
UNIT 18 NUTRITIONAL REQUIREMENTS FOR SPECIAL CONDITIONS

Structure

- 18.1 Introduction
- 18.2 Calamity and Emergency Management
- 18.3 Information Required for Management of Emergencies
 - 18.3.1 Nutrient Requirements during Emergencies
 - 18.3.2 Major Nutritional Deficiency Diseases in Emergencies
 - 18.3.3 Monitoring Assessment and Surveillance of Nutritional Status and Relief Measures in Emergencies
- 18.4 Nutritional Requirements for Extreme Environments
 - 18.4.1 General Adaptive Mechanisms to Environmental Extremes and Role of Nutrition in Successful Acclimatization
 - 18.4.2 Health Hazards Associated with High Altitude
 - 18.4.3 Nutritional Requirements in High Altitude
 - 18.4.4 Nutritional Requirements in Cold and Polar Environment
 - 18.4.5 Nutritional Requirements in Hot Environments
 - 18.4.6 Nutritional Requirements for Space Missions
- 18.5 Let Us Sum Up
- 18.6 Glossary
- 18.7 Answers to Check Your Progress Exercises

18.1 INTRODUCTION

In the previous unit, we saw how involvement in sport or vigorous activities can affect the body's nutrient needs. In this unit, we will focus on nutritional needs of humans who are away from the normal conditions of living environment i.e. affected by calamities or emergencies (natural or man made) or exposed to environmental extremes such as hot, cold, rugged terrain environments as high altitudes. All major emergencies often result in food shortage, impair the nutritional status of population and cause excessive mortality in almost all age groups. In such cases, nutritional awareness becomes important for planning the emergency management.

Human beings can function effectively in extreme environments, provided adequate behavioural precautions (proper clothing, shelter, food and water) are taken. Expeditionary or recreational outdoor activities are generally conducted in hot, cold, rugged terrain environments such as high altitudes. Mountaineering, cross-country skiing, snowshoeing, sledging and backpacking can be physically demanding along with an added element of danger due to environmental wilderness. These areas need to be manned by armed forces personnel if national boundaries run through such locations for security reasons.

In such cases, it has been observed that miscalculation of physical abilities or inadequate preparedness can be life threatening. Nutrition is a prime need for survival, sustaining physical and mental performance. Under this unit, you will read how nutritional requirements vary with the environment and also about the minimum requirements to prevent malnutrition-related diseases and mortality in emergency situations. You will appreciate the role of nutritional sciences in human success on the planet Earth and in space exploration, which is relatively a new frontier with microgravity as main stress factor.

Objective

After studying this unit, you will be able to:

- describe nutritional needs during calamities and emergencies,
- understand the nutrient requirements for working under environmental extremes i.e. hot, cold and high altitudes, and
- discuss the nutritional needs during space travels.

18.2 CALAMITY AND EMERGENCY MANAGEMENT

During past many years, we have seen, as well as, realized that natural calamities strikes countries, both developed and developing, causing enormous destruction and creating human sufferings and producing negative impacts on national economies. What are calamities? In simple terms, *calamity refers to any great misfortune or a cause of misery which is applied to events and disasters*. Due to diverse geo-climatic conditions prevalent in different parts of the globe, different types of natural calamities like floods, droughts, earthquakes, cyclones, landslides, volcanoes etc. strike according to the vulnerability of the area. Natural calamities have been broadly grouped into *major* and *minor* types depending upon their potential to cause damage to human life and property. Earthquakes, droughts, floods and cyclones have been identified as *major* type of calamities while hailstorms, avalanches, landslides, fire accidents etc. whose impact is localized and intensity of the damage being much less, are categorized as *minor calamities*. India is considered as the world's most disaster prone country. It has witnessed devastating natural disasters in recent past like droughts, tsunami, floods, cyclones, earthquakes, landslides etc.

The occurrence of both natural and man-made emergencies has risen in the recent years with a large number of affected communities, refugees and displaced persons. Droughts, floods, earthquakes and crop destruction by diseases or pests cause nature-induced famines while war and civil conflicts create man made famines. Regions that produce barely enough food for survival under normal conditions are vulnerable to famines induced by calamities. All major emergencies often result in food shortage, impair the nutritional status of a population and cause an excessive mortality in almost all age groups. Nutrition is therefore a key public health concern in emergency management. Malnutrition in one or more of its various forms is the main feature during calamities. When nutritional needs of an affected population or a subgroup of population are not met completely, it is observed that the signs of malnutrition and deficiency diseases emerge among helpless or vulnerable individuals. Can you think of a few deficiency diseases which might prevail under such conditions? Well, there are underweight children, anaemic mothers and marasmic babies. The cases of vitamin deficiency diseases i.e. blindness, scurvy, beriberi, pellagra and other deficiency diseases are also observed. Knowledge of nutritional requirements for management of emergencies is therefore, important due to the following reasons:

- i) Assessment of nutritional needs of individuals, vulnerable groups, families and population.
- ii) Monitoring of nutrient intake in these groups.
- iii) Ensuring that adequate quantities of food are being procured/made available for rations and supplements etc.

Identification of most vulnerable groups is also essential and generally these are the groups with additional nutrient requirements e.g. *pregnant and lactating women, infants and young children, single adults e.g. widows and widowers in the older age group*.

In the initial stages of disaster (0-6 months), there is instability, acute shortage and mass movement of people. The victims are totally dependent on aid. There are inevitable delays in evaluation, planning, requesting, and receiving donations, transportation and formation of distribution system. At this stage, the management is generally controlled by internal government and NGOs. If an affected population crosses an international boundary, then they are called 'refugees' and United Nations High Commission for Refugees (UNHR) can help them and if they remain in the country, they are called 'internally displaced persons'. The second stage of disaster (usually after 6 months) is *stage of establishment*. The affected people are organized or they organize themselves and use newer coping strategies i.e. start cultivating, set up of small home industry and selling of labour. At this stage, relief can be more targeted towards more needful persons.

Now that we have an overview of what is a calamity and an emergency and who are the most effected, let us next study about the issues specific to the management of emergencies.

