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Immune function, infection and diseases of affluence

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OBJECTIVES

- To understand how immune function might be affected by nutritional factors, adversely, aberrantly and favourably.
- To relate proneness to infection to malnutrition and nutritionally acquired immune deficiency syndrome (NAIDS) to diseases of affluence.
- To identify the nutrients which affect immune response.
- To consider the potential for nutritional reversibility of immunodeficiency in the aged, HIV positive and otherwise immunosuppressed individuals.

INTRODUCTION

Over the past few decades it has been well established that poor immunity and malnutrition (mainly protein energy undernutrition associated with famine) increase the risk of infectious diseases such as typhoid and influenza. Malnutrition was first linked to poor immune status in epidemiological studies and from historical accounts of famines and pestilence, especially in underdeveloped countries. Scrimshaw et al. reviewed the literature linking malnutrition and immune response in 1959 and reported 'many of the important infections of human populations are rendered more serious in their consequences by the presence of malnutrition; that a few infections are indeed less severe when associated with nutritional deficiency; and that many infections themselves precipitate nutritional disturbances'. Beisel (1992) coined the acronym NAIDS to describe nutritionally acquired immune deficiency syndrome and reported that a combination of infection and malnutrition in children with NAIDS accounted for over 40 000 deaths/day in underdeveloped countries, plus countless other deaths of adults with NAIDS in modern hospitals.

In the 1990s there was a paradigm shift in our understanding of the role that the immune system had

in the development of chronic diseases or diseases of affluence. Studies in the 1990s have revealed that poor immunity or immune dysfunction as a result of micronutrient malnutrition, often in the presence of an adequate or excessive energy intake common in developed countries, may increase the risk of developing several chronic diseases such as cancer and cardiovascular disease. It has been shown that the course of these chronic diseases can be altered by nutritional interventions that improve immune function. However, stronger immune responses are not advantageous in all situations. Allergies and auto-immune diseases such as rheumatoid arthritis are examples of hyperactive or misdirected immune reactions.

The immune system

The human host defends itself against infection in two ways, *innate* immunity which is inborn and always present, and *adaptive* immunity, which antigens induce (Janeway and Travers 1994). Macrophages are particularly involved in the former, and lymphocytes in the latter (see Figure 31.1). There are also non-adaptive components of host defence which include cytokines and interferon production and natural killer (NK) cells. This is not to say that environmental factors may modulate these components.

Infection must surmount various barriers of the innate defence system (as shown in Figure 31.1) before requiring the adaptive response of lymphocytes, supported by other mechanisms like cytokine production or interferon production. Lymphocytes may be B, T or Null natural killer (NK) cells (in antitissue immunity). B cells which have been antigen stimulated can become highly specialised plasma cells in extravascular sites which secrete immunoglobulins (IgG, IgM, IgA, IgD and IgE). This is known as *humoral immunity*. The T cell mediates cell-mediated immune responses. The T cells, known as helper or inducer CD4, activate B cells. Those known as cytotoxic or suppressor CD8 kill infected target cells and also suppress B cell and T cell responses. There are other T cell subsets. The immune system not only deals with infections of various kinds (bacterial, viral and parasitic), but other foreign material like transplant tissue and, at times, may be directed against the self as auto-immunity. The allergic response is an aberrant or idiosyncratic response of the immune system involving tissue mast cells and IgE antibodies to the antigen, and sometimes in eosinophilia (eosinophils in excessive numbers in blood) or an eosinophil infiltrate in tissue. Nutritional factors, through immuno-modulation, are thus important in preventing tumour formation (see Chapter 32).

