making one third of the early historic period ending with the beginning of the Christian era. This itself shows some sort of contest for the ownership of the island between the Tamils and the Sinhalese during this period.

The other phase of Tamil rule is also clearly presented in the Pail Chronicles. They are not only depicted as adventurers, usurpers and aliens but also as anti - Buddhist. This could be seen with reference to Elara,[45] Dutthagāmani [46] nd Vattagāmani.[47]

5. DAMEDA IN BRAHMI INSCRIPTIONS

These inscriptions are found in the Anuradhapura. Vavuniya, Seruwila and Kuduvil in Amparai district[48] The longest and the most important among these is the inscription engraved on the vertical rock face behind a terrace carved

on a boulder in the area to the North West of the ancient Abayagiri Dagaba at Anuradhapura. The socket - holes on the sides of the terrace show that it had wooden pillars fixed on it to support a roof probably tiled. Paranavitana while calling this as Tamil householder's Terrace inscription observed that the floor of the Terrace is on different levels and engraved on the forward sloping boulder, close to the ground, below each portion of the terrace of a different level, is a short record stating that it was the seat of a person who is named, most probably one of the Dameda house holders. Of these, one name is lost, the five legible ones are Saga, Nasata, Katissa, Kubira, Sujhata and Karava, the mariner (Navika) (Navika-Karavaha asane). Further he adds that 'The difference in level at the surface of the various compartments of the platform was probably intended to indicate the difference in rank and social status of the individuals whose seats were on them.[49] If so, it is interesting to note that the ship captain (navika) occupied the highest seat. This inscription according to him records that terrace (pasde) was of the Tamil householders (gahapatikana) and was made by Samana, the Tamil of Ilubarata (Ilubaratahi Dameda - Samane Karite).[50]

Nevertheless the recent studies in the Brahmi inscriptions show that Paranavitana has inadvertently read the letter 'La' occurring in the initial form of this inscription as Lu and interpreted this as a place named Ilubarata in Anuradhapura region where Dameda had lived. However the reading of similar letter in Tamil Nadu shows that it should be read as la and not as Lu.[51] Hence this could be read as Ila and barata not as Ilubarata. That means barata of Ila. For, we all know that the perusal of Brahmi records of Sri Lanka shows that 'Barata' mentioned in them is actually a reference to a social group, known as Parata/Paratavar.[52] We have also literary evidence for the Paratavar living on the Pandyan

coast of Tamil Nadu as well.[53] Therefore this could mean Parata of Īla/Īlam (Sri Lanka) and not a place name as Paranavitana has opined. However, Paranavitana's interpretation of 'Dameda gahapatikana' as householders from Tamilakam is convincing. For, the recent studies nevertheless show that the word 'Gahapati' denotes an aristocratic class engaged in trade.[54] Hence the actual meaning of this inscription would be the Terrace at Anuradhapura for the use of Traders of Tamilkam was put up by Sumana of Tamilnadu and Barata of Īlam (Sri Lanka) most probably for their deliberations.

The association of Buddhist names with these Tamil traders is not something surprising. For, the role of the Jains and Buddhists in the Indian trade is well known. As Basham has observed 'We can parallel the rise of Buddhism and Jainism and of the many other smaller heterodox systems of salvation which came into being about the 6th century BC, with the rise of an important mercantile class needing less expensive and less complicated rituals and demanding a more significant role in the religious life of India than Brahmins would concede.[55] This has been proved by the excavations at Kaveripattinam and Arikamēdu.[56] In fact the very name Arikamedu is a corruption of the term 'Arukan Medu' meaning 'mound of the Arahat' (Buddhist monk). This is also borne out by the Brahmi inscriptions of India going back to the Pre-Christian era mentioning the donation of caves, and providing other amenities to the Buddhist clergy at this time by the trading community.[57]

It is against this background only, one has to view the Anuradhapura Tamil householders Terrace inscription. The members of the Tamil trading group seem to have been Buddhists as evident from the names used by them. The other two epigraphs found at Periya Puliyamkulam in Vavuniya also mention the donations made to the Buddhist clergy by an individual who is described as 'Dameda Vanijha gapati Visaka'[58] This means

that he was also a trader from Tamil Nadu named Visaka, of a mercantile class. This supposition is confirmed by the occurrence of the form 'Vanijha Gapati' in these inscriptions. However, the presence of the name Visaka, as one of the titles of lord Muruga in this epigraph may indicate that this trader was originally a worshipper of lord Muruga and who would have recently become a convert to Buddhism as indicated by the names of the Gods of the Hindu – pantheon found in the Pre-Christian Brahmi inscriptions of Sri Lanka.[59]

The third inscription is found at Seruwila in the Trincomalee district which mentions about a joint donation of a cave to the Buddhist Sangha by Bata Mahatissa and Gahapati Dameda.[60] This in fact highlights the link between the Paratavar and Tamil merchants in their trading venture. However, there is another equally important epigraph which has been discovered at Kuduvil in Amparai district.[61] Though this inscription is fragmentary yet it mentions the cave of a Tamil lady Tissa (Dameda Tisaya le (ne). This unlike the earlier inscriptions at Periyapuliyamkulam and Seruwila does not say that this cave had been donated to the Buddist Sangha. However, the most important information of this inscription is that it mentions 'Digavapi - p (o) rana Vani jhana' (the ancient traders of Dighavapi). The adjective ancient shows that these traders must have engaged in these activities from very early times in this region, and it records the presence of Tamil traders in Dighavapi which was an important place as that of Magama in the South East as we see in the account of Dutthagamani in the second century B.C. Finally the find spots of these inscriptions in the dry zone of Sri Lanka, which was the area of early settlements testify to the fact the traders of Tamilakam had played a vital role in the early trading activities of Sri Lanka

It is very likely that the references in the Pali Chronicles regarding the capture of power by the Damilas was interlinked with the trading activities of Tamils of Tamil Nadu. For, Sena

and Guttaka are mentioned as sons of horse freighters (Assanāvika). Probably this would have been the motive behind the capture of power by the Cholian Elāra and the Pandyans too. This is also clearly indicated in the form 'Barata' occurring in the earliest Brahmi inscriptions of Sri Lanka. This form occurs as 'Bata' and 'Barata' in these inscriptions. It was Maloney who followed up the suggestion made by Bell in the twenties of the present century and expressed the view that it denoted a social group known as 'Paratavar who had their abode in the Pandyan region of South Eastern Tamil Nadu.[62] The recent study of these Brahmi inscriptions shows the presence of this form in more than a hundred inscriptions.[63] The occurrence of this form in these inscriptions shows that this form and the Parata / Paratavar of the Sangam literature are synonymous. At this juncture it is pertinent to recount the early Pandyan connections with Sri Lanka narrated above.

The study of the Sangam literature shows that the Paratavar were living in the Tāmraparni delta and had Korkai as their trading centre. They accepted the Pandyan hegemony and engaged in pearl fishing, conch shell and gem trade. Pearls, conch shells and gems seem to have been the earliest products for which the Pandyan Kingdom and Sri Lanka were famous. Since oyster beds productive of pearls are located in the Palk Straits it is very likely that this was exploited profitably by the traders of both the countries. Mahavamsa too mentions that pearls, conch shells, gems, horses were the main items of trade in the early historic phase.[64]

Sangam literature depicts a section of the affluent Paratavar community living in mansions at the coastal towns and engaging themselves in trading activities. They had their own ships and warehouses, Conch shells, salt, gems, spices and horses were the items of trade.[65] Moreover Paratavar community and trading ventures are praised in Cilappatikāram too.[66] It also mentions about the affluent

Parata Kumarar.[67] Interestingly enough there is also a reference in a Sri Lankan early Brahmi inscription from Kutti Kulam which records a joint donation made by Parumaka and Bata-Kumara.[68] The form Bata-Kumara of this inscription is no other than Parata Kumarar appearing in Cilappatikāram. Tamil literature has references to the title 'e t t i' conferred on the merchants who have distinguished themselves.[69] There is a strong similarity that the term 'etti' has with the term c e t t i / S e t h i which refers to a member of a mercantile group in Tamil Nadu. It is also equally interesting to note that the term 's e t t h i' does figure as a member of the delegation sent by Devanampiya Tissa to Asoka.[70] There are also references to the trading guilds known as 'cāttu' in the Tamil literature. These 'Cāttus' were engaged in trade via land. In fact the very names 'Mācāttuvān, and 'Mānāikan' figuring in Cilappatikāram as fathers of Kovalan and Kannaki respectively bespeak the fact that they were the leaders of trading guilds engaged in trade via land and sea.[71] The prefix 'ma' occurring in the form ctatu, meant a leader of caravan moving via the land. In fact this form Mānāikan reminds us of a similar form 'nāvika' who is mentioned as the leader of the Tamil trading guild stationed at Anuradhapura. His social standing is also indicated by the word Kārava which means Karaiyar.[72]

In 'Kannaki Valakkurai' also there are references to Paratavar, and Mukkuvar communities.[73] It mentions the chief of 'Paratavar' who had the title 'atiyarasan' by the name of Mīkaman. In fact the word Mīkaman itself means the captain of a ship. The Mankulam inscription in Tamil Nadu records the existence of a Tamil trading guild known as 'Nikama'.[74] The head of this guild had the title 'Kaviti'. The members of this guild acted in their corporate capacity in making endowments. Thus the evidence mentioned above shows that in the early trade between Tamil Nadu and Sri Lanka, the sea

farers, namely the Paratavar, Karaiyar and the Mukkuvar had a major share. This is confirmed both by the literary and epigraphical sources.

The Greek sources do mention the Sri Lankan trade with India and they make it clear that during the Pre-Christian times the Roman traders came to Tamil Nadu only to purchase the Sri Lankan trading goods.[75] They mention about gold, larger pearls, elephants of Sri Lanka.[76] Strabo says that in olden days Sri Lanka sent ivory, tortoise shells and other wares in quantities to the Indian markets.[77] This is confirmed by the Tamil classics Pa'tinappalai. It refers to boats laden with merchandise coming from Sri Lanka to the ports of Kaveripattinam.[78]

There is evidence in the Brahmi inscription from Tiruparankunram in Tamil Nadu for the presence of Sri Lankan traders stationed in Maturai for purposes of trade.[79] This reads as follows.

Erukotūr Īla – Kutumpikan Pōlalaiyan
Ceyta āy – cayana – Nedu – Cātanam.

Mahalingam has translated the above Brahmi version as follows,

The bed intended for sleep and (also) for long (or deep) meditation made by Pōlalaiyan, a (husbandman) householder of Īlam (Ceylon) and a resident of Erukōttūr.

Thus this donation of a cave has parallels in the similar donation of caves by the traders from Tamil Nadu in Sri Lanka. However the most important aspect of this inscription is the appearance of the forms Īla / Īlam and Kuttumbikan. Īla like the similar form appearing in the Tamil householders Terrace

inscription at Anuradhapura refers to Sri Lanka. That the forms Ĩla and Dameda denoted Sri Lanka and Tamilakam respectively is also evident from the occurrence of these in the early inscriptions.

However, the most important evidence from this inscription is the presence of the form Kutumbikan of Ĩlam. The form Kuttumbika too appears in a solitary inscription from Sri Lanka.[80] Nevertheless, it appears in the Brahmi inscriptions of the Deccan and North India as well as in Indian literature where it denoted a wealthy aristocratic mercantile class.[81] Hence it is very likely that this term like the 'Gahapatis' of the Sri Lankan Brahmi inscriptions where the Tamil traders are mentioned was used for a similar connotation. Like the Tamil traders from Tamilakam who had their residence in Sri Lanka, but preferred to be called by the name of their land (Dameda Vanijha), this trader too preferred the appellation 'Ĩla Kutumbikan' the ancient name of Sri Lanka.