18.3 INFORMATION REQUIRED FOR MANAGEMENT OF EMERGENCIES

Management or intervention needs accurate information about the actual situation and includes many non-nutritional components, programmes, although food remains the most compelling basic necessity. The factors which need to be considered are:

- 1) Population size, geographical dispersal of the population, map of the affected areas, including location of camps etc.
- 2) Age groups
- 3) Current nutritional status
- 4) Nutritional deficiencies and endemic diseases
- 5) Purchasing power, coping mechanisms and market prices
- 6) Access to potable water
- 7) Fuel supply
- 8) Access to food, seeds, tools etc.
- 9) Seasonality and forecast system
- 10) Cultural beliefs and taboos
- 11) Threats to security, political and military situation
- 12) Underlying causes of the crisis

In major emergencies, most urgently needed action is to prevent death and illness caused by malnutrition. Basic energy and protein requirements are the primary concerns but micronutrient needs must also be met if blindness, disability and deaths are to be avoided.

Let us now get to know about the nutrient requirements in the following sub-section.

18.3.1 Nutrient Requirements during Emergencies

The nutritional requirements of the people do change during conditions of unforeseen stress and/or any calamity. Certain recommendations for energy, protein and micronutrients have been formulated based on a few assumptions. Let us begin with energy and protein and find out what are the recommendations and assumptions.

Daily energy requirement and safe protein intake

The estimated mean daily per capita energy requirement of 2070 Kcal rounded up to 2100 Kcal is based on WHO technical report No. 724 published in 1985 and on the following assumptions:

- The age/sex distribution of the population is a characteristic of developing countries
- The mean height of adult men and women are 169 cm and 155 cm respectively, which is the approximate value in sub-Saharan Africa
- The body mass index (BMI) (kg/m²) is between 20-22
- Physical activity is light
- All infants are breast-fed from birth to 6 months, and half of the infants of 6-11 months are still breast-feeding and deriving half of their energy and protein requirement from breast milk
- Safe daily protein intake, from an average mixed diet of cereals, pulses and vegetables is estimated to be 46 g.

Next, we move on to micronutrient requirements.

Micronutrient and other specific nutrient requirements

The recommended average daily per capita intake of various specific nutrients for typical population requiring emergency food aid in developing countries is given in the Table 18.1.

Table 18.1: Recommended mean daily per capita nutrient intake for emergency food in developing country

Nutrient	Recommended Daily Intake
Vitamin A (retinol equivalents)	500 mcg
Vitamin D	3.8 mcg
Thiamin (Vitamin B ₁)	0.9 mg
Riboflavin (Vitamin B ₂)	1.4 mg
Niacin equivalents	12.0 mg
Folic acid	160 mcg
Vitamin B ₁₂	0.9 mcg
Vitamin C	28 mg
Iodine	150 mcg
Iron *	22 mg
Calcium	0.5 g

*From diet that provides iron of low or very low bioavailability.

After requirements, let us find out the consequence of not being able to meet the recommendations and review a few major deficiency diseases that occur during emergencies.

18.3.2 Major Nutritional Deficiency Diseases in Emergencies

Earlier, in this unit we learnt that energy protein malnutrition along with micronutrient deficiencies like anaemia, blindness etc. may result during emergency situations. Let us briefly review these conditions.

- *Protein-Energy Malnutrition (PEM)*

Even in normal times, PEM is a problem in many developing countries, most commonly affecting children between the ages of 6 months to five years. In times of nutritional

emergencies, primarily the more acute form of PEM is observed, that has to be dealt with. This is characterized by the rapid loss of weight and may affect larger number of older children, adolescents and adults than usual. The clinical symptoms of PEM, as you may recall studying in the Public Nutrition Course (MFN-006), are summarized in the Table 18.2. Infants and children suffering from severe PEM must be treated as soon as possible; otherwise they are very likely to die. Let us study the clinical symptoms of PEM in both children and adults.

Table 18.2: Main clinical symptoms of PEM

Population Group	Clinical Symptoms/Signs	
	Always Present	Sometimes Present
<i>Children</i>		
Marasmus	Wasting	Hunger, Wizen appearance
Kwashiorkor	Oedema	<i>Mental change:</i> irritability, poor appetite <i>Skin change:</i> dermatitis <i>Hair:</i> sparse, loose, straight
Marasmic kwashiorkor	Wasting and oedema	Any of the above symptoms and signs
<i>Adults</i>	Wasting and weakness	Oedema, mental change

Now, how to prevent or overcome this nutritional deficiency? A large number of government schemes and programmes have been launched about which we have already studied in the Public Nutrition Course. Along with these programmes, new initiatives need to be put in place to deal with these conditions. Selective feeding programme should be initiated for PEM affected individuals and these include supplementary feeding programmes, providing an extra 500-700 Kcal/day from cooked food or by distribution of dry take home rations (1000-1200 Kcal/day). Breast-feeding must be encouraged. Blanket supplementary feeding programmes should be needed only temporarily when the malnutrition rates (weight-for-height below median -2 SD) exceed 15% or 10% in the presence of other aggravating factors. Targeted supplementary feeding (i.e. extra food given to the selected individuals), is indicated if the malnutrition rate exceeds 10% or 5% in presence of other aggravating factors e.g. high mortality and/or epidemic infections diseases. Therapeutic feeding is required to reduce the death rate among infants and young children. A rehabilitative diet, with high-energy foods (providing 150-200 Kcal and 2-3 g of protein/kg body weight daily) should be served at frequent intervals. For the first few days, there should be a close medical supervision and feeding should be made at every 3 hours on a 24 hour basis. Mothers should feed their sick children themselves. Broad spectrum antibiotics for the treatment of emerging infections, immunization against measles and normal doses of vitamin A should be made available.

Let us next move on to micronutrient deficiencies.