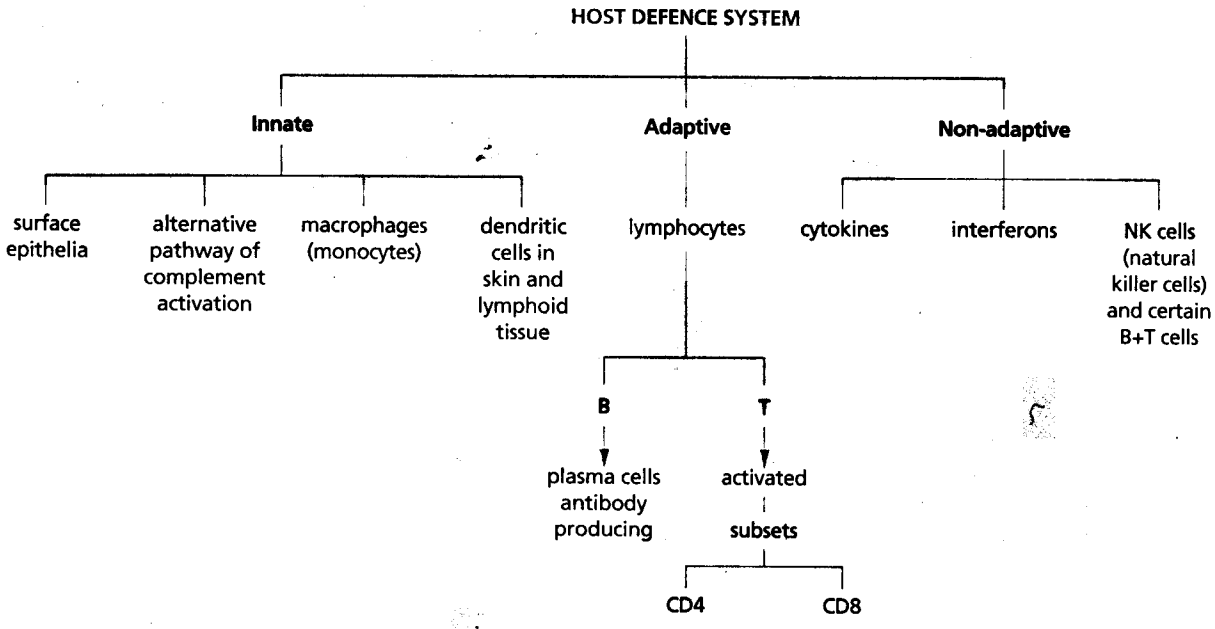

Figure 31.1 The host defence system

THE NEXUS BETWEEN MALNUTRITION AND IMMUNE DYSFUNCTION

Primary malnutrition can occur as a consequence of disease, even infections, but including any wasting disease like malabsorption, cardiac failure, chronic obstructive lung disease, neoplastic disease. Secondary malnutrition may precipitate if there is an inadequate food intake as a result of natural or man-made emergencies or because of poor food choices due to problems with household food security.

Malnutrition can have several classifications:

1 *Protein energy malnutrition (PEM) or undernutrition*—where both protein and energy are inadequately consumed, along with many micronutrients; most commonly seen in underdeveloped/developing countries and sometimes in food insecure vulnerable groups in developed and developing countries.
2 *Energy overnutrition and micronutrient undernutrition*—where energy intake is excessive relative to energy expenditure and the micronutrient quality of the diet is poor; most commonly seen in developed and in some developing countries in nutritionally vulnerable 'at risk' groups with high prevalences of obesity.
3 *Protein and micronutrient undernutrition*—where energy intake is adequate but protein and micronutrient quality of the diet is poor or where there is some malabsorption; most commonly seen in developed and in some developing countries in nutritionally vulnerable 'at risk' groups.

Both primary and secondary malnutrition can impair immune status through the various arms of the immune system, innate and adaptive, cellular and humoral. For example, the ability of an epithelial surface to repair an injury may be impaired in protein or in zinc deficiency and, therefore, allow invasion by infective organisms. With protein and several water soluble vitamin deficiencies, antibody responses are suppressed. In PEM, the reduced production of secretory IgA from epithelial or mucosal surfaces presents particular problems of susceptibility to infection in the ears, eyes and gastrointestinal tract.

It is clear, therefore, that malnutrition, whether primary or secondary, predisposes the individual to infection and to other health problems where the integrity of the immune system is vital (see also Chapter 30).

Increasingly, this means that individuals in the following groups are at risk of immune dysfunction:

1 where there is food shortage and food insecurity (see Chapter 40), as with poverty and famine (Chandra and Kumari 1994; Lukito et al. 1994; Myrvik 1994);
2 in those who make poor food choices in the presence of an adequate food supply; this may include people who lack access to suitable transportation and readily available nutritious foods or those with poor budgeting skills, inadequate cooking skills or storage facilities;
3 in those who cannot eat enough or whose nutritional needs are increased;
4 in the immunosuppressed, whether
   i for medical reasons (such as through use of steroids as in rheumatoid arthritis, asthma, or chronic inflammatory bowel disease or with transplant patients)
   ii through HIV (human immunodeficiency virus positivity) and AIDS (acquired immunodeficiency syndrome) (Lukito et al. 1994; Lustig 1993)
   iii through declining immune function with age, although not all of this decline is inevitable (Lukito et al. 1994).

