uranium in ceramic form in a semi-homogeneous system (which is capable of breeding), this reactor should, if it is successful, make it possible to achieve temperatures exceeding $1,000^{\circ}\text{C}$. in the heat cycle.

If such a system, using a replaceable graphite moderator, cannot be evolved, the alternative would be to use heavy water as a moderator, so that radiation damage can be repaired or removed during circulation. At that stage it would probably be convenient to use steam instead of carbon dioxide as a coolant. American reactor development has generally been on the lines of water-moderation and cooling. As they make their way towards higher temperatures in the heat-cycle, they will probably be forced to use steam cooling instead of water cooling. If this happens and if British development takes the line suggested, the two streams of development, starting so far apart, will have flowed logically together.

Meanwhile, we are faced with the fact that if the present rate of technological progress in the nuclear field is to continue, there appears to be little prospect that research and development costs will fall; they are likely to remain at about 30 per cent of capital expenditure.

For how long can the electricity industry justify this? The rate of advance in the nuclear field was determined initially by effort which was part of, and was justified by, the defence programme. Remembering that the demand for electricity has a doubling period of ten years, that the total fuel requirements of the Generating Board (expressed as coal equivalent) are now 54 million tons a year and will rise to 90 million tons a year by 1970, and remembering that it is improbable that sufficient British-mined coal would be available to meet the Board's total fuel requirement by some date in the 1970's, it appears reasonable to aim at continuing the high rate of advance of nuclear technology to the point where nuclear power breaks even in cost with conventional power; we shall then have freedom to manoeuvre in a three-fuel economy. After that date, which is not remote, it is surely reasonable to think that research on reactor technology should be justified by savings

which can be expected to arise from its industrial application. It is interesting to speculate how much the downward trend in the cost of conventional power could be increased if it could attract as great a research and development effort as its nuclear rival. There is no suggestion that it should attract such expenditure, but it is suggested that re-deployment of research and development resources must be carefully considered and that this consideration will probably demand a changed distribution in a few years time.

It is possible that there is, to-day, a danger that the deployment of research effort can be distorted by development work directed to defence and paid for by defence funds. Although work in the defence field may be directed to a few major projects, the ancillary work is widespread; for example, the development of nuclear weapons has demanded and fostered intensive and expensive research in ion exchange, solvent extraction, fluorine chemistry, vacuum technology, the metallurgy of a wide range of metals, the development of high-speed digital computers and other things. All these developments find industrial applications, so that the 'hot-house' growth of technology in the defence field affects the rate of development in many industrial fields where application is possible. When this happens only in the limited time of a war, the effect is beneficial: when peace returns, the injection of defence technology into industrial practice is a useful stimulus. But since 1946 conditions have been such that a war-time rate of development has continued in defence and its many ancillary fields, and one wonders whether the injection of these developments into the industrial field has not over-stimulated some industries in a way that makes it hard to live with them, while diverting effort from others. To avoid this would be difficult: but, as the emphasis of defence development moves from one field to another (and, one hopes, is ultimately relaxed overall), it is possible and desirable to examine the rate of advance which has been induced, and to ensure that it is adjusted to what is economically justifiable and that it does not continue by pure habit at a rate which is artificially high.

FOOD AND ANIMAL PRODUCTION

A SESSION on "Food and Animal Production Overseas", arranged by Section M (Agriculture) of the British Association, was held in Cardiff on September 2.

Mr. J. H. Anderson, of the National Agricultural Advisory Service, presented a rather gloomy picture of the present position of "Food Production Problems of the Middle East"—low rainfall, uncertain time of onset of the spring rains and, when it did come in quantity, the flooding of large areas and soil erosion.

For example, it had been calculated that in Iraq some 170 million tons of soil was carried down in the Tigris every year. Soil destruction by arable cultivations only and by over-grazing are leading to a worsening of the position. The average size of the holdings is small; for example, 90 per cent of the farms in Egypt cover less than 3 acres. In many cases these provide only enough food for the occupiers and none to supply the rapidly growing urban population. Throughout the area higher education tends

to be directed to law rather than to technical training for the agricultural advisory or even medical services, there being only about two medical practitioners for every 3,000 inhabitants. He proceeded, however, under various headings, to describe what is being attempted and what is further needed to improve these conditions. Except for Egypt, better land and water-use is required: afforestation is wanted on the mountains. In Syria some 30,000 trees, in addition to windbreaks, are being planted to hold the water. In the discussion afterwards, it was mentioned that very deep ploughing with tractors, rather than the present shallow cultivation with wooden ploughs, would allow the water to sink in rather than run off or evaporate. Mr. Anderson also pointed out that it is increase in yield per acre which is required rather than increase in cultivated area. For this purpose nitrogenous fertilizers are one of the chief requirements, but the cost of importation is too great; Iraq is, however, setting up a nitrogen plant. Except for Turkey, Israel and Egypt, new improved varieties

of crops with better yielding capacity are also required. Throughout the whole area, locust destruction is needed. Much more irrigation is required; great advances are being made in Israel, where it is hoped by 1975 to double the present area and triple the crop output. One problem with irrigation is increase in the salinity of the soil, some 70 per cent of the irrigated area in Iraq being more or less affected by this: research is needed in desalinating.