6. BRAHMI INSCRIPTIONS AS A SOURCE FOR EARLY DRAVIDIAN SETTLEMENTS

Brahmi inscriptions of 3rd to 1st century B.C. numbering more than a thousand are scattered in most parts of the Dry Zone and are often quoted as revealing the language allied to Indo-Aryan languages of North India and hence to represent the Proto-Sinhala language.[82] Although it is generally believed that the Brahmi script came along with Buddhism the possibility of its earlier introduction was never discounted. This assumed significance with the study of the Brahmi inscriptions from Tamil Nadu. The physical makeup of the caves, the palaeographical features, and finally the survival of Dravidian forms are the other common features which link these two regions.

The analysis of the find spots of the inscriptions too confirms the close link that existed between the far South of Tamil Nadu and Sri Lanka. The earliest Brahmi inscriptions are found in the region south of present Maturai in Tamil Nadu. Only the later Brahmi inscriptions have been found in the North of Maturai. Likewise in Sri Lanka too the earliest Brahmi inscriptions are found in the north western region of Sri Lanka, centering round Anuradhapura which is geographically closer to Southern Tamil Nadu. Probably this geographical proximity has given an identity to the script used in these regions as well. Buhler has classified this form as Southern Brahmi and named it as Dravidi.[83] P. E. Fernando while concurring with Buhler argued for the existence of an earlier form of Brahmi script in vogue in both Tamil Nadu and Sri Lanka before the introduction of the Brahmi script associated with Buddhism during the middle of the third century B C.[84] Fernando while claiming that the Brahmi scripts of Tamil Nadu and Sri Lanka represent the earlier tradition of script said that these records were carved by scribes of one and the same school and if so, it has to be assumed that a school of scribes, differing in several respects from those who carved the inscriptions of Asoka, was existing in South India and Sri Lanka and was practising its art in these regions even before the time of Asoka. With the introduction of the North Indian Brahmi forms associated with Buddhism these early forms were gradually supplanted, as Karunaratne had indicated.[85] This is clearly seen not only in the palaeographical features where the earlier and later forms continued in usage for some time till the earlier forms finally went out of use by the 1st century BC. Surprisingly enough, the early Dravidian forms too suffered a similar fate as that of the early Brahmi characters by losing their identity by the beginning of the Christian era.

Of these, the most important forms is 'Parumaka'. This appears in more than a quarter of the Brahmi inscriptions.[86] The perusal of this title shows that it denoted a group of aristocracy immediately below royalty but high in the social

scale. Most of the high officials belonged to this class. It is surmised that they formed the backbone of the rural administration as well. Now coming to the origin of this form, scholars who believed in the early Aryan colonisation traced its origin to Sanskrit Pramukha. However the etymological origin of this title and the role played by the Parumakas in ancient Sri Lanka, indicate its link with Tamil Nadu rather than with the North Indian Pramukha.

The etymological derivation of this form shows that it could be derived in two ways, either Paru with the addition of suffix maka/makan or Peru with the addition of maka/makan and which would mean Parumaka/Parumakan or Perumakan. The feminine form would be Parumakal or Perumakal. Interestingly enough the feminine form of Parumaka too occurs in eight instances in the Brahmi records of Sri Lanka. Paranavitana however, inadvertently read the letter 'la' of this form Parumakal as Parumakalu. However, in the Sangam and later Tamil literature, the form Perumakan is most common. Hence it is very likely that Parumaka is the early form and Perumakan is its later derivation. This shows that unlike in Tamil Nadu, in Sri Lanka too we have the earliest form Parumaka going back to early Proto-historic days like that of Barata, occurring in these early Brahmi inscriptions. However, it may be noted that the form Barata, appears in the early Sangam literature as 'Parata'.

The other notable Dravidian forms which survived in the early Brahmi inscriptions are clans such as Vels and Ays. As mentioned above Paranavitana had inadvertently read this letter as lu, instead of l and concluded that it represents Velu, a derivation from Sanskrit Vailwa.[87] However, the deciphering of this form lu as l in the Tamil Nadu Brahmi inscriptions as well as the evidence from the Sangam literature clearly shows that this should be read as Vel, an ancient clan

of Tamil Nadu. The recent discovery of potsherds bearing inscription mentioning 'Vel' in Poonakery area further confirms the presence of Velir in Sri Lanka.[88]

The other notable form is Āy of these inscriptions. Paranavitana derived it from Sanskrit Arva and Pali Ayya.[89] It is very likely that Aya of Sri Lankan Brahmi inscriptions which has been given the meaning of a 'Prince' and viewed as title could be read as Āy, a clan of local chieftains closely related to the Vēls and who ruled in the South Western extremity of Tamil Nadu.[90] Likewise, the form Abi which sometimes appears with Āy but in other instances singly and viewed to represent the feminine form of Aya and hence given the meaning of a princess could be derived from Tamil Avvai, Kannada Avve, Telugu Avva and Tulu Abbe meaning a mode of address to ladies with love and respect.[91] However, the context in which the form 'Abi' occurs in the Brahmi inscriptions of Sri Lanka as wives and daughters does not sustain the meaning of a Princess and hence the feminine form of Āy, is a clan mentioned in the Sangam literature. Like the Tamil Avvi this too denoted a mode of address to ladies who played an important role in the administration as that of the Parumakas.

Finally it is relevant to mention about the form Marumakana which appears in eight places of these inscriptions.[92] This has survived in Tamil as Marumakan. But Paranavitana while accepting this as a Dravidian form, however renders its meaning as 'grandson' by linking this with later Sinhalese form 'Munumburu'.[93] But Kanagaratnam while quoting from medieval Sinhalese literary evidences argues that there is no connection between these forms Marumakan and Munumburu.[94] He had also convincingly shown as to how the Tamil form Marumakan which means nephew as well as son in Tamil becomes son through marriage (maru). This itself is an evidence for the prevalence of the cross-cousin marriage system, and the matrilineal system among the ancient Dravidians. However

the continuance of this custom even today among the Sinhalese as well as Tamils bespeaks its hold in our early society. However the most important element here is the form 'Marumaka'. This shows that like Parumaka, Barata, Īla, Marumaka too speaks of early Dravidian hold in Sri Lanka preceding the early historic phase, most likely during the Proto-historic phase. These evidences in fact necessitate a deeper study of the Brahmi inscriptions of Sri Lanka

The discovery of a Bronze seal at Anaikkoddai has filled the vacuum created by the absence of Brahmi inscriptions which again is due to the non-availability of the rock formation in the Jaffna Peninsula. In fact this has added new epigraphical data regarding the early Dravidian settlements in this region as in the case of other parts of Sri Lanka. This seal is datable to 3rd century B C. and found buried along with the burial.[95] It has two forms of writings. They are pictorial and early Brahmi. The legend of this seal has been deciphered by Indrapala as Kōvēnta and Kōvēntan.[96] However Ragupathy gave a different reading as Kōvēṭa and Kōvēṭam.[97], which too means the 'king' in Tamil. More evidence regarding the use of Brahmi writing has come from the recent discovery of potsherds with Brahmi characters and legends in the Poonakery region by Pushparatnam [98] The notable finds are potsherds with the Tamil Brahmi characters such as l, na and r and the Brahmi legends in Tamil such as Vēl and Īla.

The linguistic similarities between Tamil and Sinhalese as indicated by the scholars,[99] along with the survival of the early Dravidian forms show that the Proto-Sinhalese which has been identified as Elu by scholars and Tamil had a long existence in the Island, during the Proto-historic phase before, Elu, with the introduction of Pali, and state religion Buddhism began to acquire North Indian characteristics which made the Sinhalese to acquire North Indian, Indo-Aryan elements which came along with Buddhism.

In the absence of any archaeological evidence for the early Aryan colonisation of the Island it is now evident that the monastic language Pali Prakrit had gradually spread to the population over a period of centuries by assimilating the earlier Elu language, the end product of this is the development of Sinhalese as a distinct language. Thus, Sinhala language gradually got an identity of its own from the period of 4th century to the 8th century, the era Geiger calls the 'Proto-Sinhalese' era.[100] The change from the early period is so sharp that Geiger names it, 'a period of radical linguistic revolution'. The 'Proto-Sinhalese inscriptions 'differ so much from the Brahmi inscriptions that it looks nearly a break'. This is clearly brought out by Susantha Goonetillake who says that 'the extant evidence of the 'Sinhala' language development is of a script closely associated with the monks and monastic establishment gradually unfolding into a new identity after a period of several centuries... by the 5th century the Sinhala identity is virtually complete as indicated not only by the emergence of Proto-Sinhala but also by the emergence of the Mahavamsa as an ideological document with a strong ethnic identity. The above explanation suggests very strongly that Sinhalisation was a culturalisation process associated with the spread throughout the land of Buddhism and its consolidation. In short, Sinhalisation came after and not before Buddhism.[101]

7 ĪLA / ĪLAM BEFORE SIHALA / SINHALA / SIMHALA

It is in the above context only we have to view the evidence from the Pali Chronicles regarding the early colonisation by Vijaya. Referring to Sihala, Dipavamsa, the earliest Pali Chronicle of Sri Lanka and assignable to the 4th century A.D. states that 'This Island of Lanka existed as Sihala after the lion. Listen to this Chronicle of the origin of the Island which I narrate.[102] On the other hand Mahavamsa written in the 6th/7th century A. D. says that 'But the king Sihabahu, since he had slain the lion (was called) Sihala and by reason of the ties between him and them, all those (followers of Vijaya) were (called) Sihala.[103]

Scholars who have studied the above statements of the Pali Chronicles hazarded different opinions. L. S. Perera who wrote on the Vijayan Era expressed the view that the form 'Sihala' of this legend is in fact the evidence for the totemistic origin of the Sinhalese.[104] Even Geiger felt that Sihala too was one of these tribes and that all these were totemistic in origin. However, as Mendis has correctly perceived it, apart from the Vijaya legend there is no reference in the ancient Pali Chronicles to the tribe called the Sihala.[105]

Mendis who examined the Vijaya legend opined that the 'Vijaya legend is not a story that came down from the original settlers.[106] It does not seem to contain even facts that were handed down by them. It is a later product of the mind and not a re-creation of what actually took place in the past'. According to him the real provocation for the story was the name Sihala which was applied to the Island. While referring to the ancient names of Sri Lanka, such as Tāmraparni (Tambapanni), Lanka and Sīhala (Simhala) he says that it was Tambapanni and Lanka which were in the common usage and Sihala (Simhala) is rare both in Dipavamsa and Mahavamsa. He further continues that it occurs in the Dipavamsa only once that is in the Vijaya legend and in the Mahavamsa only twice, in the Vijaya legend and in the account of Vattagāmani Abhaya of the first century B.C. where the king is referred to as Mahākāla Sihala. Finally he concluded by saying that 'Thus it is clear that this name was not in common use in Ceylon either for the Island or for the people even up to the beginning of the fourth century A.D., when both the Chronicles end. In fact the name Sihala or Simhala is popular in Ceylon only in later Pali and Sinhalese writings..... Simhala was originally the name of the Island and the people got their name from it many centuries later'.