A vicious cycle may supervene, which is possible to interrupt at any point (see Figure 31.2). The most threatening health problems in this cycle are the advent of anorexia and diarrhoea, which may limit the ability to support nutritionally the immunocompromised (Tomkins 1992). Failure to recognise or failure to anticipate the development of hospital malnutrition can allow the needless presence of nutrition-related immunodeficiency and proneness to infection, with increased hospital morbidity and mortality (Lukito 1995) (Figure 31.3).

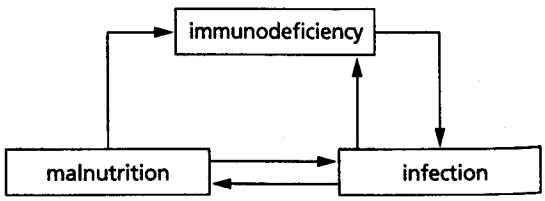

Figure 31.2 The nexus between malnutrition and infection

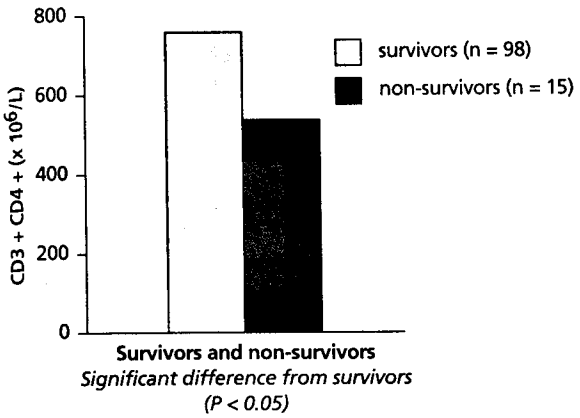

Figure 31.3 Immune function is predictive of mortality. Baseline lymphocyte subset counts in 113 elderly institutionalised people in Melbourne, Australia who do or do not survive over 22 months (Lukito 1995)

EFFECTS OF NUTRITION ON IMMUNE RESPONSES

The nutrient deficiencies which can impair immune function are summarised in Table 31.1. Not only deficiencies but also imbalances of nutrients can impair the immune system, as with leucine excess and iron excess, and with changes in omega-3 and omega-6 essential fatty acid ratios (Ayala and Chaudry 1995; DeMarco et al. 1994) (see also Chapter 13). Non-nutrients or other food components are now recognised as immuno-modulatory, notably flavonoids and other polyphenolic compounds (Middleton and Kandaswami, 1992) (Figure 31.4).

Energy intake and nutrient density of the diet

Undernutrition

Protein energy malnutrition (PEM) is a major cause of immunodeficiency. Kwashiorkor (protein deficiency) and marasmus (generalised undernutrition or starvation) are the two clinical manifestations of PEM. The immunologic manifestations of PEM are broad and include lymphoid tissue atrophy, decreases in lymphocyte numbers, and abnormally low cellular and humoral immune responses.

PEM is characterised by impairment of the complement system (this cascade system of substance production amplifies the inflammatory response), of cellular immunity, of cytokine production (especially IL-1, an interleukin) by macrophages, and of phagocytic function by monocytes (the reticulo-endothelial system) and polymorphonuclear-leucocytes (neutrophilic granulocytes). Consequently, PEM is associated with a high incidence of morbidity and mortality from infections which are usually accompanied by other nutrient deficits.

Table 31.1 Nutrient deficiencies which can impair immune function

Nutrient	Innate	Adaptive immunity: Humoral	Adaptive immunity: Cellular
Amino acids			
essential	Yes	Yes	Yes
non-essential			
arginine		Yes	
glutamine	Yes	Yes	Yes
Essential fatty acids (ω-3 and ω-6)	Yes	Yes	Yes
Elements			
zinc	Yes	Yes	Yes
copper	Yes		Yes
iron			Yes
selenium	Yes	Yes	Yes
magnesium	Yes	Yes	
Vitamins			
B-2	Yes	Yes	Yes
B-6		Yes	Yes
folic acid	Yes	Yes	Yes
B-12		Yes	Yes
biotin		Yes	Yes
C	Yes		
A	Yes	Yes	Yes
D	Yes		
E	Yes	Yes	Yes
Non-nutrients			
flavonoids	Yes		Yes
peptides (glutathione)	Yes		Yes