Livestock improvement is also wanted; except for Israel and Egypt, from cattle and buffaloes respectively, milk is in poor supply. To produce this, more feed from arable cultivation is necessary. In the other countries, the browsing goat is a useful source of milk supply. The need for tractors is great, but development in this respect is slow owing to the cheapness of labour. However, as pointed out in the discussion, tractors are necessary for deep ploughing on hard soil before the rains come. As in most places, a better system of agricultural credit should be made available to effect these improvements. Methods of helping the small farmer to accumulate capital were mentioned in the discussion on the paper by Mr. B. N. Chatterjee. Much could be done to improve food production in this area if the advisory services for farmers could be raised to a higher level and their personnel better trained.

Dr. J. Griffiths Davies, of the Australian Institute of Agricultural Science, gave an account of "Pasture Development of Tropical Australia". In the northern area the rainfall is a summer one, which ranges from 10 to 180 in. as one passes from the southern to northern tropics and from central to coastal areas. In general, the soil is poor and suffers from deficiency of nitrogen, calcium, phosphate and potash, as well as many of the trace elements too. Throughout most of the area cattle rather than sheep are the main product. Slides were shown of typical primitive vegetation areas and the methods used for their improvement. In areas of long dead grass, burning allows the young green shoots at the base to become available to cattle. In the acacia country, the bush is pulled over by chains between powerful tractors, piled, burnt and grass seed, such as that of Buffel and Rhodes grass, sown. One of the features of grass growth in tropical areas is the very rapid and luxuriant growth which occurs in the wet season; this, with the onset of the dry season, develops fibre and is low in protein and energy value for feeding purposes. During the discussion which followed, it was suggested that under such conditions the grass should be cut frequently during the wet season and made into silage for feeding during the dry season.

One of the main limiting factors for growth of grass throughout the tropical parts of Australia is the supply of nitrogen in the soil, and it is one of the most costly to apply, being about £39 per ton. Whereas in the south of Australia the application of phosphates and seeding with subterranean, strawberry or white clover supplies nitrogen for the grass, there are at present no suitable legumes for this in the northern areas; search for these is now in progress. Throughout the tropics, legumes, such as cow peas, etc., have been found for arable culture, but none suitable for incorporating into grassland has yet been used. Slides of some species which might prove suitable were shown; one came from Brazil and another from Guatemala. Various requirements are necessary in addition to their capacity for fixing nitrogen—a perennial character, palatability and

non-toxicity for cattle. In addition to finding suitable species, there is also the problem of finding the right strain of organism to inoculate the seed. Slides were shown to illustrate the very large differences which exist in the growth of the legume due to this factor.

The importance of the problem is seen in the fact that there are some 90 million acres of poor soil in tropical Australia on which such legumes could be incorporated into the grassland.

Mr. B. N. Chatterjee, of the Department of Agriculture, Bihar, in his paper on "Animal Production and Fodder Resources in India", described the five main agricultural zones, conditioned mainly by rainfall and altitude, and compared the vast differences which exist between the level of nutrition of the people there and in the United Kingdom. Typical examples of some of the breeds of zebu cattle were shown. The two dairy breeds, the Sindhi and Sahiwal, are small, both in size and numbers, but they give reasonable quantities of milk. Some dual-purpose work-milk types exist, but for the most part the breeds in India are specialized for draught purposes. Buffaloes supply much more milk than cattle and their milk contains some 7.5 per cent of fat. Goats, too, are used widely as sources of milk and meat supplies.

Three main systems of animal husbandry exist. The State breeding farms form the main and practically the only source of livestock improvement. As was pointed out in the discussion, these are not large enough or numerous enough for the work that needs to be done in improving the milk yields of their cattle. The village farms, which are very small, provide little more than draft bullocks and barely enough milk for their own needs. Thirdly, there are the nomadic herdsmen, mainly with sheep and goats which are folded on crop residues and graze marginal land. For the most part, feed for animals is supplied from crop residues, many of which contain large quantities of fibre. The village grazing areas are overstocked and provide more exercise than nutrition. The growing of fodder crops and the making of silage for the dry season are badly needed, while the killing of the older cattle is necessary to allow of a higher nutritive level for those which have a productive value.

In the discussion which followed, it was pointed out that not only would the production of more milk in the villages and its collection by organizations in nearby towns such as that existing in Poona, be of advantage to the nutrition of the urban population, but also the weekly income derived from it would keep the villager out of debt, so that when his crop came to be harvested it would be his and not the moneylenders. Moreover, if more milk were consumed, it would have a sparing action on the need for cereals, and so some land could be released to grow fodder crops, after which the yields of cereals would be higher. In pig-feeding experiments in England, it has been shown that it requires some 5 lb. of cereals to produce 1 lb. live weight, whereas when a little animal protein such as milk is added, this is reduced to about 4 lb. The question of whether the essential amino-acids in animal protein could be added to extracted leaf protein is at present out of the question, owing to the high cost of the synthesized products.