- *Micronutrient Deficiencies*

Micronutrient deficiencies are more common during calamities. Can you guess, why? This is due to the lack of diversified food items and nonavailability of fresh foods. All forms of vitamin and micronutrient deficiency diseases can be seen in an affected population if preventive measures have not been taken in time. These include iron deficiency anaemia, vitamin A deficiency blindness, beriberi, pellagra, oedema and goitre. There are several approaches for preventing the onset of micronutrient deficiencies in emergency situations affecting large populations. These include:

- increasing the daily ration that will allow a surplus to be sold for other purposes like procuring fruits and vegetables,
- varying the composition of food basket such as pulses, groundnuts, fresh fruits and vegetables and red palm oil. A better alternative is the local production of fruits and vegetables in home gardens,

- including micronutrient fortified foods in ration e.g. cereals/pulse blends, iodized salt, vitamin A enriched skim milk or vegetable oils, and
- providing supplementation when there is likely to be a specific deficiency based on dietary assessment and overt signs and symptoms.

Another important aspect to be considered for the management of emergencies is monitoring assessment and surveillance of nutritional status and relief measures in emergencies. The next sub-section focuses on this aspect.

18.3.3 Monitoring Assessment and Surveillance of Nutritional Status and Relief Measures in Emergencies

What do we mean by the terms monitoring and surveillance? Do you recall studying about this aspect in the Public Nutrition Course in Unit 10? Well, we suggest you look up this unit again before you continue with your study on this topic here in this unit.

What is their need during an emergency? Let us find out. Monitoring, we know, is *the act of observing something and sometimes keeping a record of it* while surveillance is *a repeated survey using a standard methodology*. During nutritional emergency, relief foods may be scarce and may need to be provided preferentially (targeted) to the people in greatest need. Food relief programmes should be planned and implemented on the basis of initial, rapid nutrition assessment followed by systemic surveys and continued monitoring and surveillance of nutritional conditions. Suitable arrangements must be made for evaluating the nutritional status at levels of communities (to assess extent of severity of malnutrition and micronutrient deficiencies, and composition of emergency ration; to ensure that fuel and cooking utensils are available and to monitor the changes in nutritional status over a period of time) and of individuals (to screen for supplementary or therapeutic feeding programmes).

Various simple indicators may be used such as:

- 1) Weight-for-height
- 2) Body mass index (weight in kg/square of height in meters) of adults
- 3) Mid upper arm circumference (MUAC) can be used as an alternative for initial screening
- 4) Oedema is an essential indicator when kwashiorkor is present

Let us next review at the nutritional relief programmes and interventions required during an emergency condition.

Nutritional Relief Programme and Interventions

A general feeding programme is required during first stage when the affected population does not have sufficient food to meet the nutritional needs. If the population is entirely dependent upon external aid, the general ration must provide for a minimum intake of 2100 Kcal per person per day and more, if population is already malnourished, exposed to cold, or engaged in heavy work. Refer to Table 18.3 where the requirements based on activities are given. Besides being nutritionally balanced, the general ration should be acceptable culturally, fit for consumption and easily digestible for children and other affected vulnerable groups. Although nutrient needs are different for different age groups in a family but same general ration components should be provided for each person, regardless of age, families would divide ration among themselves. The general ration is normally provided dry, for cooking at home.

Distribution of cooked food should be avoided except as a short term measure that should be stopped as soon as people have necessary arrangements to prepare their meals due to following reasons:

- Such programme is often culturally inappropriate and may cause offence

- Hygiene is difficult to ensure
- Food intakes are often lower and difficult to meet needs of young children.

Table 18.3: Mean Energy Requirements and Recommended Adjustments for different activity levels, environmental temperatures and food losses during transport

		Developing Country	Industrialized Country
<i>Mean energy requirement (Kcal)</i>		2080	2180
Adjustment for activity level			
<i>Moderate</i>	Adult male	+300	+370
	Adult female	+100	+105
	Whole population	+140	+180
<i>Heavy</i>	Adult male	+850	+890
	Adult female	+330	+340
	Whole population	+350	+460
<i>Adjustment in Kcal for mean daily temperature</i>			
20°C			—
15°C			+100
10°C			+200
5°C			+300
0°C			+400
<i>Adjustment in energy requirement (Kcal) for food losses in transport</i>			
Country with port			+5%
Land locked country			+10%

Source: WHO 2000, The Management of Nutrition in Major Emergencies.

For distribution of cooked food, locally available fuel and local methods for making fire can be used. Individuals may be asked to collect and bring wood, cow dung etc. for fuel and if collection is difficult or there are chances of deforestation in area, kerosene oil should be used as an alternative.

In second stage, supplementary feeding programme (SFP) is given for vulnerable groups and therapeutic feeding programmes (TFP) are provided to those already severely affected due to malnutrition or deficiency diseases as mentioned in earlier sections.

For distribution of items, ration cards should be issued and maintained. Effectiveness of programme should be monitored at the regular intervals.

With this, we come to an end on our discussion on the management of emergency situations. In our next section, we shall deal with nutritional needs during extreme environmental conditions. But before that, let us find out what we have learnt so far.

Check Your Progress Exercise 1

- 1) What do you understand by the terms 'calamity' and 'emergency'? State the major nutritional deficiency diseases in calamity affected area.

.....

.....

.....

.....

2) What factors must be considered for the management of emergencies?

.....

.....

.....

3) Mention the basic assumptions on which per capita energy requirements are recommended by WHO.

.....

.....

.....

4) Discuss the approaches for preventing the onset of micronutrient deficiencies. How many calories must be provided during the emergency situation?

.....

.....

.....

5) Match column A with column B:

A

- a) Marasmus
- b) Kwashiorkor
- c) Night Blindness
- d) Goitre
- e) Scurvy

B

- i) Iodine deficiency
- ii) vitamin C deficiency
- iii) Oedema
- iv) vitamin A deficiency
- v) Wasting

6) Tick the correct answer.