On the other hand R.A.L.H. Gunawardena while acknowledging the fact that the earliest reference to Sihala is in Dipavamsa, that too for the Island, further referred to its

subsequent occurrences as Sihaladipa as the name of Island in Samantapasadika, a work of the 5th century A.D., as Heladivi, the equivalent of Pali Sihaladipa in one of the graffiti at Sigiri dated between eighth to tenth century. Further he contended that by the eighth century the name was being used to denote a group of people.[107]. Finally he asserts that hypothetically, it is possible to postulate a dynasty, Kingdom, people of the Kingdom sequence in the development in Sinhala consciousness. According to him Sihala/Simhala was a dynastic symbol of the early dynasty ruling at Anuradhapura as in the case of South Indian dynasties who had various emblems such as lion, tiger, fish etc. as their dynastic symbol. Thus he states 'it is very likely that, similarly, the lion was the emblem of the ruling house of Sri Lanka and that the dynasty got its name from that emblem. As in Sri Lanka, in South India too, there were myths which sought to explain these emblems.' Thus while hypothesizing this Sihala as an emblem of the dynasty he traces its development till it found a place in Dipavamsa as the earliest reference to the Island. The evidence from a Brahmi inscription at Tiruparankunram quoted above datable to the first century, A.D., where the form Īla occurs has been treated by him as a derivation from Sihala. To add validity to his argument he has quoted the Tamil Lexicon where Īlam is mentioned as having derived from Pali Sihala and Sanskrit Simhala.

Nevertheless, the progress made in the epigraphical studies during the last decade in Sri Lanka shows that the earliest occurrence of the form Īla is not in the Brahmi inscription of Tamil Nadu, but in Sri Lanka. The form Īla is in fact coeval with Damila/Dameda, found recorded in the Pali chronicles as well as in the Tamil householders terrace inscription at Anuradhapura. Unfortunately the form Sihala has not been found in these early Brahmi inscriptions of Sri Lanka.

If one derives Īla from Sihala, it should have preceded Īla in its appearance in either literary or epigraphical sources. Unfortunately its earliest appearance in epigraphical sources is

in the Nagarjunikonda inscription of the 3rd century A.D., where it appears along with Damila as a name for the Island of Sri Lanka.[108] Similarly among the literary sources it is claimed that the Chinese rendering of Sihaladipa occurs in the Chinese literary documents datable to second and the third centuries A.D.[109] It also appears as a name for the Island in Divyavadana around this time.[110] Among the Sri Lankan sources it is in Dipavamsa only it makes its first appearance as a name for the land (Sihala). Thus all available evidences mentioned above go to prove that Īla preceded the form Sihala by a few centuries and hence it is very unlikely that Īla is a derivation from Sīhala.

Even if Sīhala is taken to denote a dynastic symbol, there is no evidence for its use in that context in any literary or epigraphical documents in those very early days in Sri Lanka. Moreover, the association of la with Siha which means 'Lion' in the form 'Sihala' shows that this form cannot be taken as a dynastic symbol. If so, the original form would have been 'Siha' and not 'Sihala'. Hence it is very unlikely that the form 'Sihala' which denoted the Island was derived from a dynastic or totemistic symbol. Equally untenable is the derivation of this form Sihala from the personal name Sihala appearing in the Kharosthi inscriptions of the 1st or 2nd century A.D., as opined by Paranavitana.[111]

However the most important element in this form 'Sihala' is Hala. The analysis of the Sinhalese inscriptions of the period after 8th century A.D., and the Sinhalese literature after 9th Century shows that Hala has variant forms such as Hel/Hela in these sources.[112] While Paranavitana and others derived Hela, as the ancient name for the Sinhalese people from Sanskrit Simhala/Pali Sihala no explanation has been given for the elision of the initial syllable (Si). This factor raises serious doubts as to the validity of the very base of the derivation of Hela from Sihala. It appears to be proper to explain the element (Si) as a later addition to the original name Hela/Hala, being derived from

Sanskrit (Sri) just as in the case of the name Lanka we find the addition of Sanskrit Sri in later times. Incidentally it may be pointed out that this form Hela/Hala could be traced to Īla/Elu. For, it may be noted that this name Īla is not found in the Chronicles except in one solitary instance as a name of the King called Īla Naga who ruled in Anuradhapura in the early part of the first century AD.[113] The fact that the form Īla Naga appears in Rajavaliya,[114] a later Sinhalese Chronicle as Elun Naga clearly indicates that it is the name Īla that is meant. That Īla and Elu were treated as equivalents is also borne out by the above evidence. As mentioned above the form Īla appears initially in the epigraph of Tamil householders Terrace Inscription datable to 3/2nd century BC. and later in the epigraph at Tirupparankunram of Tamil Nadu of the 1st century A. D. Thus, the chronological priority of Īlam shows that its original form was Īla as in the case of Damila. Hence it is very likely that 'hala' is derived from Īla–Ela–hela–hala and later with the addition of 'Si' or Sri it became Sihala/Simhala. Subsequently a legend seems to have been evolved to explain the form Sihala/Simhala, which denoted the Island as in the case of Īla/Īlam.

At this juncture it is pertinent to say some thing on the origin of the word Īla/Īlam Burrow[115] an eminent Dravidiologist while deriving Sihala/Simhala from Īram expressed the view that in the case of this word it is very likely that Indo–Aryan has borrowed from Dravidians and opined that Tamil and Malayalam hardly ever substitute r, a peculiarly Dravidian sound, for Sanskrit – l – and Sihala/Simhala could easily have been adopted by popular etymology from an original Dravidian ciram. It is to be presumed that the Dravidians of South India had a name for Ceylon before the coming of the Indo–Aryans. Veluppillai,[116] while agreeing with Burrow says that it is a Dravidian word and has given its meaning as 'Gold' and 'toddy'. He says that 'it is quite possible that our

country was named after gold as Indians who went abroad to trade with South-East-Asia designated those parts as Swarnabhumi and Swarnadeepa; following a similar tradition our country might have been designated as Īlam.' Burrow while commenting on 'toddy' another meaning for Īlam however, asserted that possibly iram (Ceylon) was named from iram toddy, after the palm trees with which it is well stocked and the toddy produced from them.[117]

Veluppillai in fact has drawn our attention to Ēl appearing in the countries which have been devoured by the sea as mentioned in Iraiyaṉār Akapporul Urai.[118] They are Ēl teṉkaṉāṭu, Ēl Maturainātu, Ēl Munpālainātu, Ēl Pinpālainātu, El Kunranātu, El Kunakarainātu, and Ēl Kurumpanainātu. He futher continues that 'so actually seven names only are mentioned. All the seven names have an adjective Ēl. The numeral adjective Ēl in Tamil means seven. So, forty-nine are being derived by having seven into seven. But it is difficult to accept here that the adjective could have denoted seven in a symmetrical way in all the cases. This Ēl could have some connection with Īlam. Vowel 'i' and 'e' are closely related front vowels. The Tamil Nadu had a name Tamilakam in ancient times, our country also could have had a name like Ēlakam which became Īlakam and then changed to Īlam. As Dravidian metaphony usually has an alternation in the form of i/e it is very likely that Īla might have been an earlier form. Because Pattinappālāi has Īlam and whereas Iraiyanar Akapporul Urai, a later composition mentions, Ēl.

Whatever the case may be it cannot be doubted that the form Īla appearing in the earliest Brahmi inscriptions of Sri Lanka and Ēl were in vogue in the region between Tamil

Nadu and Sri Lanka. It is also possible that Īl would have been the earlier form which gave way to Īla like Damil becoming Damila. Hence the reference in the Tamil sources regarding the disappearance of Kumari river and the adjoining forty nine lands of which Īlam has survived may be treated as part of a historical memory. Then it is no longer possible to maintain that Tamil was not spoken in ancient Sri Lanka because the ancient Tamil works like Tolkāppiyam and Cilappatikāram while speaking of the Tamil speaking regions have excluded Sri Lanka[119] As Veluppillai has clearly shown the commentators of the above works have indicated that these works meant only the Kumari river and Kumari mountain after the forty nine countries were engulfed by the sea and the present Kumarimunai (Cape Comorin) became its southern boundary.[120] It may be also noted that even the word Lanka' which means the Island in Telugu, another Dravidian language bespeaks of the early Dravidian connection with Sri Lanka.[121] Its earliest appearance as Ilankai is in Cilappatikāram as Katal cūl ilankai.[122] It may be that there may be a link between the forms Īlam and Lanka. Thus it is now quite evident that the presence of the form Īla before Sihala shows that Sihala was a later derivation from Īla/Ilam and subsequently a legend was evolved to explain the form 'Sihala' which means the descendant of the killer of the lion as the author of the Mahavamsa has stated.

The absence of any tangible archaeological evidence for the early Aryan colonization of the Island clearly shows that what we today speak of as the Aryan elements in the Sri Lankan culture is the result of cultural expansion associated with Hinduism and Buddhism. It is the Megalithic culture, presented in the Sangam literature and associated with the present day Dravidian language speakers of South India that was the base for the development of later Sri Lankan civilization.[123] The beginning of this cultural phase could be taken to 1000 B. C., the dawn of the Proto-historic phase in Sri Lanka, although these

cultural elements continued to be in vogue around the beginning of the Christian era as well. It is not merely the find spots of the Brahmi inscriptions in close proximity to the megalithic sites but also the link between the non-Brahmi symbols of the early Brahmi inscriptions and the graffiti marks of the early Megalithic Pottery as well, which indicate the close connection between the two.[124] What we hear from the Pali Chronicles as the early centres of Aryan settlements are no other than the Megalithic cultural centres, the authors of these are Dravidians, the progenitors of the present day Sinhala - Tamil speakers.

8. CONCLUSION

To conclude, the progress made during the last two decades in the archaeological excavations and the reappraisal of the Brahmi inscriptions has necessitated a new look at the early Tamil colonisation of the Island. Hence in view of the new accumulated data one need not depend upon the evidence from the Pali Chronicles alone which speak of the Tamils as aliens, usurpers and adventurers. This picture of the Pali Chronicles is proved wrong by the deeper study of the Brahmi inscriptions. These inscriptions not only indicate the early Dravidian colonisation in the Island beyond any doubt but also present a picture as to how the early Dravidian base of the Sri Lankan society while being subjected to North Indian or the Aryan cultural penetration mainly associated with Buddhism began to adopt those elements so as to mean an actual colonisation. However, the credit for the actual colonisation of the Island lies with the authors of the Megalithic culture who are no other than the Dravidian language speakers. They, together with the pre-historic population, who were also of the same group as that of the people of Tamilnadu as indicated by the stone tools, developed the Sri Lankan civilization. What we later have as Elu, a Proto-Sinhala or Tamil are in fact the offshoots of this culture as in the case of Tamil, Kannada,

Telugu and Malayalam emerging from a common Megalithic cultural base in South India. Since the Megalithic culture lies outside the purview of the title of this paper discussion on this is avoided here.

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FROM BASIC SCIENCE TO TECHNOLOGY

* Prof. Rajaratnam Kumaravadivel

Chairman, Friends and Colleagues:

I wish to express my deep appreciation of the honour the Association has done me by electing me the Chairman of the Section on Pure Sciences.

If I were to follow the tradition of speaking on one's speciality, I would have spoken on some aspects of Theoretical Condensed Matter Physics. However I have chosen to speak on a topic titled "From Basic Science to Technology" since I felt it more appropriate to talk on a subject common to both Physical and Biological Sciences.

