Summary and recommendations

D. W. T. CROMPTON[1] and L. SAVIOLI[2]

[1] *WHO Collaborating Centre for Soil-transmitted Helminthiases, Department of Zoology, University of Glasgow, Glasgow G12 8QQ, Scotland, UK*
[2] *Programme of Intestinal Parasitic Infections, Division of Communicable Diseases, 1211 Geneva 27, Switzerland*

According to Carpenter (1993), the first problem for nutritional science, to identify the chemicals required in a diet to support human growth and maintenance, has been solved. Enough information has been amassed from the study of many populations to enable nutritionists to offer safe recommendations about daily intakes of energy and nutrients for all stages of the human life cycle (see reviews by Nesheim and by Solomons, this volume). Adoption of these recommendations would generally correct deficiency diseases and would reduce the incidence of health complications which are linked to excessive intakes of fat, sodium, alcohol and other substances. Carpenter also drew attention to malnutrition, the solution of which he believed to have become largely political and economic although the fact remains that very many people still do not receive or grow enough food. In the context of this volume, Carpenter's most interesting point was his view that our understanding of the complex relationship between nutrition and disease was still at an early stage.

Protein-energy malnutrition (PEM) refers to the range of syndromes among infants and children in whom manifestations of growth failure occur because of protein and energy deficiencies (Newman, 1993). Traditional interpretations of the aetiology of PEM emphasized the role of diet, with protein singled out as the most important missing ingredient. Behavioural variables such as the duration of breast feeding, food habits and the distribution of food in the family or household were also considered to be critical processes in the generation of PEM. Newman stressed that current opinion is concerned with the influence of the availability of nutrients to cells in the aetiology of PEM and indicated that, in this regard, infections can act as an equal if not even more important limiting determinant than deficiencies or behavioural and cultural factors. The extensive evidence reviewed by Solomons, Hodges, Stephenson and by Thein Hlaing (this volume) strongly supports that proposition. Growth-faltering and even permanent growth retardation in children can now be ascribed to a variety of parasitic infections which act as agents of impaired energy supply. Adults in developing countries, as well as children, suffer from chronic energy deficiencies often exacerbated by the presence of parasitic infections. There can be serious economic consequences; labour-intensive effort is needed to maintain agriculture and undertake construction (Basta *et al.* 1979; Brooks, Latham & Crompton, 1979; Wolgemuth *et al.* 1982). Iron-deficiency anaemia, invariably worsened by hookworm infections (see review by Crompton & Whitehead this volume), also reduces worker productivity and has deleterious effects on pregnancy (Yusufji, Matham & Baker, 1973; Crompton & Stephenson, 1990; Pawlowski *et al.* 1991).

If Carpenter is right in his view that more research is needed to discover the mechanisms underlying the interactions between nutrition and infection, then the work on HIV, reviewed by Bell and colleagues (this volume), may prove to be opportune. HIV afflicts the immune system, which is now recognized as sensitive to nutritional perturbation (Chandra & Newberne, 1977; Chandra, 1980), but, despite the fact that once AIDS has set in and opportunistic infections have become established, patients appear to die from chronic malnutrition. Furthermore, since HIV is a problem for people of developed as well as developing countries, there is the possibility of adequate research funding to enable investigations to be carried out. Perhaps the system involving a form of murine AIDS, described here by Watson (this volume), will lead to more experiments in which casual rather than associational relationships will be identified. HIV and related opportunistic parasites are not the only infections which impinge on the nutrition of the populations of developed countries. Many food-borne microparasites continue to threaten human health and cause disease leading to acute nutritional problems (see review by Lacey, this volume).

Several recent and novel studies have set out to examine the putative or suspected effect that parasitic infections may have, perhaps through detrimental effects on nutrition, on cognitive performance in children (Nokes *et al.* 1991, 1992; Kimura *et al.* 1992). In their review, Connolly & Kvalsvig (this volume) describe the methodological problems that must be catered for in designing appropriate studies and so identify many confounding variables which have to be controlled in the data analysis. We also hope that the reviews by Durnin and by Dills (this volume), which deal with particular aspects of the energy metabolism of foetuses and tumours respectively, will provide ideas about the energy

Parasitology (1993), **107**, S201–S203

metabolism of host–parasite relationships. Understanding the intricacies of parasite metabolism and identifying differences between parasite and host cells may provide clues for the development of new drugs either for killing parasites or managing disease (see review by Levander & Ager, this volume). Nor should it be forgotten that parasites are often totally dependent for adequate supplies of energy nutrients from their hosts (see review by Storey, this volume). Often, parasite growth and fecundity are impaired when hosts are nutritionally deprived; much needed improvements in the nutrition of communities in developing countries may be accompanied by increased parasitic infection.

Many topics for further research may be gleaned from the reviews in this volume and we will be pleased if the contents stimulate more basic research to increase knowledge of interactions between nutrition, infection and immunity. Some of the results should contribute to the debate about the public health significance of parasitic disease and the setting of health priorities (Walsh, 1984). Application of this body of knowledge for the relief of human suffering will be difficult and will require operational research intended to help develop the limited resources available to Primary Health Care Systems.