During the course of the discussion, Prof. J. Grossman from Bihar gave a short illustrated account of

the agricultural zones there. The projects for irrigation in the highly populated areas were mentioned. The grassland areas in the south with a 60-in. rainfall could, with phosphates and clovers, produce suitable feed for cattle. While in the far south European

breeds of cattle can be kept, farther north it is necessary to use zebu cattle. Recently, however, improved beef types which are tolerant of heat, such as the new Santa Gertrudis breed from Texas, have been introduced.

JOHN HAMMOND

GROWTH BY CELL DIVISION IN INSECT TISSUE CULTURE

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THE cultivation of insect tissues and cells, first attempted about fifty years ago¹, has been an unexpectedly difficult problem²⁻⁴. A method for the routine production of insect cultures in a medium that can be easily prepared, and the provision of adequate evidence of growth by cell division taking place in them as in vertebrate cultures, has not hitherto been available⁴. The delay in devising such a method arises largely from pioneer work having to rely on knowledge of the requirements that favour the growth of vertebrate tissue in culture⁵. Recently, however, encouraging results have been obtained in maintaining insect tissue in a physiological solution based on the composition of insect haemolymph^{6,7}, which differs profoundly from that of the blood of vertebrates⁸⁻¹¹.

The purpose of this article is to describe briefly the results of an investigation undertaken to try to devise a method of producing insect tissue cultures in a routine fashion, and to evaluate in particular the extent and nature of growth by cell division in the cultures obtained. The work is based on the use of diapause pupae of the silkworm, *Philosamia advena*, as a source of ovarian tissue for explants, and of haemolymph for inclusion in the culture medium. It so happens that development in these pupae is arrested for about six months extending from the autumn to the early summer, a period that can be lengthened if need be by storing the pupae continuously at 25° C. (ref. 12). The pupae, in providing tissue in a more or less uniform state over such a long period, thus favour the design of a method of producing insect tissue cultures as required. So does the use of a medium that can be prepared easily. The one employed in the present work consisted essentially of salts, sugars and organic acids, based on previous work⁶, lactalbumin hydrolysate ('Difco'), TC yeastolate ('Difco'), and pupal haemolymph. The latter was pre-heated before it was added to the medium⁶. The usual precautions were taken in preparing hanging-drop cultures to ensure freedom from contamination. Streptomycin and penicillin were also added to the medium at 100 i.u. and 50 i.u. per ml., respectively (Table 1).

In the preparations incubated at 25° C., cells began to migrate from the explants on about the third day, and from the fourth to ninth

Table 1. COMPOSITION OF THE MEDIUM FOR THE CULTIVATION OF OVARIAN TISSUE OF THE DIAPAUSE PUPA OF THE SILKWORM *Philosamia advena*

	Mgm./ 100 ml.		Mgm./ 100 ml.
A. NaH ₂ PO ₄	110	D. Malic acid	60
MgCl ₂ ·6H ₂ O	300	Ketoglutaric acid	35
MgSO ₄ ·7H ₂ O	370	Succinic acid	6
KCl	300	Fumaric acid	5.5
B. CaCl ₂	80	E. TC yeastolate	100
C. Glucose	70	('Difco')	
Fructose	40	F. Lactalbumin	1,000
Sucrose	40	('Difco')	

The salts were dissolved in 30 ml. water; calcium chloride in 7 ml. water; sugars in 10 ml. water; organic acids in 5 ml. water and neutralized with potassium hydroxide. Lactalbumin was dissolved by autoclaving at 10 lb. pressure for 10 min. in 35 ml. water; TC yeastolate in 5 ml. water. The solutions were mixed, adding the calcium chloride last. pH was adjusted to 6.35 with 10 per cent potassium hydroxide, and then pre-treated haemolymph was added, and finally antibiotics. See text for further information.

days the cellular outgrowths spread extensively over the surface of the coverglass (Fig. 1). The medium was changed every fifth day. The cultures remained healthy for up to four weeks, and in appearance they resembled primary chick fibroblast cultures.

To permit an estimation of growth by cell division in the outgrowths, and to ascertain the nature of the cells involved, a technique was devised for making permanent stained preparations of cultures *in situ*. Adhesion of the explants and the outgrowths to the coverglass, an important requirement for carrying it out successfully, was greatly favoured by the presence of 10 per cent haemolymph in the medium, and by inverting the culture chambers during incubation.

Examination of such preparations revealed that several kinds of cells originating from the different

Fig. 1. Inner region of cellular outgrowth, eighth day *in vitro*

Fig. 2. Relatively large vacuolated cells derived from the ovariole sheath and other cells mostly from the intermediate layer of the ovariole present in cellular outgrowth, ninth day *in vitro*, phase contrast