1. Link between science and technology:

What is technology? Edward de Bono in his book "Technology today" writes:

> "Philosophy is the creation of understanding
> Art is the creation of response
> Science is the generation of knowledge
> Technology is the use of knowledge"

Technology is the process of producing something useful through the use of knowledge. There is no doubt that technology can bring about far reaching economic and social changes leading to national prosperity of a country. Science is the generation of knowledge and hence the relationship between science and technology is clear. Technology can only grow out of the study of science and its applications. Science exerts a powerful influence on technological progress and therefore on the productive forces and eventually, on the economy and hence the prosperity of the nation.

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The link between science and technology was not known in the early days of industrialisation, that is, in the late 18th centuary and the early 19th centuary. At that time technology was based on trial and error methods and the development of science was in a rudimentary state. Today, virtually all significant new technologies follow science and technology cannot thrive without a good scientific base.

In this context I should also emphasize the importance of craftsmanship. The degree of craftsmanship is related to the degree of development of science. For example a craftsman needs materials. Modern materials are created by the scientist and are produced by the technologist. They are worked on by the craftsman. It is a three way collaboration. Every nation must build up its scientific, its technological and its craftsman base.

Basic research is aimed at revealing the basic characteristics of a phenomenon rather than solving practical tasks. As a result, the practical implications of a discovery are not always immediately clear. For example, when Faraday demonstrated electromagnetic induction effects before a learned audience a member of the audience asked him "of what use is all this?" Faraday's reply at that time was itself a question, namely "Of what use is a new born baby?" We all now know the relevance of this question. Faraday's fundamental work forms the basis of electric power generation and transmission which is at the base of all modern industries. Such examples are numerous. The Joule – Thomson effect discovered by Joule as a persuit of scientific curiosity, using his own funds, later had application in the refrigeration industry. The discovery of transistors, lasers, liquid crystals and the applications that followed are other examples. Therefore one cannot underestimate or ignore any basic research as of less importance to development.

2. Interdependance of different fields of science and technology:

Often results of research in one field can contribute to the development of a different field. To give an example, the use of X-rays in medicine was originally a spin off from atomic and

nuclear research. Development of nuclear physics and atomic and nuclear spectroscopy in physics contributed rapidly to studies in chemistry. Holography is another good example. Holography was first developed for image enlargement. But it is now used in the creation of three dimensional images. In the future it may be used in design and information storage systems.

An achievement made at interfaces between sciences can be a combination of the results of several independently conducted research programs, each important in its own field. A combination of inventions in semiconductors, thin films and metallurgy led to the development of microelectronics and integrated circuits. The combination of different kinds of research and engineering equipment such as lasers, computers and holography is expected to help expand the potential of spectrography and promote research in the three dimensional structure of complex molecules and proteins.

3. **Is there a need for research in basic science in developing countries ?**

It is the view of some that the developing countries should import technology straight away from developed countries. In my opinion such a step will not do any good to the country in the long run. It is like importing ready-made goods. But this does not mean that we should build up research in basic science in all subjects. We should build up research in basic sciences that appear to have immediate relevance to a country's need. It is not easy to prepare a list of fields that will be useful to developing countries. It is something that will have to be worked out by scientists living and working in a country after careful analysis of various aspects and needs of development in that country. Surely, basic sciences such as quantum theory which is at the heart of Solid State Physics and eventually of Solid State devices, basic mathematics for computing, basic modern biology, at the heart of biotechnology and the like are undoubtedly relevant to all developing countries. The science of cosmology may be cited as an example of a field not relevant to a developing country.

But as I have mentioned before, since the technological importance of certain scientific discoveries does not become clear immediately, we can only say that a field like cosmology is not of immediate relevance to a developing country. Also, setting up a 200 inch telescope like the one installed at Mount Palomar in the USA for astronomical research or setting up of the great, but costly laboratories like CERN in Geneva for Particle Physics research are definitely of no immediate use to a developing country.

4. Need for regional corporation

There are fields of research in basic science which a single under developed country might not be able to undertake alone but which a number of such countries can jointly carry out by pooling their resources for their mutual benefit. Space science in an example.

The outer space offers unprecedented potential for studying natural phenomena and processes on earth. The huge amount of information about our planet received from space is ot great value for most sectors of the economy of all countries. The findings of remote sensing by the instruments and equipment on a spacecraft are used in geology, oceanology, agriculture and the monitoring of forests and plough fields. Remote sensing provides data on a broad range of subjects such as geological structures, coast lines, water reserviors, oceanic currents, natura disasters, and man's impact on the enviornment.

The development of communication technology without the space component can hardly be imagined. Communication satellites relay data in a wide frequency range along numerous telegraph-telephone and TV channels. Radio linkups in outer space make numerous surface and underwater cables unnecessary. They can reach the remotest areas and thus promote education and culture, especially in the developing countries.

Space based exploration techniques are a reliable research tool used by geologists. Space photography enables the geologist in a laboratory to identify many elements on the earth's mantle

and locate the areas where deposits of useful minerals are most likely to be found. Multispectral imaging and near-infrared photography from satellites detect underwater vegetation and these data are used for identifying areas of good fishing, for fish is attracted to places where food is plentiful.

Relay satellites help to locate any ship or aircraft anywhere in the world and maintain communication links with them. This makes sea and air transportation safer and cuts cost. It also helps to rescue people in emergency situations.

Space exploration has brought about the advent of a new scientific and technological field — space based materials technology. It is still in the infant stage. For example, it is possible to produce some new materials in outer space — in zero gravity.

A small country like Sri Lanka cannot obviously afford to build up research in space science on its own. What is needed is regional corporation in Science and Technology. In my view the SAARC countries could build up a strong research group in space science with India playing a leading role. Already India has made remarkable advances in space science and technology.

5. Some technologies relevant to underdeveloped countries:

Some of the technologies based on major research discoveries that are of importance to a developing nation are nuclear power engineering technology, computers, semiconductors, microelectronics, laser technology, plasma technology and biotechnology to mention a few. I shall now discuss in some detail the technological potential of some of the basic scientific discoveries that will have their impact on mankind in the near future — specially on the population living in the developing countries. I have chosen three scientific discoveries in Physics and one in biology. They are laser emission, high temperature superconductivity, semiconductor photovoltaics and molecular biology.

6. Laser Technology:

The basic idea of laser emission was first theoretically predicted some forty years ago. In an ordinary light source atoms emit light in all directions with random phase. In a laser the atoms are made to emit light in phase in a particular direction with the result the intensity is very high. The laser was invented in 1963. Within a year or two equipment based on laser were developed and began to be applied in various technologies. Lasers are now used in practically all spheres of human activity. Scientists and Engineers soon created dozens of varieties of lasers differing in the state of aggregation of their active medium, modes of oscillation, and regimes of operation etc. Now, there are lasers operating in a broad wavelength range, from the ultraviolet band to submillimeters. Laser technology has now reached a stage where many types of lasers are no longer a research object but instruments applied in various areas. Laser equipment is used to produce and study thermonuclear plasma, to finish materials used in engineering and machine parts, in photochemistry, data storage, processing and transmission systems etc.

One of the most important applications of lasers is in the field of communication. Since optical frequencies are extremely large (10^{15} Hz), as compared to the conventionalradio waves (10^{6} Hz) and microwaves (10^{9} Hz), more information. in comparison to radio waves and microwaves, could be carried by a light beam when used as a carrier wave. The demand for flow of information traffic is becoming so high that only a light wave would be able to cope with the demand. Laser beams are therefore used in terrestrial communicatton (e. g. interoffice, intercity, intracity etc.) However because of the turbulent nature of the terrestrial atmosphere (rain, fog etc.) a guiding medium is needed to trasmit the information carrying laser beam to have an efficient and dependable communication system. In the

1970s with the realisation of low transmission - loss optical fibre waveguides, the use of laser light in terrestrial communication has become widespread.

The laser beams have been used to demonstrate various new phenomena in Physics and Chemistry and they have opened up new avenues of research. Phenomena of second harmonic generation, stimulated Raman emission and the self-focusing phenomenon are some of them. Laser beams are also used for triggering chemical and photochemical reactions. They are also used in isotope separation. If isotopes could be produced economically, there are many applications for pure isotopes in science, medicine and technology.

In industy, high power lasers are used in welding, for drilling holes in various substances and in cutting materials. It has been reported that aluminium sheet metal similar to that used in the aerospace industry could be cut with high-powered laser beam and that it is 60–70% less expensive than the conventional techniques. Laser cutting has also been used in the textile industry for cutting cloth. This is said to be the greatest advance in apparel manufacturing since the sewing machine.

Laser medicine and biology are also being developed. New ideas concerning the use of lasers in diagnosing and treating various diseases are born literally every day. Lasers are now mainly applied in ophthalmology, surgery and intravisceral therapy (laser endoscopes).

Laser based methods of monitoring the structure and functional properties of the eye, the treatment of glaucoma and point-welding of detached retina are applied on a broad scale.

Laser therapy has produced good results in the treatment of tropic ulcers, purulent wounds, burns, rheumatoid arthritis and certain cardio-vascular diseases. Researches are being conducted on laser-based methods of bloodless surgery, treatment of skin diseases and tumors, removal of moles etc.

The description of the applications of lasers in science, medicine and industry is by no means exhaustive. It is amazing that laser emission, a discovery of basic research, has been put to uses in just a few decades in ways that are numerous to mention here. One potential and important application of the future is the design of optical parallel computers which will be a thousand times faster than the present electronic computers.

7. High Temperature Superconductivity:

Superconductivity is one of the most spectacular and remarkable effects of the microcospic physical universe. It touches on many aspects of solid state physics. Intensive experimental and theoretical work over the last forty years has transformed the subject into a significant branch of solid state physics with many important technological applications.

In 1911, the Dutch physicist Kamerlingh Onnes, discovered that the electrical resistance of mercury drops abruptly to zero at a temperature of 4.3K. He found that below this temperature the resistance remained practically zero. Electric currents flowed in the mercury in the absence of voltage differences and without causing the heating associated with electrical resistance. Mercury, below 4.3K, has passed into a new state, called the superconducting state. The phenomenon of superconductivity remained an object of purely academic interest for several decades. An explanation of the phenomenon in terms of the behaviour of the electrons in the superconducting materials was first given in 1957 by Bardeen, Cooper and Schrieffer. Today, some 24 elements and well over a thousand compounds are known to be superconducting at atmospheric pressure. The compound Bi–Sr–Ca–Cu–O has the highest T_c of 125 K.

When a superconductor is cooled below a certain temperature called the critical temperature, there is not only an abrupt loss of electrical resistance as discovered by Onnes but there are also abrupt changes in many of the other properties of the material. The maximum current that a superconductor can carry and yet

remain resistanceless is called its critical current. This critical current decreases as the temperature is raised and falls to zero at the transition temperature T_c. If the current exceeds the critical value, superconductivity is destroyed and the metal reverts to its normal conductivity. Another peculiar feature of a material in the superconducting state is that it does not permit any magnetic flux to exist in the body of the material. When a magnetic field is applied to a superconductor, resistanceless currents begin to flow on the surface and they circulate in such a manner that within the bulk of the metal, the magnetic induction and hence the magnetic flux are both zero. ie. superconductors are perfectly diamagnetic. This property, discovered by Meisner and Ochsenfield in 1933, and called the Meisner effect has important consequences on the distribution of current flowing along a superconductor. Since field cannot exist within a superconductor, all currents must flow on the surface. The current flows in a very thin layer of about 5×10^{-6} cm thick. The magnetic field and the current therefore penetrates a very small distance into the superconductor, and the thickness of the layer is called the penetration depth. Now, in the above, we assumed that the applied magnetic field is weak, because there is a limit to the strength of the magnetic field which can be applied to a superconductor. As the field is increased, the surface currents also increase and eventually the critical current is reached and when this happens, superconductivity is destroyed. The magnetic field strength at which superconductivity is destroyed is called the critical magnetic field, H_c. The transition from superconducting to normal state is abrupt and it would be induced by raising either the temperature or the magnetic field.