Protein-energy malnutrition remains one of the world's most prevalent and important public health problems. Since the existence of a link between PEM and communicable disease is widely accepted (ACC/SCN, 1989; Newman, 1993), an increase in operational research projects and training programmes will be needed to develop flexible systems for improving nutritional status and reducing morbidity due to parasitic disease. There is already considerable activity aimed at dealing with intestinal parasitic infections (Savioli *et al.* 1992), but ultimate goals of seeing successful parasite control and better nutrition will depend on first supporting national and local initiatives and then withdrawing as sustainable programmes continue and evolve. Tackling PEM, including related infection, within PHC is a formidable problem. The population of developing countries is growing rapidly (Facer & Cook, 1993) and, according to one recent estimate, the world demand for staple cereal foods is likely to rise from the 1990 value of 2×10^9 tonnes to $3{\cdot}6 \times 10^9$ tonnes by 2030 (Cassen, 1993). Ninety per cent of this projected demand for a further $1{\cdot}6 \times 10^9$ tonnes of cereal foods is the result of an expected 68% increase in the world's population. Given the political and economic factors involved in food distribution (Carpenter, 1993), much of the extra food may have to be grown in the developing countries where the demand will originate. Meeting a need on this scale would appear to have global environmental implications with increased deforestation to release more land for agriculture and increased irrigation to ensure its fertility (Cassen, 1993). Extending irrigation and other water-resource projects can provide conditions for the spread of parasitic infections unless properly managed (WHO, 1993*a*, *b*). A further problem to be considered in the formulation of policies for relieving nutritional shortages and controlling parasitic infections is the mass migration of people with agricultural skills from the rural areas to unplanned urban settlements (Crompton & Savioli, 1993). These are some of the challenges that face the world's fragile health care systems which offer the outlet for using our expanding knowledge for the benefit of humans everywhere.

REFERENCES

ACC/SCN (1989). ACC/SCN State-of-the-Art Series. *Nutrition Policy Discussion Paper no. 5*. Geneva: World Health Organization.

BASTA, S. S., SOEKIRMAN, KARYADI, D. & SCRIMSHAW, N. S. (1979). Iron deficiency anaemia and the productivity of adult males in Indonesia. *American Journal of Clinical Nutrition* **32**, 916–25.

BROOKS, R. M., LATHAM, M. C. & CROMPTON, D. W. T. (1979). The relationship of nutrition and health to worker productivity in Kenya. *East African Medical Journal* **56**, 413–21.

CARPENTER, K. J. (1993). Nutritional chemistry. In *The Cambridge World History of Human Disease* (ed. Kiple, K. F.), pp. 140–7. Cambridge University Press.

CASSEN, R. H. (1993). Economic implications of demographic change. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **87** (supplement), S1/13–S1/18.

CHANDRA, R. K. (1980). *Immunology of Nutritional Disorders*. London: Edward Arnold.

CHANDRA, R. K. & NEWBERNE, P. M. (1977). *Nutrition, Immunity and Infection*. New York and London: Plenum Press.

CROMPTON, D. W. T. & STEPHENSON, L. S. (1990). Hookworm infection, nutritional status and productivity. In *Hookworm Disease* (ed. Schad, G. A. & Warren, K. S.), pp. 231–64. London and Philadelphia: Taylor and Francis.

CROMPTON, D. W. T. & SAVIOLI, L. (1993). Intestinal parasitic infections and urbanization. *Bulletin of the World Health Organization* **71**, 1–7.

FACER, C. A. & COOK, G. C. (eds). (1993). Implications of demographic change. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **87**, (supplement) S/1–S/38.

KIMURA, E., MOJI, K., UGA, S., KILIKU, E. M., MIGUI, D. K., MUTUA, W. R., MUHOHO, N. D. & AOKI, Y. (1992). Effects of *Shistosoma haematobium* infection on mental test scores of Kenyan school children. *Tropical Medicine and Parasitology* **43**, 155–8.

NEWMAN, J. L. (1993). Protein-energy malnutrition. In *The Cambridge World History of Human Disease* (ed. Kiple, K. F.), pp. 950–5. Cambridge University Press.

NOKES, C., COOPER, E. S., ROBINSON, B. A. & BUNDY, D. A. P. (1991). Geohelminth infection and academic assessment in Jamaican children. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **85**, 272–3.

NOKES, C., GRANTHAM-McGREGOR, S. M., SAWYER, A. W., ROBINSON, B. A. & BUNDY, D. A. P. (1992). Moderate to heavy infections of *Trichuris trichiura* affect cognitive function in Jamaican school children. *Parasitology* **104**, 1–9.

PAWLOWSKI, Z. S., SCHAD, G. A. & STOTT, G. J. (1991). *Hookworm Infection and Anaemia: Approaches to Prevention and Control*. Geneva: World Health Organization.

SAVIOLI, L., BUNDY, D. & TOMKINS, A. (1992). Intestinal parasitic infections: a soluble public health problem. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **86**, 353–354.

WALSH, J. A. (1984). Estimating the burden of illness in the tropics. In *Tropical and Georgraphical Medicine* (ed. Warren, K. S. & Mahmoud, A. A. F.), pp. 1073–85. New York: McGraw-Hill Book Company.

WHO (1993 *a*). The control of schistosomiasis. *Technical Report Series* **830**. Geneva: WHO.

WHO (1993 *b*). Parasitic diseases in water resources development: the need for intersectoral negotiation. Geneva: WHO

WOLGEMUTH, J. C., LATHAM, M. C., HALL, A., CHESHER, A. & CROMPTON, D. W. T. (1982). Worker productivity and nutritional status of Kenyan road construction workers. *American Journal of Clinical Nutrition* **36**, 68–78.

YUSUFJI, D., MATHAN, V. I. & BAKER, S. J. (1973). Iron, folate and vitamin B12 nutrition in pregnancy: a study of 1000 women from Southern India. *Bulletin of the World Health Organization* **48**, 15–25.