Moderate energy restriction

Unlike the unequivocal immunodeficiencies observed in severe PEM, the effect of moderate energy restriction on the immune system is controversial. Moderate energy restriction in mice without severe alteration of protein, vitamin and mineral levels has been associated with increased T cell functions and longevity. Similar studies on humans are limited. A primary consideration among claims of enhanced immune responses with energy/food restriction is the accurate determination of the nutritional intake of the subjects under study.

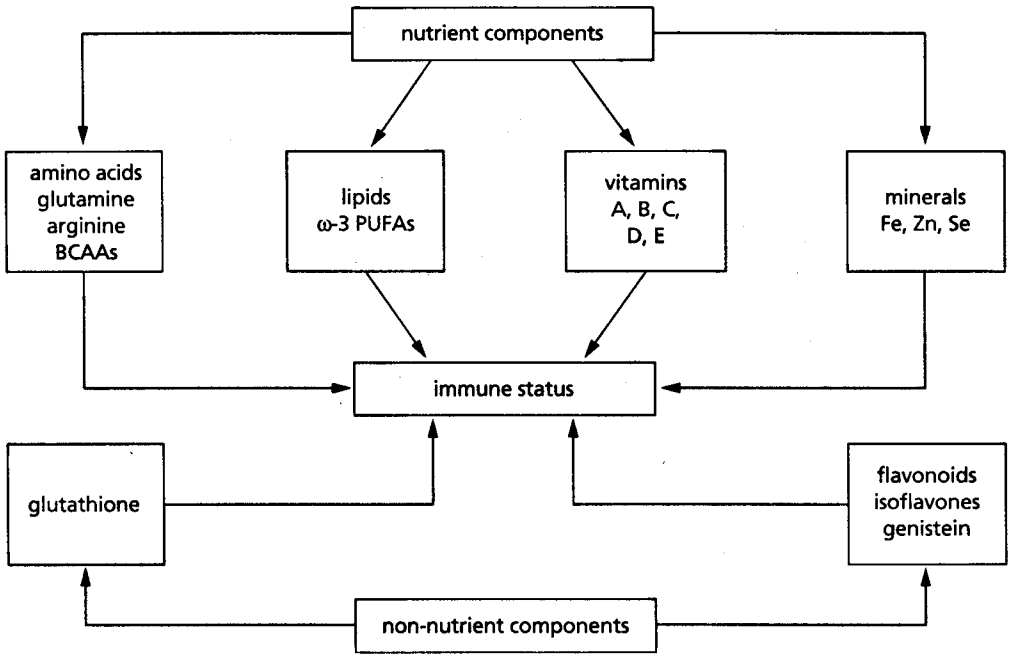

Figure 31.4 Food factors affecting immune status (BCAAs = branched chain amino acids; PUFAs = polyunsaturated fatty acids)

Defining the sources of calories is important, since fatty acids provide functions other than energy (for example, eicosanoid signalling), while certain amino acids (for example, glutamine) are energy sources for leukocytes. Subtle changes in micronutrients such as zinc may offset any gains produced by energy restriction. This suggests that energy restriction, often practised by people trying to lose weight, may increase the risk of immune dysfunction if the foods selected are not nutrient dense. Therefore, the alleged benefits of energy restriction should be evaluated with caution.

Overnutrition

Although it is still unclear, there are indications that obesity may also lead to immune dysfunction (Stallone 1994; Lukito et al. 1995; Klurfeld 1993). Here, part of the problem may be the nature of the pathogenesis (mode of development) of obesity with physical inactivity and use of food of low nutrient and phytochemical density. Yet another contributor may be recurrent dieting and weight loss which may include loss of lean mass resulting in reduced skeletal muscle stores of glutamine—an amino acid required by lymphocytes and macrophages (see below). The balance of energy intake relative to expenditure partially determines body weight and composition, which in turn influence immune characteristics. Leaness has been associated with resistance to tumours and infection.