The features I described above (ie. zero resistance, perfect diamagnetism and the existence of a critical current and critical magnetic field) were for many years believed to be characteristic of all superconductors. However, in the 1960s Abrikosov showed theoretically that there is another class of superconductors with

somewhat novel properties. These 'new' superconductors are referred to as type II and the 'old' or 'conventional' superconductors are referred to as type I.

The type II superconductors have three states: Superconducting, mixed and normal. The mixed state is resistanceless but, unlike the superconducting state, flux from an applied magnetic field penetrates through it. In consequence, the mixed state persists even in high magnetic fields, but if the material is pure and homogeneous, only a small resistanceless current can be carried. The presence of imperfections and defects enables much larger currents to be carried.

The properties of a material in the superconducting state has led to many interesting applications. Superconducting heat valves are widely used devices to control the flow of heat. In the superconducting state the thermal conductivity also drops to a small value. For example in lead, the thermal conductivity falls by a factor of 200. This makes thermal valves controlled by magnetic fields possible. The valves are particularly important at extremely low temperatures (0.4K) where the moving parts of mechanical valves are inclined to produce troublesome vibrations. The energy of these vibrations is converted into heat, creating unwanted temperature increases.

Type I superconductors exist in either of two distinct states, the normal state or the superconducting state. Since a duality of states typifies all logic elements used for computation in the binary code, superconductors have been actively considered as components of computing systems. In addition to the duality of states, type I superconductors also possess the other basic characteristics needed in a computing element: very fast switching speeds between states, small size, low power requirements and low power loss.

Two fundamental types of logic elements exploiting these properties of superconductors are being developed: They are the cryotron and the Crowe cell (and its descendant, the continuous film memory). The cryotron (1956) is essentially a switch formed

from a pair of superconducting amplifiers and can be used to perform the algorithmic functions of a computer. The continuous film memory (CFM) is a bit storage unit capable of a very high packing density. The ability of a superconductor to store circulating current indefinitely is used as the basis of the computer memory unit. Circulating currents can be stored in a porous evaporated film of tin or indium in a particular spatial array symbolising the binary digits 1 or 0.

A Josephson junction is a thin insulating barrier between two superconducting metals, through which tunnelling of electron pairs can occur. Since these junctions can be switched very rapidly into and out of the superconducting state by means of magnetic fields, the development of Josephson junction controlled persistent current loops has been found possible. These current loops can be switched from one storage state to another in less than 10^{-10} secs. There are other techniques of computer storage using the Josephson effect.

The rapid variation of resistance with magnetic field strength at the transition field can be used as a mechanism of amplification, and a family of electronic devices can be developed. These include amplifiers, detectors, oscillators, multipliers and bistable circuits. A variety of properties of superconductors is employed in these devices. Both type I and type II superconductors are used in electronic devices. Superconductive bolometer is an example of the electronic applications of superconductors. A bolometer is an instrument used to detect electromagnetic radiation. The advantage of the superconducting bolometer, when combined with modern techniques of amplification has made superconductive bolometers the most sensitive radiation detectors we possess, particularly in the important far infra red region of the spectrum where most other tpyes of radiation detectors are inoperative.

A most important application of superconductors is in the creation of dissipation – free magnetic fields of the order of 100,000 oersteds or above. In this application of superconducting

coils, using a persistent current mode makes it possible to generate large magnetic fields with no steady power dissipation. This is in contrast to the use of normal metal coils, with which the production of 100,000 oersted fields necessitates electricalg enerating and cooling equipment which becomes intolerably expensive. Superconducting high field magnets are used in laboratory instrumentation and in nuclear particle accelerators.

A unique property of superconductivity is what is known as flux quantisation. The magnetic flux threading a closed superconducting current loop can only take an integral multiple of 2×10^{-15} Wb. This remarkable and important characteristic can be exploited directly and indirectly in a number of quantum – measuring devices. These include the absolute fluxmeter, absolute ammeter and absolute voltmeter.

Since magnetic flux cannot penetrate into type I superconductors, a superconductor placed in a magnetic field experiences an inward hydrostatic-type pressure. Supperconductors can be supported by static magnetic fields, which can themselves be generated by persistent currents circulating in other superconductors. This makes it possible to produce superconducting gyroscopes with very low drift, superconducting motors and other superconducting mechines. The advantage of superconducting machines are low cost, low weight, small size and efficiency.

Trains with speeds in excess of 100 mph are being considered for ground transportation in areas of concentrated population. For such speeds, wheel-on-track systems become impracticable, and as a result magnetically suspended trains have been under consideration. In one of these systems, superconducting magnets are placed on board the vehicle and a conducting sheet is laid along the track. As the train, which initially runs on wheels, is accelerated, eddy currents induced by the moving magnets in the conducting sheet repel the magnets on the train, thus causing it to "float". Experiments using various configurations

have been undertaken in several countries and the Japanese National Railway has demonstrated the levitation of a four man vehicle.

8. Semiconductor photovoltaics:

Energy is at present the biggest concern of man kind. The level of a country's economic development is correlated to per capita energy consumption. Therefore as we strive to lift ourselves up economically, the energy consumption will rise. Oil which provides most of the present energy supply, may be completelye xhausted within a few decades. A serious energy problem lies ahead of us. Alternative energy resources must be employed on a larger scale in the future. Fortunately, we are provided with other sources of energy in tremendous quantities and it is simply a question of development to make them accessible. It is not my intention to make an inventory of all available energy resources. The ultimate answer to the energy crisis lies in the utilization of solar, wave, tidal, wind, geothermal, oceanthermal and nuclear energy.

Since the oil crisis of 1973, solar energy has been a subject of intensive research The direct conversion of sunlight into electric power is achieved by means of solar batteries, made up of solar cells, by a process called the photovoltaic effect in physics. A solar cell is a semiconductor diode with appropriate characteristics. When foreign donor atoms, in concentration of less than one percent, are introduced into a semiconductor, the number of electrons will be increased, and we get a n-type semiconductor. By introducing acceptor atoms, the number of holes will be increased and the semiconductor is said to be p-type. When a n-type and a p-type semiconductors are joined together, a semiconductor diode is obtained. A potential barrier exists between the two sides of the diode. When this dio le is illuminated, the photons are absorbed to create electron-hole pairs. These pairs will be separated by the barrier into positive charges on one side and negative charges on the other. (the electrons flowing towards the n-side of the diode

and the holes towards the p–type), producing a voltage across the diode. Power can therefore be generated in an external load. This is the physics of the photovoltaic effect and is the basic science of solar electric power generation.

Photovoltaic effects in semiconductors was first discovered by Adams and Day in 1876. Although the physics was known long time ago, the technological application was developed only with advances in space technology. Solar cells were first used in 1958 on the satellite Vanguard I Until recently, the space market has continued to provide the major impetus for solar cell development. The advantage of direct converson of solar energy into electricity by means of solar cells is that it is inexhaustible and pollution free. But the installation costs (capital costs) are high. The conversion efficiency is very low. Condensed matter physicists are working on various semiconducting materials to achieve maximum efficiency. Research and development on various semiconducting materials during the last thirty years has increased the efficiency manyfold. Many millions of dollors have been put into research and development in many countries, both developed and underdeveloped.

Several solar devices are already available in the market. In the USA, Australia, Japan and some other developed countries thousands of houses have been built during the last two decades that are run partially or totally by solar energy. In some developed contries 80% of the domestic heating is done by solar energy and tens of solar stills are in operation all over the world.

The fact that solar energy is free does not mean that it will automaticaly have a low utilizing cost. The interest lies in generating, say, electricity, and the equipment that converts solar energy to electricity through some devices has to be of low or reasonable cost before it can replace hydroeletricity or a steam generation plant. Twenty years ago, solar energy devices were more expensive than any fuel-burning device. But now, due to rising cost of conventional fuels, more countries are com-

peting in using solar energy as an alternative fuel. Since the element of competition has increased, this will certainly lead to lower costs for producing less expensive solar appliances, and the solar devices will eventually gain ground in the market. An optimistic forcast is that within the present generation solar electricity will advance to the level of large scale utilization and solar electricity will then become a major element in the economy of many countries.

The developed countries, fully aware of the limitations of conventional power resources, and threatened by dependence on imported energy are showing considerable interest in developing solar energy. Developing countries stand to benefit more from implementation of solar energy conversion for the following reasons:

(a) most of the developing countries have a high insolation rate.

(b) solar power plants of any desired size could be constructed. This favours decentralised development which is socially desirable, as it allows rural populations to progress and evolve in their natural habitats.

The success of decentralised development will depend to a large extent on the availability of small and medium sized independent power plants. This increasing use of solar power will facilitate the decentralisation of industry and the development of rural areas, because it means independence of foreign fuel and promise of reliable, long-life operation. Many pilot projects have already started in many developing countries in Africa, Latin America and Asia.

In Sri Lanka, an integrated rural development project – called the Mahiyangana Solar Infrastructure Project – has been launched last year to bring electricity to the lower Uva region. This project costs about Rs. 70 million and is funded by the Australian government. The program is implemented through the National Housing Development Authority. The installation work has been sub-contracted to Sunpower Systems (Pvt) Ltd.,

a member of Maharaja Organisation. The solar packages to be installed are provided by BP Solar, a giant global solar organisation.

Phase I of this project was completed in December 1992, providing solar powered electricity to 83 remote public locations such as hospitals, water pumps, community centres and temples in remote villages of Badulla and Moneragala districts.

Nineteen solar powered pumping systems have been installed in the region. A pump can surface upto about 5000 gallons of fresh water a day enough to meet the daily cooking and washing demands of a small rural community. Each complete pumping system costs about Rs. 800,000/-.

Seven residential and non-residential hospitals have been sun-powered under phase I at a cost of Rs. 2.7 million per installation. 35 solar panels set into an array are connected to a battery bank of 2200 Amp-hrs with an inverter stepping it upto conventional electricity of 230 V. The battery bank has a reserve capacity for about seven days, making it possible for a hospital to cope with a few cloudy days.

Twenty seven rural maternity clinics are sun-powered by smaller solar systems each valued at Rs. 600,000/-. This consists of 8 solar panels connected to a battery bank of 1100 Amp-hrs. In addition to providing lights and hot water to the clinic, it powers a refrigerator where vaccines and child immunization are stored. It also provides lights to the adjoining family health officer's quarters. Health officers are also given a portable solar lantern to be used on night call duty. During the day, the lantern's batteries can be recharged by being left out in the sun.

Several community centres and village temples are solar powered by a smaller domestic system. A 3-panearray powers a battery of 360 Amp-hrs, providing four to six lamps plus a plug outlet for a colour television set. The phase I of this project also includes solar power to six vocational training

centres in the region, providing lighting and electricty outlets for students to work with power tools and carry out experiments even at night.