- i) Micronutrient deficiencies are common during calamities because of
 - a) Lack of diversified food items and fresh foods.
 - b) Lack of cooked foods.
 - c) Lack of fried foods.
- ii) Targeted supplementary feeding is indicated
 - a) if the malnutrition rate exceeds 15% or 10%
 - b) if the malnutrition rate exceeds 10% or 5%
 - c) if the malnutrition rate exceeds 20% or 10%
- iii) Recommended daily per capita vitamin A intake for emergency food in developing country is
 - a) 3.8 mcg
 - b) 500 mcg
 - c) 160 mcg
- iv) Recommended daily per capita riboflavin intake for emergency food in developing country
 - a) 14 mg
 - b) 1.4 mg
 - c) 0.14 mg
- v) Mean energy requirement for a moderately active adult male living in refugee camp
 - a) 2080 Kcal
 - b) 2380 Kcal
 - c) 300 Kcal

18.4 NUTRITIONAL REQUIREMENTS FOR EXTREME ENVIRONMENTS

Human beings have been able to survive and work under extreme environments of almost all regions of the earth, from poles to equator and also in space. Some of these places are visited for very brief periods due to inhospitable environment. An extreme environment can be defined as *an environment where basic needs, like acquisition of food, shelter and protection, require extraordinary efforts*. One important feature of these environments is that an error in judgment and behaviour can have serious, even fatal consequences. These environments can be natural, as well as, man-made and are listed in the Table 18.4.

Table 18.4: Condition and environmental extremes

Primary Natural	Primary Man made	Condition	Environment
X		Low temperature	Arctic/Antarctic/Altitude
X		High temperature	Tropics
X	X	Reduced pressure	Altitude/flight
	X	Increased pressure	Diving
X	X	Reduced gravity	Space
	X	Increased gravity	Flight
X		Decreased oxygen availability	Altitude
	X	Increased oxygen availability	Diving
	X	Change in inspired air composition	Diving
X		Lack of water	Desert
X	X	Lack of food	Anywhere
X		Increased radiation	Space/Altitude
X	X	Isolation	Arctic/Antarctic/Space

When faced with hot, cold, high altitude (terrestrial heights above 2700 meters) or space environments, human beings either try to modify the microenvironment accordingly or physiologically adapt themselves to fit the environment or use a combination of these two strategies. Let us review these adaptive mechanisms.

18.4.1 General Adaptive Mechanisms to Environmental Extremes and Role of Nutrition in Successful Acclimatization

Although human beings are remarkably adaptive but the main limitation is *homeothermy* which means ‘regardless of environmental temperature, the normal body temperature must be maintained within a relatively narrow range’. We have several physiological defense mechanisms to overcome this problem e.g. shivering, sweating, vasodilatation or vasoconstriction. When the capacity of these mechanisms is exceeded and body core temperature drops below 35°C (95°F) or rises above 41°C (106°F), the physical and mental performance deteriorates rapidly and both these conditions may be life threatening. Similarly, hypoxia associated with cold at high altitude imposes severe restriction on adaptability. Metabolic adaptations to heat, cold and high altitude hypoxia may in some instance be accompanied by the changes in nutrient requirements. Inadequate nutrition can impair metabolic response as illustrated in Figure 18.1.

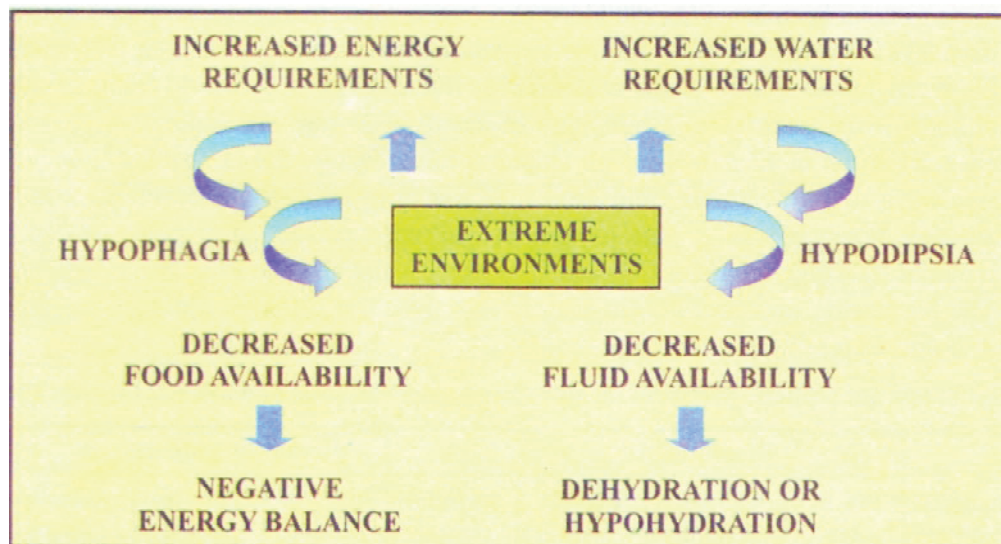


Figure 18.1: Cascade effect of environmental extremes

The energy and nutrient requirements are generally more under environmental extremes as can be seen from Figure 18.1 and also highlighted in Table 18.5. Appetite and thirst perceptions are generally inappropriate in these environmental extremes, which lead to an inadequate food and water intake. The availability of food and water is often limited due to logistic constraints or often get second priority for carrying of essential equipments, clothing and gear. Proper nutrition is often overlooked but is a critical component of effective work under these conditions.

Table 18.5: Energy requirement for physical activity in temperate, cold and hot environment (Kcal/kg body weight)

Physical Activity	Environment		
	Temperate	Cold	Hot
Light	32 - 44	35 - 46	40 - 54
Moderate	45 - 52	47 - 55	55 - 61
Heavy	53 - 63	56 - 68	62 - 75

Altitude energy requirements are similar to temperate. Hot > 30°C / 86°F, Cold < 0°C/ 32°F, High altitude > 3050 m or 10,000 ft elevation.

The diet of humans differs in quantity and composition in different climatic regions. Although much of this variation may be due to availability of food in that area, there is an intriguing possibility of selection of certain classes of foods or adaptation to some dietary habits, which help in acclimatization process in that environment. Several studies on relationship of diet and extreme environment are the outcome of military research or expeditions to mountains and Polar Regions. *Captain Cook* kept his crew entirely free of scurvy during his second voyage to South Seas (1772-75) by using germinating seeds and lime juice along with food items. Beriberi was the scourge of the Japanese Navy prior to 1882 when *Admiral Takaki* eliminated it by increasing allowances of vegetables, fish, meat and barley in addition to staple diet of polished rice.

Another important aspect linked to high altitude is *hypoxia*. Let us understand about this adaptive mechanism.