Lipids

Fatty acids provide energy, function as cell membrane components, and as mediators of cell signalling. Cell membrane composition is partially dependent on the fatty acids taken in through the diet, therefore dietary fats are an important influence on cell function, especially cells involved in immune function. Eicosanoids belong to the family of 20 carbon omega-3 and omega-6 polyunsaturated fatty acids. They are involved in cell signalling (that is, they transmit messages between cells), inflammation, immunity, reproduction, blood flow and temperature regulation. Omega-6 linoleic is converted to arachidonic acid which in turn is converted to the following eicosanoid II series: prostaglandin E2 and thromboxane A2 (in platelet membranes promote platelet aggregation) and leukotriene B_4 (in neutrophils promote inflammation). Omega-3 linolenic acid is converted to the fatty acid omega-3 eicosapentaenoic acid (EPA) which in turn is converted to the following

eicosanoid III series which have opposing actions to the eicosanoid II series: thromboxane A3 and prostaglandin I3 (in platelet membranes which inhibits platelet aggregation) and leukotriene B5 (in neutrophils which inhibits inflammation) (see also Chapter 13).

The contribution of dietary fatty acids in attenuating a number of inflammatory states and immune mediated diseases (for example, auto-immune diseases, multiple sclerosis) is highlighted in studies replacing omega-6 rich vegetable oils (sunflower, safflower, corn) with omega-3 rich oils (canola, fish). Many of the anti-inflammatory and anti-aggregatory properties attributed to omega-3 fatty acids are believed to be due to them replacing arachidonic acid (derived from omega-6 fatty acids) in membrane phospholipids which in turn leads to more anti-inflammatory eicosanoid III series to be produced. Therefore the ratio of omega-6 to omega-3 fatty acids in the diet may be important.

The effect of saturated (of different chain lengths) and mono-unsaturated fatty acids and the total fat content of the diet on immune function is controversial. Low fat diets have not been shown to be unequivocally advantageous for immune function and shorter-chain saturated fatty acids with less than fourteen carbons may have more favourable effects on immune function than the longer-chain varieties (Yoshida et al. 1999).

Proteins and amino acids

Protein malnutrition leads to sub-optimal tissue repair and decreased resistance to infections and tumours and can have selective effects on immune function. Emerging evidence on the amino acids arginine and glutamine point to their potential uses in food supplementation to enhance wound healing, increase resistance to tumour formation and infections, and improve immune function in aged and immunocompromised persons.

Arginine

Arginine, a non-essential amino acid important to the urea cycle, assists in the synthesis of other amino acids and of polyamines, urea and nitric oxide. Arginine is important for cell-mediated immunity; exogenous sources are often required during sepsis. A product of arginine metabolism, nitric oxide, has tumouricidal and microbicidal activities, induces blood vessel dilation and influences leukocyte-endothelial cell adhesion. Growth hormone receptors are widespread in the immune system and it is suspected that arginine triggers the release of growth hormone which in turn increases the cytotoxic activities of macrophages, natural killer cells, cytotoxic T cells and neutrophils (Yoshida et al. 1999). Good sources of arginine include nuts and fish (see Chapter 14).

Glutamine

Glutamine is an amino acid and lymphocytes and macrophages use it as a source of energy. It is also used for the synthesis of DNA nucleic acids (purine and pyrimidine). It is the most abundant amino acid in the blood and in the body's free amino acid pool. There are large intracellular stores of glutamine in skeletal muscle and it is also synthesised by the lungs. Infection and inflammation release glutamine from skeletal muscles and there is evidence that it may play a role in regulating leukocyte metabolism. Therefore, a deficiency in glutamine stores which can occur with the loss of muscle mass or through poor food intake is likely to lead to poor immune responses. Dietary sources of glutamine include meat, eggs, wheat and soy beans (see Chapter 14).

Nucleic acids

Preformed purines and pyrimidines in the diet appear to enhance a number of cell-mediated immunologic mechanisms. For example they appear to increase the natural killer (NK) cell activity. Foods containing substantial quantities of purines include: anchovies, sardines, shellfish, fish, meat, offal, wine, lentils, dried beans and peas, asparagus, spinach, cauliflower, mushrooms, wheatgerm and bran.