The phase II of the project aims to light up 25,000 households in these areas and is about to begin soon. The government of Sri Lanka has also decided to set up 35 similar solar projects in certain villages in the Anuradhapura distric

9. Bio technology:

This may truely be considered a topic for a biologist but I make no apology for including it in this talk. After all the structure of the DNA was deciphered in a Physics laboratory by physicists in X - ray diffration studies!

In 1953 James Watson and Francis Crick advanced a model of the secondary structure of desoxyribonucleic acid (DNA). The model is the so called "double helix". Its importance is said to be equal to that of Lord Rutherford's model of the atom proposed in 1911. The entire "heritage" of a living organism was found to be "recorded" in a gigantic DNA molecule on a specific sequence of its component nucleotides. A gene is a molecular fragment which encodes a protein that enables the hereditary potential to be realized. In 1960 Har Gobind Khorana synthesized a part of the spiral and obtained the first artificial gene. Numerous important contributions were made in the 1960s to the process of identifying the mechanism whereby genetic information is transmitted. This made it possible to move towards construction of new genes containing fundamentally new hereditary information.

According to the late PMS Blackett, a well known Nobel laureate in physics, molecular biology has revolutionized the science of the living world to the same extent that the quantum theory revolutionized nuclear physics about fifty years ago. Indeed, the latest achievements of biological science are revolutionary and epoch-making.

In 1973 Herbert Boyer and Stanley Cohen developed a technique to recombine DNA molecules so as to "assemble" artificial microorganisms with new previously nonexistent, sets of features in their progeny, or created a new organism.

If a gene is cut off from a DNA molecule and attached to another, an artificial DNA molecule is obtained. In a cell, these molecules will be multiplied acting as a natural genetic structure producing the protein associated with the artificial gene. This basic scientific idea was the beginning of the technology of creating genetic structures in vitro, which is known as genetic engineering. It gave man a fundamentally new potential to interfere in natural processes by replacing, moving or adding genes. In other words, the DNA structure can be designed in the desired way. This means new genetic systems, and consequently, entirely new organisms can be obtained in compliance with a "design".

For basic research, this is the most effective way of studying the heredity mechanism, structure and functions, and tremendous progress has been made in this field. But how are the results of this basic research on genetic manipulations useful to the human? There are many potential applications. New organisms whose properties are useful for man are obtained. A few examples are:

(a) production of microorganisms with a very high productivity (ie. producers of amino acids, antibiotics or feed protein)

(b) production of plant hybrids which would yield record harvests and are stable under unfavourable environmental conditions.

c) elimination of hereditary defects in animals.

The application of genetic engineering has resulted in the advent of what is known as the DNA industry. This industry is now producing physiologically active proteins for medical and agricultural purposes. One of the outstanding achievements of this industry is the manufacture of interferon.

(*Interferons are natural antiviral agents with which an organism reacts to viral infection. They are effective. It is virtually impossible to produce them in large scale in pure form*). Interferon is currently manufactured in pilot plants.

Another important use is in the manufacture of human insulin, which was inaccessible for medical purposes. Animal insulin has been in use to treat acute diabetes. But animal insulin is somewhat different from human insulin and some patients develop acute allergies. Biotechnology has now made this human hormone accessible.

Research is also being done to produce human growth hormone to treat burns and fractures.

We shall now see how the basic research on genetic manipulations could be used in agriculture.

Certain kinds of cells have been found to respond easily to hybridization. Under favourable environments, the vegetable cells can evolve into a full plant that is capable of reproducing. Although this is not possible now in all plants, it is hoped that eventually it will become possible. In any case this property makes it possible to create a new plant with the desired features. This new field – called cell engineering of plant reproduction has the following advantages :

(a) independent of climate and season

(b) independent of the size of the land

(c) high yield

(d) highly resistant to diseases and pests.

Cell engineering can, therefore, be expected to solve the food problem once and for all.

Another promising area of research is the decoding and transplantation of nitrogen-fixing genes. Nitrogen can only be fixed by microorganisms which live in soils and the tubers of legumes. It would be useful if this property could be

imparted to cereals such as rice and wheat and some vegetables. If nitrogen – fixing genes were introduced into the genetic machinery of other microorganisms and cereals and made useful for farming, the need for nitrogen fertilizers would be drastically reduced. This would be a true revolution in farming.

Biotechnology, a new, revolutionary field in the science and practice of biology has itself become an integral system. The application of its discoveries and inventions will significantly increase the production of food and biological renewable sources of energy. It will improve the potential for achieving ecological equilibrium and the treatment of serve hereditary, virus and cancer diseases. It will help overcome the food, energy, raw-material and ecological crises.

The revolutionary changes in industrial practices that will result from biotechnology are quite properly compared with those which followed the discovery of nuclear energy, the advent of semiconductors and electronics. The twentyfirst century is now referred to as the biotechnological age.

The development of bioengineering is another striking example of how theoretical research and discoveries of basic sciences in molecular biology, chemistry, physics, mathematics and interdisciplinary fields such as biochemistry, biomedicine, bioorganic chemistry, biophysics, biomechanics and immunology give rise in their practical application to the manufacture of new products, to accelerate economic development and hence to elevate the standard of living of the common man.

Let me conclude this talk with a quote from Nobel Laureate Abdus Salam:

"Unless and until basic knowledge has been accumulated no technicalfix can be achieved in this age when science must precede technology".

Thank You.

RECENT ADVANCES IN PENAEID SHRIMP HATCHERY FEED TECHNOLOGY

K. Chitravadivelu*

1.0 Introduction

World fish production was 85 million tonnes in 1985. With a maximum substainable yield reaching 100 million tonnes by the year 2000, world demand for fish and shellfish is estimated to be 130 million tonnes. Shrimp landings are only 1–2% of the total fishery catches. Increased shrimp productions from natural sources are unlikely as most rich fishing grounds for shrimps have already been discovered and presently been exploited at their upper limit or over fished and therefore cannot meet the present consumer demands which are growing at a rate of at least 4% per annum in Europe and America (Alexandratos, 1988; Jones 1988).

In penaeid shrimps, the abdomen is mainly of muscle tissue comprising 60% of the entire body weight. In addition the firm protective covering of exoskeleton, prevents damage during handling and resists entry of bacteria that would cause spoilage (Kurian and Sebastian, 1976). The almost universal acceptability, popularity, demand and unlimited market potential for shrimps as a food item is due to their unique flavour, texture and versatality (Neal and Maris, 1985).

Annual world supply of shrimps was about 2 million tonnes in 1988 of which 85% was from tropical countries. The contribution from aquaculture to the supply rose from 12% in 1985 to about 22% in 1988. Shrimp farming in Asia is already an industry of significant size and estimates indicate a potential of 800,000 metric tonnes of shrimps by aquaculture by the 2000th year (Casavas, 1988).

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Static supplies of shrimps from capture fisheries and continuing high demand for shrimps in local and foreign markets have made shrimp mariculture attractive and generated interest among many individuals, private and State organisations and International Development Agencies.

Tropical areas are highly appropriate for the development of Penaeid farming for the following reasons – (i) the high temperature allows production throughout the year, (ii) since the tropics are the natural habitat of majority of fast growing species of Penaeids, a supply of gravid females and in many cases abundant wild fry is guaranteed, (iii) tidal filling and draining of ponds is possible without the use of external energy for pumping since the tidal ranges from 2m to 4m exist in many situations, (iv) more land is available and coastal areas are obtained on lease, relatively easy and (v) low cost labour is abundant and taxation mild (Pedni, 1981 and Aquacop, 1985).

2.0 Species cultured

Penaeus monodon the giant tiger prawn is one of the largest penaeid prawns in the world, reaching about 250 mm in body length This species is of commercial importance in the market and is farmed in the Indian Ocean and West Pacific regions (Motoh, 1985). *P. vannamei* and *P. stylirostris* are farmed throughout the tropical East Pacific and Central America and *P. japonicus* throughout subtropical Japan and recently introduced into the Mediterranean (Jones and Canavate, 1987).

3.0 Culture systems and hatcheries

The existing shrimp culture systems could be conveniently grouped into three categories namely, extensive, semi-intensive and intensive (Kungvankiji, 1985).

In all the systems of culture of shrimps, the juveniles are kept and fed in captivity till they reach the harvestable size. Whatever the culture system, the availability of quality prawn

seeds as and when required by culturists is one of the basic requirements for proper planning of the culture operations. The distribution patterns and abundance of prawn seeds in the coastal lagoons, estuaries and brackish water areas fluctuate widely due to biological and physical factors (Vance et al., 1983).

Collected seed is usually cheap, at any rate cheaper than hatchery–rared seeds (Casvas, 1988). There is always the danger of undesirable predators entering ponds during the tidal trapping periods. However, the supply of wild fry for stocking is periodical, unreliable and most important, limited.

The lack of reliable sources of post larval juveniles for stocking has given rise to the development of a separate hatchery industry. Establishment of hatcheries has increased dramatically since 1975 to keep pace with the demand for seed prawns, with the result there are now estimated to be some 1500 hatcheries in Taiwan, 70 in Japan, 400 in the Philippines, 300 in China, 100 in Eucador and 04 in Sri Lanka (Wickins, 1986). In 1988 the hatcheries in Taiwan alone supplied more than 3 billion post–larvae which ultimately produced 50,000 metric tons of markctable prawns.

Over the last ten years, various hatchery and nursery techniques have been developed and are being adopted by both private and Government hatcheries.

In Taiwan and Japan, over 1.5 billion post larvae of *P. japonicus* and *P. monodon* are produced annually. In these countries, entirely hatchery bred post–larvae are used for stocking the pond. The Philippines, Indonesia and Thailand among Southeast Asian countries, are the main producers of *P. monodon* post-larvae. In seed production of *P. monodon* post–larvae, the Philippines leads with 300 million per annum, while Thailand and Indonesia produce only about 100 million each per annum. The recent development of shrimp farming techniques and consequent upgrading of traditional shrimp farming in this region have created the need for more fry.

The role of a shrimp hatchery is to rear the larvae from hatching to suitable size at which it can be introduced into a pond for further growing. A hatchery requires – (i) Healthy sprawners, (ii) Algal cultures and (iii) Zooplankton cultures (Rotifers and *Artemia* nauplii).

4.0 Spawners

Although shrimps spawn throughout the year, there are distinct periods when majority of shrimps spawn. For example, *P. monodon* in Southeast Asian waters, spawns during December to March and June to September. Professional fishermen collect spawners from coastal waters. They are provided with necessary facilities such as aerators, containers, etc., and taught proper identification and handling techniques to ensure getting quality spawners.

In some countries like Japan, spawners can be easily obtained by the hatchery operators from the fish market because shrimps are kept alive and sold alive to consumers because they prefer live to dead ones. On the other hand, hatchery operators in some Southeast Asian countries like India and Sri Lanka have to obtain live spawners directly from fishermen.

One of the major constraints in the development of shrimp farming industry, especially that of farming of *P. monodon* is the inadequate supply of wild spawners. Many hatcheries in Southeast Asian countries have been developing techniques for maturing *P. monodon* in captivity. A technique known as unilateral eye stalk ablation has been developed recently for maturing *P. monodon* in captivity (Liao, 1973 ; Liao and Chen, 1983). This technique ensures consistent supply of spawners and offers the culturists considerable scope for extending the natural breeding season and for culturing certain species outside their natural geographic range (Wilkins, 1986).