Decreased oxygen availability at high altitude (Hypobaric hypoxia)

The governing biophysical factor at high altitude is decrease in barometric pressure with increase in altitude. Although atmospheric concentration of oxygen remains at a constant 20.93% at all terrestrial altitudes, the partial pressure of oxygen falls along with decline in barometric pressure ($PO_2 = 0.2093 \times \text{barometric pressure}$). As the altitude increases, the lowered oxygen pressure (PO_2) in pulmonary alveoli causes a decline in saturation of haemoglobin in arterial blood, and a lower oxygen pressure

gradient throughout the body, especially at the level of capillaries, where PO_2 may be close to zero. With low PO_2 , the blood flow is too rapid to allow appropriate gaseous exchange, resulting in unfavourable oxyhaemoglobin dissociation. The CO_2 that is produced metabolically exerts a tension of 40 mm Hg at sea level while at high altitude, it is decreased to a minimum of about 24-27 mm Hg while water vapours exert a tension of 47 mm Hg at all altitudes. Thus, $PCO_2 + PH_2O$, that is, 71 mm Hg is always to be deducted from total available gas pressure in alveoli at a given altitude. When breathing pure oxygen, the nitrogen present in alveolar air can be replaced by oxygen (but not CO_2 and H_2O vapour) and alveolar PO_2 can be increased. The barometric pressure, PO_2 in the air and alveoli at different altitudes are given in Table 18.6.

Table 18.6: Effect of low atmospheric pressures on alveolar gas concentration and arterial O_2 saturation

	Barometric Pressure (mm Hg)	Breathing Air				Breathing pure oxygen		
		PO_2 in Air (mm Hg)	PCO_2 in Alveoli (mmHg)	PO_2 in Alveoli (mm Hg)	Arterial Oxygen Saturation (%)	PCO_2 in Alveoli (mm Hg)	PO_2 in Alveoli (mm Hg)	Arterial Oxygen Saturation (%)
0	760	159	40 (40)	104 (104)	97 (97)	40	673	100
10,000	523	110	36 (23)	67 (77)	90 (92)	40	436	100
20,000	349	73	24 (10)	40 (53)	73 (85)	40	262	100
30,000	226	47	24 (7)	18 (30)	24 (38)	40	139	99
40,000	141	29				36	58	84
50,000	87	18				24	16	15

Numbers in parentheses are acclimatized values.

Source: Guyton and Hall, 1996, Textbook of Medical Physiology, ninth edition.

Arterial hypoxia precipitates the immediate physiological adjustments to altitude and process of acclimatization in case of longer duration of exposure. Table 18.7 presents the immediate and longer term adjustment to altitude hypoxia.

Table 18.7: Immediate and longer term adjustment to altitude hypoxia

System	Immediate Adjustment	Long Term Adjustment
<i>Pulmonary</i>	Hyperventilation	Hyperventilation
Acid base balance	Body fluids become more alkaline due to reduction of CO_2 with hyperventilation	Excretion of base via the kidneys and concomitant reduction in alkaline reserve
Cardiovascular	Increase in submaximal heart rate Increase in submaximal cardiac output Stroke volume remains same or slightly lowered Maximum cardiac output remains the same or slightly reduced	Submaximal heart rate remains elevated Submaximal cardiac output falls below sea level values Stroke volume is lowered Maximum cardiac output is lowered
Haematological		Decreased plasma volume Increased haematocrit Increased haemoglobin concentration Increased total number of red blood cells
<i>Local</i>		Possible increase capillarization of skeletal muscle Increased red blood cell 2,3-DPG Increased mitochondrial density Increased aerobic enzymes in muscle Loss of body weight and lean body mass

After going through the above discussion, the variations in oxygen availability at altitude and the extent of adjustments to be made accordingly, it is quite obvious that such a condition could possibly lead to health hazards. What are these? What are their symptoms and the remedies? Let us find out in the following sub-section.

18.4.2 Health Hazards Associated with High Altitude

Abrupt exposure to altitudes greater than 10,000 ft (3050 m) elevation is frequently associated with symptoms of altitude sickness. Altitude sickness or acute mountain sickness (AMS) is a general term referring to *a combination of symptoms, including headaches, anorexia, nausea, vomiting and malaise*. The condition improves automatically with acclimatization. Best way to avoid AMS is gradual ascent at heights above 3000 m and stay for 2-3 days at every 1000 m elevation. The gradual acclimatization to progressively higher altitude exposure is the best preventive medicine for high altitude sickness. Life threatening conditions in susceptible individuals are high altitude pulmonary oedema (HAPE) and high altitude cerebral oedema (HACE). In both the cases, immediate evacuation to lower altitude is prescribed after the initial treatment. Other problems are cold injuries such as frostbite and chilblains, and can be prevented using adequate precautions.

Let us now move on to the nutritional requirements and varying food intake patterns for high altitude.

18.4.3 Nutritional Requirements for High Altitude

High terrestrial altitudes and mountains have aroused great fascination and charm for mankind. Every year millions of people go to mountains for recreation and adventure sports. Besides these visitors, there are some 140 million permanent inhabitants of high lands in the Himalayas, Central Asian, East African Andean and Rocky mountain regions. Permanent residency is restricted to about 4300 m, although some ethnic groups e.g. miners in the Peruvian Andes are reported to live at heights 5500 m for a short period of time.

Himalayas constitute the northern frontiers of our country with human habitation up to an altitude of 4300 m, while soldiers are deployed even up to 5800 m for fixed tenure. High altitude, we have studied above, presents an extreme environment with hypoxia, cold, high solar radiation as physical stresses beside the psychological stress. These areas are also arid in nature with sparse vegetation and shortage of potable water. These factors vary in magnitude depending upon the location and season, and set a formidable challenge to human adaptability and nutrition.

Let us then learn about nutrient needs, food intake, basal metabolism and energy expenditure at high altitude.