Minerals

Copper

Copper deficiency is associated with increased susceptibility to infections by decreasing phagocyte functions, decreasing T cell numbers and activities, increasing B cell numbers and lowering interleukin production. Excess copper intake can decrease immune function. It has these effects because of its involvement in complement function, cell membrane integrity, immunoglobulin structure, Cu-Zn dismutase and interactions with iron. Mild or subclinical copper

deficiency is seen in humans. Cocoa (mainly as chocolate) is the highest contributor of daily copper intake in developed countries with some people getting over 50% of their daily copper from chocolate foods. Dark chocolate has three times more copper than milk chocolate and a 90 g bar of dark chocolate provides about 80% of the RDI or 0.75 mg of copper. Other good sources include whole grains, nuts, raisins, shellfish, liver and legumes.

Selenium

Chronic selenium deficiency decreases resistance to infection by reducing antibody synthesis, cytotoxicity, cytokine secretion and lymphocyte proliferation. Cancer has also been associated with selenium deficiency in human populations. Selenium and vitamin E are essential components of glutathione peroxidase, an antioxidant enzyme that prevents peroxidation of lipids in cell membranes. For example, lowered antibody production caused by selenium deficiency can be reversed by vitamin E supplementation. Limiting the potential for lipid peroxidation during immune and inflammatory processes is important to prevent autoxidation as well as damage to surrounding tissue. Dietary sources include seafood, offal, meat, milk and brown sugar.

Iron

Microbial infection can be associated with increased iron storage. At the same time, infection (and inflammation) can increase blood concentration of the storage iron ferritin, an acute phase reactant, even though plasma iron itself may be low. This response limits iron availability for microbial agents and promotes the antimicrobial and antitumour effects of nitric oxide, a locally produced blood vessel hormone. Chronic inflammation seen in various disease states (for example, arthritis) is also associated with low serum iron concentrations and increased iron stores—known as 'anaemia of chronic disease'. Iron deficiency appears to both stimulate and inhibit most parameters of immune function. This may be related to its involvement in folate metabolism, mitochondrial energy production and its involvement in metalloenzymes (for example, nitric oxide synthase, catalase). Excessive iron intake and storage may increase susceptibility to some infections. Thus, optimal iron nutrition needs to be addressed in relation to the body's overall defence systems.

Zinc

The best-documented immunologic consequences of zinc deficiency are T cell defects, including reductions in T cell numbers and responsiveness and T cell help toward antibody production. Inadequate zinc intake is a mineral deficiency often seen in people consuming diets high in cereals and low in animal products. Zinc deficiency in older people is likely to be an important contributor to proneness to infection and the proneness to respiratory infection, especially pneumonia.

Vitamins

Retinol and beta-carotene

Retinol and related retinoids maintain the integrity of epithelial surfaces (such as lungs, intestines, skin) and the production of mucosal secretions. Vitamin A deficiency results in a reduced number of leucocytes, reduced circulating levels of complement and antibodies, impaired T cell functions and decreased resistance to immunogenic tumors. Beta-carotene directly protects cells from oxidation and it promotes lymphocyte proliferation, T cell functions, cytokine production and cell-mediated toxicity, for example natural killer cell cytotoxicity. However, carotenoids can exhibit prooxidant as well as antioxidant activity and their record in attenuating chronic disease is not consistent, especially when taken as a supplement.

B-vitamins

Vitamin B-6 (pyridoxine) and biotin deficiencies impair both cell-mediated and humoral immunity. Vitamin B-12 (cyanocobalamin) and folate deficiency depress phagocytosis and T cell function. Inadequate intakes of pantothenic acid, thiamin or riboflavin commonly lead to decreased antibody responses.

Vitamin C

Immunologic problems associated with vitamin C deficiency include decreases in resistance to infections and cancer, skin allograft rejection, decreased wound repair and enhanced antibody responses and phagocyte function. Research does not support the use of megadoses of vitamin C (>1 g/day) to prevent common

colds, but low doses may reduce incidence and duration of symptoms.

Vitamin D

Vitamin D both stimulates and inhibits immune responses because of its influence on mineral metabolism and its function as a hormone. Receptors for vitamin D can be found on the surface of lymphocytes and phagocytes. It can activate innate responses (phagocytosis) and inhibit an acquired immune response (antibodies). Vitamin D can stimulate differentiation of monocytes and macrophages and it can reduce tumour growth. The immunosuppression it promotes may be important in the reported modulation of auto-immune diseases and tumourigenesis.