5.0 Life History

In the majory of shrimps including *P. monodon* the sexes are separate. Mating occurs as the sexes migrate to more saline conditions or deeper waters where vitellogenesis and spawning

take place. Copulation among penaeid species results in the deposition or insertion of spermatophores onto or into the female thelycum. The number of eggs produced in a complete spawning varies from 200,000 to 1,000,000 with an average of 500,000 eggs for *P. monodon* spawners caught in the wild.

Typically penaeid eggs hatch within 36 hours into the first larval stage the nauplia. The nauplius does not feed but subsists on its yolk reservs and passes rapidly through a number of moults. *P. monodon* larval stage consists of 6 nauplia, 3 protozoea and 3 mysis stages. The mysis metamorphoses into a benthic post larva or fry referred to as PL for commercial purposes. The whole pelagic larval phase takes about 11–12 days to complete at temperatures above 28°C.

6.0 Feeding habits of larvae

The non-feeding nauplii larvae on metamorphores to the protozoea stage feed on unicellular algae. The next larval stages the mysis and post larvae require live zooplankton in the form of rotifers and *Artemia* nauplii. Hatchery operations for seed production of Penaeids therefore depend on the culture of living food organisms. Majority of hatcheries have algae cultures and zooplankton systems such *Chlorella*, *Chaetoceros*, *Skeletonemia*, *Tetraselmis* and *Branchionus* to meet the food requirements. The nauplii of *Artemia* are obtained by hatching commercially available drought resistant cysts.

These feeds are not only costly but also difficult to culture and maintain, often nutritionally defficient in essential poly unsaturated fatty acids (PUFA) and act as a source of contanimation leading to poor larval servival. In addition, mass culture of planktonic organisms requires much manned help, expensive equipment and fluctuates with climatic conditions (Jones, 1987; Kanazawa, 1984).

These problems lead to the search for artificial alternatives to live feeds.

7.0 Artificial larval diets

There are at present three main types of artificial larvae feeds designed to replace live feeds. They are freez-dried or otherwise processed natural products, microparticulate diets and microencapsulated diets.

(i) Processed natural products: These products are mostly based on dried or freez-dried algae or yeast. The advantage these have are that the natural product still retains the correct particle size range for many first feeding herbivores larvae. However, once the cells are dead, the contents are subjected to leaching and the cell wall may break down rapidly reducing nutritional quality and stimulating bacterial growth in the culture water.

(ii) Microparticulate feeds or Microbound feeds: These are prepared by incorporating dietary ingredients into gels of carboxy methyl cellulose, calcium alginate, gelatin, carrageen, agar or zein or curing with formaldehyde or pH changes (Langdon et al., 1985). Rapid leaching of water soluble ingredients, particle breakdown due to poor stability and tank pollution are the main problems encountered with these formulations. There are no reports upto date of any microparticulate product which has been used successfully as a total replacement for live feeds on a commercial scale.

(iii) Microencapsulated feeds: Jones et al. (1974, 1979a and 1979b) demonstrated the technique of microencapsulation as a method to deliver artificial diets, in their attemps to study the nutritional requirements of planktonic larvae. Using cross-linked, nylon-protein microcapsules prepared by interfacial polymerisation which protect the diet from dissolution and bacterial contamination, they fed simple diets and obtained significant growth and survival of crustacean larvae (Jones et al., 1987). The interfacial polymerisation used in the preparation of the nylon-protein microcapsule was based on the method described of by Chang et al., (1966). However, it was found that

the nylon–protein capsule was not the ideal delivery system, because the membrane wall was too thin to withstand drying, not digestable and therefore did not provide an ideal diet and thus found to be impractable for use on a commercial scale.

In 1978 Frippak entered into an agreement with David Jones of the University college of North Wales, United Kingdom to develop an ideal capsule which is completely digestable. David Jones and the marine biologists of Frippak Research Team made the technical break through in 1979, by replacing the nylon–protein capsule by an X–linked protein walled capsule which eliminated the nylon precursor and uses part of the diet to form the wall. This microencapsulated feed can be dried for storage before rehydration as a larvae feed. The protein wall of the capsule is semi–permeable, so that it allowed the diet to rehydrate, before injestion. This technology developed in collaboration with Frippak Feeds (Basingstoke, UK), paved the way for full commercial production of Frippak microencapsulated feeds in size ranges varying from 5–250 microns diameter (Jones et al., 1987).

By 1988, the following popular artificial larval diets in commercial production were available in the market – Alma, Argent, Cell system, Nippai, Osci, Topal and Frippak. Out of these, Frippak, feed was the only one which was microencapsulated. Like all other manufactures, Frippak was involved in the evaluation and improvement of its diets with the final aim of manufacturing a 100% replacement diet. Major part of the research work involved in this was handled by the Research Team in the Marine Science Laboratory of the University College of North Wales, headed by David Jones. I joined this team in September 1988 and worked with them upto August 1989. By then the team had concluded work on the particle size, nutritional and energy requirements. Based on these findings Frippak manufactured improved diets which were evaluated at the Marine Science Laboratory of UCNW. The diets are evaluated on the basis of growth rate and survival percentage.

Because of the availability of a large number of artificial larval diets in the market, the hatchery owners were at a quandary as to which one to choose. It was at this juncture that the Research Team decided to evaluate the performance of seven most popular larval diets then commercially available in the market.

8.0 Methods of evaluation of artificial diets

Sterilized two litre round bottom flasks were filled with sea water and maintained at 28° ± 1°C. The sea water used was of 32‰ salinity, filtered through 0.2 μm cartridge filter and UV ray treated. Gentle aeration at the rate of 2 – 3 bubbles sec^{-1} was provided by means of glass delivery tube of 3 mm inner diameter, at the bottom of each flask. This arrangement in addition to providing oxygen, agitates the water and keeps the feed in suspension (Jones, et al., 1989).

Each flask was stocked with 200 *P. monodon* larvae at PZ_1 stage from the same spawning in replicated trials. The larvae used in the trials were spawned in the Frippak Research Centre at Findon, UK and air – frighted to the Marine Science Laboratory at North Wales through Manchester. The initial average body lengths of the larvae were obtained from measurements taken using an optical micrometer under a binocular microscope. The seven diets named A, B, C, D, E, F and G were rehydrated and fed four times a day at 8.00 hrs, 12.00 hrs 16.00 hrs and 22.00 hrs. at concentration according to manufactures instructions, together with microalgae as co-feed. Controls were fed on live feeds of microalgae at 20 cells μl^{-1} of *R. baltica* and 20 cells μl^{-1} *T. chuii* from PZ_1 - PZ_3 and newly hatched *Artemia* nauplii at 5 ml^{-1} from M_1 - PL_1.

Water in the culture flasks was completely changed every other day, and the number of larvae alive was counted to assess the percentage survival. Ten larvae from each flask were also measured every other day to obtain the growth in length.

To determine the factors affecting performance, ammonia was measured according to Solorzano (1969) and unionised amonia (NH_3-N) calculated from equations derived from Whitfield (1974). Nitrite was measured according to procedures described by Bendschneider and Robinson (1952). Other parameters examined were organic contents of the diet, percentage loss of dietary solubles over a period of 24 hours, particle stability and bacterial growth using Zobel's medium.

One way ANOVA was used to analyse diet treatments to determine significant differences between larval growth and survival due to different artificial feeds In addition, Schiffe's multiple pairwise comparision was employed to identify differences between individual treatment means.

9.0 Results and discussion

The organic content of the artificial feeds together with proximate analysis of dietary components are shown in Fig. 1. The major constituents of the diets are based on a combination of proteins, lipid and carbohydrate.

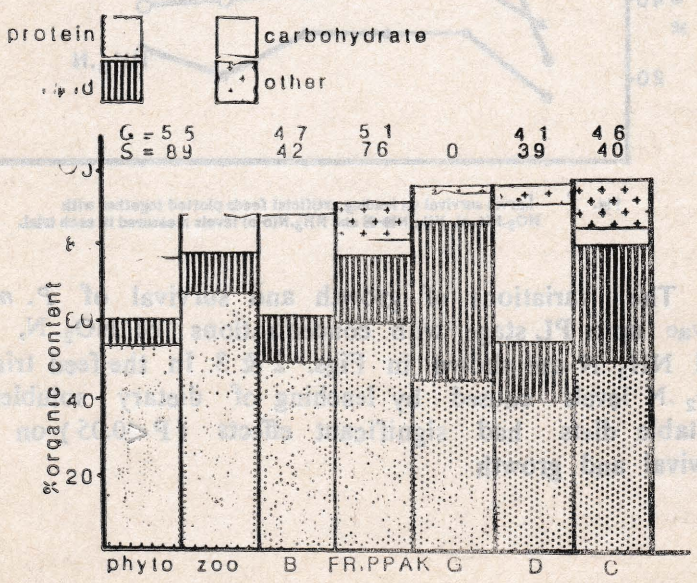

Fig 1. Organic Content (ash free dry wt) of leading artificial larval fe de together with protein lip d and ca bohydrate levels, compared to live feeds (Raymont 19B3) and corresponding larval growth (G) in mm and percentage survival (S).

The results of the larval feed trial with *P. monodon* and the diet stability are summarized in Table 1. The larvae metamorphosed from PZ_1 to PL stage in 11 days on all artificial diets except for diets, E and G, which did not support growth and survival to the PL Stage.

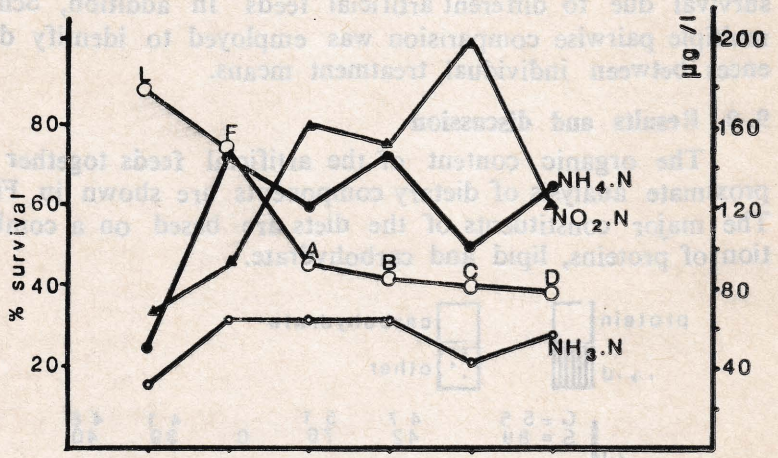

Fig. 2 Larval survival on leading artificial feeds plotted together with NO_2.N(▲-▲), NH_4.N(●-●) and NH_3.N(o-o) levels measured in each trial.