Food Intake and Energy Requirements

Many studies have shown that the subjects lose significant amounts of body mass, fat mass, as well as, fat free mass during a climb to and/or a stay at the high altitudes. High altitude-induced weight loss is mainly caused by malnutrition probably due to hypoxia related anorexia, independent of acute mountain sickness. Hypophagia is more pronounced during the first three days of exposure to high altitude even when the best possible food is available. The decreased calories consumption by 40% at 4300 m leads to a negative nitrogen balance. This, coupled with an increased metabolic rate, induced by high altitude exposure, is considered as a major cause of weight loss. The taste thresholds for sweet and salt modalities have been found to be elevated while for bitter and sour were reduced. This means we have to add more sugar to our cup of tea to get same sweet taste as at plains. The feeding behaviour is governed by several hormones, endocrine substances and can be modulated by environmental factors. Alterations in appetite regulatory hormones are the current focus of modern research for appetite regulation.

Let us now move on to the concept of BMR and energy expenditure.

Basal Metabolism and Energy Expenditure at High Altitude

The energy and nutrient requirements depend upon total energy expenditure and metabolic rate of the individual. Total energy expenditure (TEE), as you may recall studying in Unit 2, has three components i.e. *basal metabolic rate (BMR)*, *diet induced energy expenditure* and *expenditure related to activities*. Short-term measurements of gas exchange during field studies suggest that altitude hypoxia increases BMR. Some studies show these acute increases (20-30%) to be sustained for 1-2 weeks while others show elevation to be maintained throughout a three week stay. The decline in BMR with acclimatization seems to be the result of an inadequate energy intake and a decrease in metabolically active tissue that accompanies weight loss. The decrease in metabolic rate is expected to be approximately 20-25 Kcal/d/kg lean tissue lost. Finally, the stress of high altitude (HA) decreases over a period of time as indicated by a decrease in the epinephrine levels in both men and women.

Increased energy expenditure ranging from 6.9 to 25% has been reported. As regards the energy cost of various activities under stationary conditions, there is no variation as compared to the sea levels. Increased energy expenditure may be due to the heavier load carried by the troops, as cold protective garments and efforts in walking in snow bound hilly terrain.

The energy expenditure of 3250 Kcal/day is reported in climbers to Mt. Everest using doubly labeled water technique. Out of this, 1610 Kcal/day was required just for climbing activities. The physical activity level (PAL) calculated using doubly labeled water and expressed as a multiple of BMR in trained subjects during climbing reached 2.0-2.7, which was lower than the upper limit (4.0-5.0) at sea level. In a study by *Reynolds et al* (1999), energy expenditure in 7 climbers to Mt. Everest was in the range of 2675- 7872 Kcal/day. According to a expert group of nutrient requirements for Indians-2020, ICMR-NIN, energy expenditure of Indian troops is different on different height and environment as shown in Table 18.8. On the basis of data obtained from climbers who are highly motivated people, generalization of nutrient and energy requirements for the general population is difficult.

Having looked at the energy expenditure and energy requirements, let us study about the other nutrient requirements. We shall first have a look at the macronutrients followed by the fluids and micronutrients.

Macronutrient Requirements

- **Carbohydrates:** High carbohydrate diets are beneficial at HA. The advantage of high carbohydrate diet is that respiratory quotient (RQ) of carbohydrate diet is around 1.0; on the other hand, if fat is exclusively taken, then RQ is 0.7. In high terrestrial altitudes, alveolar PO_2 falls with a fall in barometric pressure and when there is a shift of RQ from 0.7 to 1.0, there is an increase in PO_2 and this gives rise to the increase in arterial oxygen saturation. Carbohydrates provide a higher yield of energy per mole of oxygen. The energy equivalent of oxygen is 4.48 Kcal/L for protein, 4.7 Kcal/L for fat and 5.06 Kcal/L for carbohydrate. Diets high in carbohydrates are shown to enhance the glucose metabolism at high altitude. Studies on dietary habits of Indian sea level residents and natives of high altitude show that up to 60% energy is derived from carbohydrates.

Negative nitrogen balance is reported at high altitude and this is mainly due to decreased food intake. Extensive studies on nitrogen metabolism at both acute and after long-term stay at high altitudes on Indian soldiers indicate positive nitrogen balance at 12 g/day dietary nitrogen intake.

- **Fat:** There is no change in fat digestibility at altitude of <4500 m. However, at extreme altitude, there are reports that fat absorption gets impaired. Intake of fat decreases due to anorexia.

D-xylose excretion, which is used as test of the absorptive activity of upper part of small intestine also remains normal, indicating that absorptive functions of the small intestine are not disturbed at high altitude up to 5000 m.

Fluid, Electrolyte and Micronutrient Requirements

- **Fluids and Electrolyte:** In addition to cold induced diuresis, hyperventilation together with a dry environment at HA makes an individual prone to hypohydration. Acute exposure to moderate altitude causes transient hypohydration, which is due to an increased diuresis and reduction in thirst perception. Prolonged stay at extreme altitudes may cause severe salt and water retention. The role of hormones in normal fluid metabolism at high altitude is not clear, but a number of hormones play a role in retention of salt and water in pathologic states like acute and sub-acute mountain sickness. Estimation of fluid requirements for Indian troops based on their energy expenditure under different environments and training can be assessed from Table 18.8.

Table 18.8 : Estimation of Fluid Requirements for Indian Troops based on their Energy Expenditure under Different Environments and Training

Type of troops and environment	Total Energy Expenditure (kcal/day)	Average Fluid Intake from Foods (ml/day)	Average Fluid Intake from Beverages (ml/day)	Average Total Fluid Requirement (ml/day)
Army				
HA warfare training	4837	2200	5050	7250
HA (2,700–4,500m)-Combat and support	3880	1750	4050	5800
HA (>4,500 m) – Combat	4270	1900	4500	6400

Source: Total energy expenditure determined from Malhotra et al. (1975) ; Force DotAaA (2003); Singh *et al.* (2014); HA: High Attitude

- **Minerals:** Increased urinary excretion of Na⁺ and K⁺ on exposure to hypoxia is reported while some workers have found only increase in Na⁺ with a decrease in K⁺ excretion.

At high altitudes, though there is always a balance between blood formation and destruction, still there is no evidence for increased dietary iron requirements. The requirements of increased haemoglobin synthesis during early phase of stay at altitude are fulfilled by redistributing body stores and from dietary iron. Urinary excretion of Zn²⁺ is more during physical exertion as observed during an expedition to Mt Everest. Reduced zinc levels are associated with anorexia.