Vitamin E

Deficiency leads to depressed leucocyte proliferation, phagocytosis, antibody levels and decreased tumour resistance while leaving natural killer cell cytotoxicity either unchanged or enhanced. Vitamin E supplementation has its greatest effect on cell-mediated immunity by reducing the synthesis of the pro-inflammatory eicosanoid II series (prostaglandin E2). High intakes have been found to increase resistance to infections among the elderly (Yoshida et al. 1999).

Phytochemicals

Polyphenolic compounds in plants are more potent antioxidants than vitamins A, C and E. Antioxidants assist in preventing the oxidation of fatty acids in cell membranes, especially of the different lymphocyte subsets. In this respect they assist in the regulation of the immune system, especially cell mediated immunity, because reactive oxygen can stimulate inflammation via T cells as seen in rheumatic diseases and auto-immune disorders such as allergies.

Food allergy

Most food sensitivities are reactions which are not allergic, although some are. These include adverse reactions to certain food proteins in seafood, chicken, nuts, milk, eggs, soy and even rice (Kamath 1995). They may manifest in the skin, respiratory tract, gut, or in mood responses. Coeliac disease is a gluten induced enteropathy of an allergic kind (see Chapter 15). Lactose intolerance is not a food allergy (see also Chapter 33).

NUTRITIONAL REVERSIBILITY OF IMMUNODEFICIENCY

There is now good evidence that, in part, immunodeficiency is reversible by nutritional means, to the extent that it has been nutritionally caused (Chandra and Kumari 1994; Chandra 1992). This applies where food or nutrient intake has been inadequate, or nutrient losses excessive or nutrient demands increased (as in metabolic stress as far as glutamine and arginine are concerned) (Cynober et al. 1995; Baumgartner et al. 1995; Gogos Kalfarentzos 1995; Adjei et al. 1995). Nutritional rehabilitation programs among children which reduce respiratory and gut infections most clearly show this phenomenon. So, too, do studies in the aged, in those known to be nutritionally impaired (Chandra and Kumari 1994) and those likely to become impaired in the community (Chandra and Kumari 1994; Lukito et al. 1994) (see Figure 31.5).

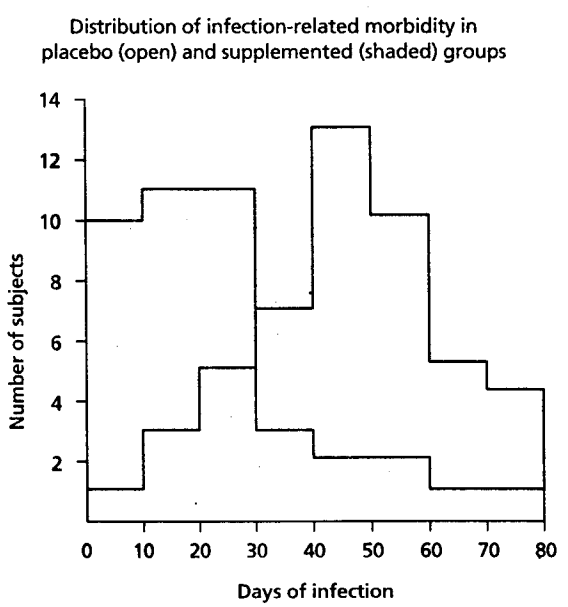

Figure 31.5 Effect of vitamin and mineral supplementation on infection (Chandra 1992)

SUMMARY

- The immune system is both innate (dependent on surface epithelia, the alternative complement pathway, macrophages and dendritic cells) and adaptive (dependent on lymphocytes, B and T cells). There are also non-adaptive components of host defence such as cytokines, interferon and natural killer cells.
- Both primary and secondary malnutrition can impair immune status and predispose the individual to infections and other health problems, including diseases of affluence like heart disease and cancer. Immune dysfunction can occur in the presence of an adequate or excessive energy intake where there are also subclinical micronutrient deficiencies.
- Immune dysfunction is more common in certain 'at risk' groups—for example, where there is food shortage and food insecurity; where poor food choices are made (often in the presence of an adequate food supply); due to poor budgeting, cooking skills or storage facilities; where there is loss of appetite or increased nutritional needs; or in the immunosuppressed.
- The following nutritional factors can alter immune responses: inadequate or excessive intakes of iron and energy (where foods consumed are of low nutrient density); inadequate intake of total fat or inappropriate balance of essential fatty acids; and inadequate intake of protein (especially amino acids, arginine and glutamine), preformed nucleic acids, copper, selenium, zinc, vitamins A, B, C, D and E and phytochemicals.
- Immunodeficiency can be nutritionally reversible.