The variations of growth and survival of *P. monodon* larvae upto PL stage with concentrations of NO_2. N, NH_4.N and NH_3 .N are shown in Figs. 2 & 3. In the feed trials high NO_2 .N levels caused by leaching of dietary solubles from unstable diets had significant effects ($P<0.05$) on larval survival and growth

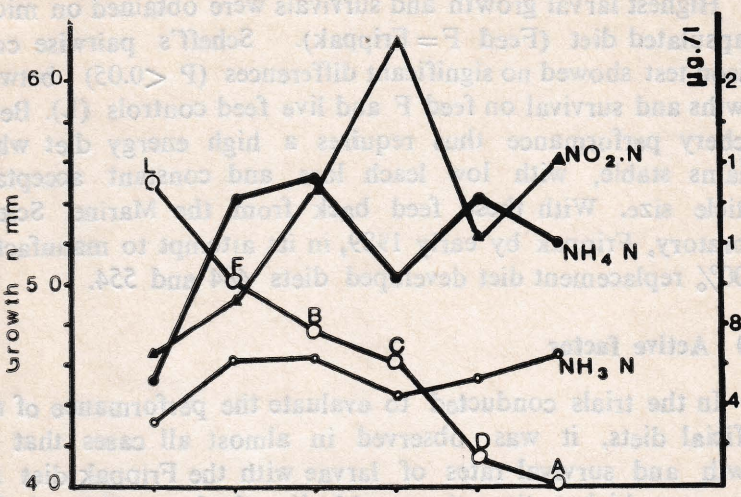

Fig 3 Larval growth on leading artificial feeds plotted together with NO_2 N ▲-▲, NH_4 N ●-● and NH_3 o-o levels measured each day.

The organic contents of the feeds compare favourably with that of natural algae and plankton (Fig. 1), but it is likely that some feeds may be nutritionally deficient in micronutrients. Results indicate that the levels of nitrate 100 μg l^{-1} rather than ammonia to be detrimental to both larval growth and survival. Chen et al. (1986) also observed larval survival to be more significantly related to nitrite levels than with ammonia. With NO_2. N levels of 78 μg l^{-1}, Chen et al. (1986) observed survival rates to be no greater than 10% in a prawn hatchery. According to Mevel and Chamroux (1981), young prawns of *P. japonicus* were sensitive to concentrations of nitrite higher than 100 μg l^{-1}. Nutrient leach as a result of feed breakdown also encourages bacterial growth and contamination (Jones et al., 1974) Particle feed size analysis shows initial particle sizes are too large to be ingested by the larvae. With unstable feeds the breakdown of the feed particles after 24 hours produces fine fractions which may be too small to be ingested by the larvae. Particle stability is the key factor for most particulate diets.

Highest larval growth and survivals were obtained on micro-encapsulated diet (Feed F = Frippak). Scheff's pairwise com, parison test showed no significant differences ($P < 0.05$) between growths and survival on feed F and live feed controls (L). Better hatchery performance thus requires a high energy diet which remains stable, with low leach loss and constant acceptable particle size. With these feed back from the Marine Science laboratory, Frippak by early 1989, in its attempt to manufacture a 100% replacement diet developed diets 484 and 554.

10.0 Active factor

In the trials conducted to evaluate the performance of new artificial diets, it was observed in almost all cases that the growth and survival rates of larvae with the Frippak diet and algae were higher than those with live feeds or Frippak feed alone (Table 2). This led us to conclude the presence of some 'active factor' in algae responsible for the enhanced growth and survival (Chitravadivelu, 1992). The next step was to isolate the 'active factor' and incorporate it in the artificial diet, by encapsulation.

10. 1 Algal diet preparation :

The following methods were used in algal diet preparations for trials designed to elucidate the basic properties of the 'active factor' and isolate it.

(i) Centrifuged from culture and homogenised : *T. chuii* and *R. baltica* were concentrated separately by centrifugation; the former at 3000 rpm for 30 mins. and the latter at 1000 rpm for 10 mins. in (Model MSE) cool spin Rotor. The algal concentrate was then homogenised in model K 43 – TRI homogeniser ; *T. chuii* at 10,000 rpm for 30 mins. and *R. baltica* at 10,000 rpm for 20 mins.

(ii) Centrifuged concentrate was frozen and kept at –19°C for 30 days, thawed and homogenised.

(iii) Separated into insoluble and soluble fractions : 50 ml of the homogenised algal concentrate was separated into soluble and insoluble components by centrifugation in MSE / Superspeed 65 in the following speds – *T. chuii* at 40,000 rpm for 40 mins. and *R. baltica* at 30,000 rpm for 30 mins.

The supernatant lipuid (soluble component) was separated and the pellet (insoluble component) was resuspended and made upto 50 ml in autoclaved sea water.

(iv) Homogenised algae boiled : 50 ml of algal concentrate was brought to boiling in a beaker, cooled, homogenised and made upto 50 ml with autoclaved sea water.

(v) Oven dried and homogenised : 50 ml of algal concentrate was dried in oven for 24 hours at 60°C, resuspended in deionised water, homogenised and volume made upto 50 ml with deionised water.

(vi) Separation of non–fat component from insoluble fraction : To 50 ml of algal concentrate, oven dried for 24 hours at 60°C, chloroform–methanol mixture (2 : 1) was added and stirred to dissolve the fat component and the fat dissolved chloroform–methanol drained out. This was repeated three times. The insoluble non–fat component was allowed to dry in a fume cupboard for 4 hours, resuspended in deionised water, homogenised and the volume made upto 50 ml. Frippak larval diets 484 and 554 were used in these investigations.

10. 2 Storage and feeding :

The volume of the algal preparation required to give either 10 cells μl^{-1} or 20 cells μl^{-1} for 2×2 L for a day was introduced into autoclaved vials using sterilised syringe, soon after preparation and used directly for feeding or stored in the deep freezer at –19°C.

12 hours prior to feeding the weight of the (0.032 gram or 0.064 gram), Frippak diet according to manufactures instructions was introduced into one vial containing the algal diet and kept in the fridge.

Just before feeding, the volume of the feed was increased with autoclaved sea water or deionised water so that the total volume will be just enough to provide 4×2 feeds of 0.8 ml or 1.6 ml as the case may be.

10. 3 Results

Table 3 gives the results of the trials conducted with different diet treatments.

In all experiments homogenised algae added at 10 cells μl^{-1} to diets 484 and 554 produced increased growth to Z_3 over live feed controls. This was apparent even when algae was boiled or oven dried and resuspended. In all cases where poor, results occurred, bacterial contamination of dead algae suspensions were responsible. Boiling or oven drying eliminates this problem.

Survival rates varied; more often they were higher on algae and diet formulations and were lower only when algal homogenates were contaminated with bacteria. Boiling or drying algae eliminates this problem as well.

Growth from mysis 1 to PL_1 was also greater in almost every case for algae and diet preparations in comparison with controls on live feeds, even though these included *Artemia*. Again, in most cases survival was also either not significantly different or actually higher than on live feed controls.

Results indicated that the 'active factor' was present in the water insoluble fraction of the algae. The last trial also indicated that the active factor was in the lipid component. The results were inconclusive then.

11. 0 Present status

Research on the isolution of the 'active factor' however, continued in the Marine Science Laboratory, even after I left in August 1989. According to a personal communication from Dr. David Jones dated 28th May 1992, the 'active factor' has been isolated, successfully encapsulated and found to retain activity. Penaeid larval diets with algal 'active factor' will soon go into commercial production. It will be a great boon to shrimp culturists since the larval diet with 'active factor' will be better than a 100% replacement to live algal feeds. Microencapsulated penaeid larval diets with algal 'active factor' will pave the way for a more profitable shrimp culture that would expand to meet the increasing world demand for shrimps.

	live feeds	Frippak	B	C	D	A	E	G
Growth (mm)	5.5	5.1	4.79	4.64	4.16	4.07	0	0
Survival %	86	76	42	40	39	45	0	0
Feed % organic cont.	82	91	88	95	95	88	86	95
% loss 24h		18	25	28	37	36	44	40
TRIAL NH_4-N ($\mu g\ l^{-1}$)	550	1513	1540	1070	1315	1200	*	*
TRIAL NO_2-N ($\mu g\ l^{-1}$)	66	89	149	210	120	160	*	*
24h NH_4-N ($\mu g\ l^{-1}$)		145	265	185	155	205	235	310
24h NO_2-N ($\mu g\ l^{-1}$)		27	37	41	30	23	38	59
Bacteria ($\times 10^{-9}$)	9	26	39	63	18	16	38	93
MPS dry (μm)	10	20	90	72	62	60	58	102
MPS 1h (μm)	10	19	107	65	62	24	45	24
MPS 24h (μm)	10	18	18	43	32	22	25	22

* not measured in feed trial

Table 1: Summary of larval feed trials with *P. monodon* and diet stability.

DIETS		DAYS			
		3rd	5th	7th	11th
1. 484	(a)	1.513	2.163	2.628	4.228
	(b)	90.3	85.3	72.5	81.5
2. *R. baltica* 40c μl^{-1}	(a)	1.501	2.222	2.634	4.117
	(b)	78.5	64.8	55.8	57.0
3. 484 + *R. baltica* 10c μl^{-1}	(a)	1.551	2.255	2,779	4.123
	(b)	89.3	83.5	71.8	84.0

(a) Average body length in mm
(b) % survival

Table 2: *Growth and survival of P. monodon larva in different diets* (Average body length at commencement = 1.046 mm)

Trial Nos.	DIET TREATMENTS	Z_3		PL_1	
		% Survival	AV. body length in mm	% Survival	AV. body length in mm
i)	i) 484 + Homog. *R. b* 10c μe^{-1}	76	2.50		
	ii) 484 + Homog. *R. b* 20c μe^{-1}	32	1.70	76	4.50
	iii) Control	86	2.35	91	4.30
ii)	i) 484 + Homog. *R. b* 20c μe^{-1}	71	2 40	45	3 35
	ii) 484 + Homog. *R b* 10c μe^{-1}	94	1.60		
	iii) 484 + Sol. fract. *R b* 20c μe^{-1}	78	1.90	56	3.35
	iv) 484 + Ins. fract, R. *b* 20c μe^{-1}	88	2.10	54	4 08
	v) 484 + Sol. and Insol recombined 20c μe^{-1}	80	2.30		
	vi) Control	81	2.30	50	3.99
lii)	i) 484 + Sol. fract. *R. b* 10c μe^{-1}	75	2.20	69	4 09
	ii) 484 + Ins. fract, *R. b* 10c μe^{-1}	81	2.30	84	4.30
	iii) 484 + Sol. + Ins. combined 10c μe^{-1}	73	2.33	69	4.20
	iv) 484 + Sol. + Ins combined + boiled 10c μe^{-1}	85	2.36	84	4.35
	v) Control	65	2.22	57	4.12
iv)	i) 554 + Homog. T. c. 10c μe^{-1}	72	2.49	95	4.57
	Homog. *R. b* 10c μe^{-1}	82	2 43	99	4 48
	ii) 554 + ,, boiled	75	1.79		
	iii) ,, frozen (only)	75	1.73	76	2.88
	iv) ,, (only)	85	2.17	93	4.31
	v) Control				
v)	i) 554 + Dried T. c. 10c μe^{-1} + *R. b* 10c μe^{-1}	94	2.35	81	4 33
	ii) Control	85	2.45	85	4.20
vi)	i) 584 + Boiled *R. b* 20c μe^{-1}	48	2.20		
	ii) 484 + Boiled T. c. 20c μe^{-1}	73	2.30		
	iii) Control	74	2.20		
vii)	i) 554 + Homog. T. c. 10c μe^{-1}	84	2.58	64	4 03
	ii) 554 + Non-fat component-1 Homog. T. c. 10c μe^{-1}	64	2.40	79	4.11
	iii) 554 + Boiled T. c. 10c μ-e^{1}	82	2.54	40	
	iv) Control	92	2.55	42	4.70

Table 3: Results of the trials with different diet treatments.
(*R. b.* = *Rhodomonas baltica*, *T. c.* = *Tetraselms chuii*, *c* = *cells*).

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