- **Vitamins:** It is observed that requirement of vitamins is not different as compared to plains. In humans, exposure to high altitude has been reported to cause a marked increase in lipid peroxidation. Antioxidant nutrients such as vitamin E, C and A (β-Carotene), as well as, selenium, copper, zinc and manganese may be required in greater amounts in cold and high altitude environments to prevent oxidative stress. These antioxidants act in a concerted manner to combat the oxidative stress arising from different sources. β-Carotene protects against photo-immuno-suppression caused by long-wave UV radiation encountered in outdoors. During rough weather, when supply of fresh fruits and vegetables becomes limited at high altitude, vitamin C supplements are recommended due to its antioxidant role.

Now that we are well versed with the nutrient requirements, let us test our knowledge of the topic by answering the check your progress exercise 2.

Check Your Progress Exercise 2

- 1) Define extreme environment. List a few factors which present high altitude as an extreme environment.

.....

.....

.....

- 2) State three characteristics of high altitude environment.

.....

.....

.....

- 3) Discuss the micronutrient requirements at high altitude.

.....

.....

.....

- 4) Multiple choice:

- i) An increase in body size and lean body mass leads to:
- a) decrease in BMR
 - b) increase in BMR
 - c) no change in BMR
- ii) During the first few days of ascent to high altitude haematocrit value:
- a) increases
 - b) decreases
 - c) unchanged
- iii) The respiratory quotient of carbohydrate is:
- a) 1.0
 - b) 0.85
 - c) 0.7
- iv) High altitude induced weight loss is mainly attributed to:
- a) hypobaric hypoxia induced anorexia.
 - b) chemical hypoxia induced anorexia.
 - c) intense solar radiation
- v) The best way to avoid acute mountain sickness is:
- a) immediate evacuation to lower altitude
 - b) gradual ascent at heights above 3000 m
 - c) stay at high altitude and get treated for the symptoms first

5) Match column A with B:

A

- a) Negative nitrogen balance
- b) Antioxidants
- c) Photo-immunosuppression
- d) Increased pressure

B

- 1) Diving
- 2) Decreased food intake
- 3) Oxidative stress
- 4) UV irradiation

6) State whether the following statements are true (T) or false (F):

- a) The atmospheric concentration of oxygen remains at a constant 20.93%. (T/F)
- b) Ascent to high altitude possibly increases capillarization of skeletal muscle. (T/F)
- c) Intake of fat increases above 4500 m due to high energy requirement. (T/F)
- d) The PO₂ in air at an altitude of 20,000 ft is 110 mm of Hg. (T/F)
- e) The energy equivalent of oxygen for carbohydrate is 5.06 Kcal/L. (T/F)

Let us now proceed with our journey to the poles now and see how our nutrient needs vary due to extreme cold conditions, the various mechanisms by which our body adapts to such conditions and thrives successfully.

18.4.4 Nutritional Requirements in Cold and Polar Environment

Energy requirements are the major consideration for providing nutritional support in a cold environment. Energy expenditure is usually limited by the rate of heat buildup and hypoxia, respectively in hot and altitude environments whereas in cold, no such type of restriction exists. Energy requirements in cold environment are influenced by the intensity of the cold, wind speed, physical factors (like melting snow, locomotion on icy or snow covered surfaces etc.) and altered solar periodicity in Arctic and Antarctic areas. Cold exposure increases energy requirements. It is reported that people in cold climate normally eat more than those in warm climate. The increased energy requirements are due to the 'hobbling' effect of the clothing weight (7-10 kg) and are associated with the efforts of locomotion. The weight of cold weather clothing has decreased as technology has improved; however, clothing is still a considerable burden. It appears that the heat loss in a cold environment is considerably reduced through thermoregulation, clothing and behaviour i.e. seeking shelter whenever possible, creating or moving to warmer environments. Moreover, skeletal muscle contractions, either during voluntary exercise or involuntary shivering are the major source of metabolic heat produced to protect against cold stress. These are a few mechanism adapted by our body to regulate the body temperature in conditions of cold. Let us next get to know about the concept of *thermoregulation*. How is it beneficial, as well as, essential to us?

Thermoregulation in Cold

Heat production parallels the increase in O₂ uptake, the magnitude of which depends on the muscle mass engaged in shivering or work and the duration of activity. Shivering alone can produce only a four-fold increase above basal rates of heat production. The increase in O₂ uptake during shivering thermogenesis is also accompanied by an increase in cardiac output. This increase is due to increase in stroke volume, which is associated with cold-induced peripheral vasoconstriction. The effect of the mechanisms used to protect against heat loss depends on the body surface area in comparison with body mass. The problems may arise in malnourished subjects who have lost both fat mass, as well as, lean body mass. Cold acclimatization

can occur in human subjects but it is minimal. An important modifying factor on the thermoregulatory response to cold is the individual's provision of subcutaneous fat, since fat reduces thermal conductance from the core to the body surfaces. Physical fitness has mixed effects; the fittest individuals show more heat production but at the same time, being lean in structure, they lose heat more quickly. Severe losses of body weight in a cold environment complicate the normal physiological responses to cold. Thus, maintaining an adequate intake in cold environment especially under physically active conditions is important. There is a common belief that cold climatic conditions lead to an increased appetite. The evidence for this conclusion is derived from changes in body weight; self reported intakes in cold environment at sea level (SL). However, the reported increase in appetite is also associated with changes in other aspects of subject's environment such as increased activity levels, energy expenditure due to thermogenesis, social isolation and modification in the diet. In animals, increased energy expenditure caused by increased thermogenesis due to cold environment is compensated by increased intakes.

In human subjects, increased energy intake requirements do not always trigger an increase intake and appetite immediately. Humans can adapt over a period of time to a high fat diet to make the food energy dense.

Now that we are aware of the concept of thermoregulation, let us look at the dietary patterns and the factors affecting food intake of the people residing in cold conditions.