REFERENCES

Adjei, A.A., Yamauchi, K., Nakasone, Y., Konishi, M. & Yamamoto, S. Arginine-supplemented diets inhibit endotoxin-induced bacterial translocation in mice. *Nutrition* 1995; 11:371–4.

Ayala, A. & Chaudry, I.H. Dietary n-3 polyunsaturated fatty acid modulation of immune cell function before or after trauma. *Nutrition* 1995; 11(1):1–11.

Baumgartner, T.G., Cerra, F.B., Jensen, G.L. & Summer, W.R. Immunonutrition in the ICU: the power of special nutrients. *Journal of Critical Care Nutrition* 1995; 3(1):4–19.

Beisel, W.R. The history of nutritional immunology. *J Nutr Immunol* 1992; 1:5–40.

Chandra, R.K. Effect of vitamin and trace-element supplementation on immune responses and infection in elderly subjects. *Lancet* 1992; 340(8828):1124–7.

Chandra, R.K. & Kumari, S. Effects of nutrition on the immune system. *Nutrition* 1994; 10(3):207–10.

Cynober, L., Fürst, P. & Lawin, P. *Pharmacological Nutrition*. W. Zuckschwerdt Verlag GmbH, Germany, 1995.

DeMarco, D.M., Santoli, D. & Zurier, R.B. Effects of fatty acids on proliferation and activation of human synovial compartment lymphocytes. *Journal of Leukocyte Biology* 1994; 56:612–15.

Gogos, C.A. & Kalfarentzos, F. Total parenteral nutrition and immune system activity: a review. *Nutrition* 1995; 11(4):339–44.

Janeway, C.A., Jr & Travers, P. *Immuno Biology. The Immune System in Health and Disease*. Current Biology Ltd/Garland Publishing Inc., London, New York, 1994.

Kamath, K.R. Antigen absorption: food, fire or fuel? *Asia Pac J Clini Nutr* 1995; 4(4):371–5.

Klurfeld, D.M. Cholesterol as an immunomodulator. In: *Nutrition and Immunology*. D.M.J. Klurfeld (ed.). Plenum Publishing Corp., New York, 1993; 79–89.

Lukito, W. Nutrition and immune dysfunction in the aged. PhD thesis, Monash University, Melbourne, 1995.

Lukito, W., Boyce, N.W. & Chandra, R.K. Nutrition and immunity. In: *Medical Practice of Preventive Nutrition*. M.L. Wahlqvist & J.S. Vobecky (eds). Smith-Gordon Co Ltd, London, 1994; 27–51.

Lukito, W., Hutchinson, P.E., Wahlqvist, M.L., Boyce, N.W., Hsu-Hage, B.H.H., Strauss, B.J.G., Kouris-Blazos, A. & Bainbridge, R. Body composition and lymphocyte subsets in an Anglo-Celtic elderly population. *Asia Pac J Clin Nutr* 1995; 4:69–72.

Lustig, J.R. Nutrition and HIV infection. *Asia Pac J Clin Nutr* 1993; 2:3–14.

Middleton, E. & Kandaswami, C. Effects of flavonoids on immune and inflammatory cell functions. *Biochemical Pharmacology* 1992; 43:1167–79.

Myrvik, Q.N. Immunology and nutrition. In: *Modern Nutrition in Health and Disease*. 8th edn. Vol 1. Lea & Febiger, Malvern, PA, 1994; 623–62.

Scrimshaw, N.S., Taylor, C.E. & Gordon, J.E. Interactions of nutrition and infection. *Am J Med Sci* 1959; 237:367–403.

Stallone, D.D. The influence of obesity and its treatment on the immune system. *Nutr Review* 1994; 52:37–50.

Tomkins, A.M. Nutrition and infection. In: *Protein Energy Malnutrition*. J.C. Waterlow (ed.). Edward Arnold, London/Melbourne, 1992; 290–324.

Yoshida, S.H., Keen, C.L., Ansar, A.A. & Gershwin, M.E. Nutrition and the immune system. In: *Modern Nutrition in Health and Disease*. M.E. Shils, J.A. Olsen, M. Shike & A. Katherine-Ross. 9th edn. Lipincott, Williams and Wilkins, Baltimore, 1999; 725–50.

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