Food Intake during Polar Expeditions

Observations made by *Easty* (1967) at Halley Bay, the British Antarctic survey base during 1961-62 expeditions indicate mean calorie intake 3600 Kcal/man day and 12.7% of those calories were supplied by protein, 39.8% by fat and 48.1% by carbohydrates. During winter months (polar night), when men were confined to the limits of base and activities showed a marked fall and there was a gain of body weight ~ 2.5 kg. Various Indian Antarctic expeditions have a common observation of increase in body weight that is mainly due to an increased intake. Several factors are responsible for an enhanced appetite in cold regions, that include the palatability of food, cold temperature, emotional factors (e.g. loneliness) and changes in physical activity and habits. The average energy expenditure was found to be 3100 Kcal/day indicating an active life style of expedition members.

The dietary pattern of natives of arctic and sub arctic regions and their obvious success in coping with harsh environment have influenced arctic explorers to choose diets high in fat in general belief that this may be helpful. Such information is largely anecdotal and probably relates more to the availability of local foods (seal, fish, whale, caribou) and familiarity of Eskimos with these foods. However, such diets are rich in n-3 fatty acids, which play an important role in the prevention of cardiovascular diseases.

Despite the arguments that can be made for suitability of high fat diets in the cold, there is an evidence suggesting that carbohydrates are more important than fat in fueling metabolic heat production during cold exposure. Increase in energy expenditure resulted in an increase in carbohydrate and fat oxidation while protein oxidation remains unaffected.

Let us go through the Do's and Don'ts to be followed during polar expedition which are highlighted in Box 18.1.

Box 18.1	Do's and Don'ts for Recreational and Expedition Meal Planning
DO provide group/hot meals whenever possible. People will generally eat more when warm meals are consumed 'socially'. DO schedule breaks for meals and snacks even when individual food has to be consumed for meal or snack. Left to their own, people generally skip meals to accomplish tasks. DO encourage increased fluid intake as water, soups and nonalcoholic beverages to ensure proper hydration. DO observe what food items are being consumed. Picky dietary habits can lead to imbalance in micronutrients.	DON'T assume that everyone is eating adequately in group as a meal prepared is not essentially meal consumed. DON'T allow junk food to substitute for meals. Snacks should augment or supplement daily meals to increase total energy intake and carbohydrates. DON'T compromise with personal hygiene. Clean hands, clean water and clean utensils are requisite for food safe meal preparation. DON'T permit individuals to use the expedition as 'crash' weight loss programme as this can be harmful for individual, as well as, team mission.

Check Your Progress Exercise 3

- 1) State the factors responsible for the increased energy requirements in cold and polar environment.

.....

.....

- 2) What is the role of an individual's subcutaneous fat and lean body mass in thermoregulatory response?

.....

.....

- 3) Mention the factors which increase food intake in Antarctica.

.....

.....

- 4) Multiple choice:

- i) The gain of body weights in polar nights is due to:
 - a) increase in food intake
 - b) increase in food intake and decrease in physical activity
 - c) decrease in physical activity
- ii) Arctic explorers choose high fat diet because:
 - a) fat is responsible for producing more metabolic heat
 - b) it contains n-3 fatty acids which reduce the risk of cardiovascular disease.
 - c) they were influenced by the dietary pattern of the natives of Arctic regions.
- iii) An average energy expenditure of Indian Antarctic expedition:
 - a) 3100 Kcal/day
 - b) 4500 Kcal/day
 - c) 1300 Kcal/day

- iv) Increase in energy expenditure in cold results in:
- increase in carbohydrate and fat oxidation
 - Increase in protein oxidation
 - Increase in carbohydrate oxidation
- 5) Match the following:
- | A | B |
|-------------------------------------|--------------------------------------|
| a) Shivering | 1) Peripheral vasoconstriction |
| b) Increased cardiac output in cold | 2) Prevents loss of core temperature |
| c) Subcutaneous fat | 3) Thermogenesis |

From cold environments, we now move on to hot environments. So, from the poles, let us move towards the equator and find out nutritional requirements of people in extreme hot conditions.

18.4.5 Nutritional Requirements in Hot Environments

Hot environments may be of two types: dry hot, as in the case of deserts or hot and humid in tropical rain forests and coastal regions. Factors other than air temperature determine physiological strain imposed by the heat stress. These factors include individual variations in body size and fatness, acclimatization, and external factors such as air currents, heat gain due to radiation, intensity of work, clothing and relative humidity. Various practical heat stress indices (e.g. wet bulb-globe temperature, Heat Stress Index) make use of ambient temperature, radiant heat and relative humidity to evaluate the environmental potential heat challenge for humans working under that environment. Refer to Table 18.9, which highlights the effects of heat stress.

Table 18.9: Effects of heat stress

- Decreased Gastrointestinal Functioning
- Increase in Core Temperature
- Decrease in Gastric Emptying and Intestinal Motility
- Hypohydration
- Leads to Decreased Physical and Mental Functions
- Heat Cramps, Flatulence, Vomiting, Diarrhoea and Nausea
- Heat Stroke

However, it is important to know that an adequate fluid replacement overshadows all other considerations of nutrient requirements for work in a hot environment. Drinking adequate amount of water at regular intervals prevents dehydration, heat, illness and maintains work performance. Heat acclimatization relatively has no effect on water requirements. Thirst is a poor indicator of hydration status. Intense thirst is usually noticed at 5 to 6% body weight loss due to hypohydration (removal of water). By this time, the physical performance is compromised. Severe hypohydration can lead to a decreased blood volume and an increase in the plasma osmolality, which can result in decreased sweating and heat dissipation.

Eighty percent of the energy metabolized during exercise in hot environment is liberated as heat (only 20% is utilized as mechanical work) and 80-90% of heat dissipation during work in a hot-dry environment is accomplished by the evaporation of sweat. Each milliliter of sweat evaporated from the skin leads to heat loss of approximately 0.6 Kcal. Sweat rates vary to a great extent from an individual to individual, but can reach 2 L/h for prolonged time periods. Hypohydration depends in a large part upon sweat rate, which, in turn, is determined by workload and duration. Other environmental factors are solar load, wind speed, relative humidity and clothing. Fluid replacement and work/Rest Guidance for warm weather training conditions and refilling frequency is given by Table 18.10. In this table you would

notice there are five flag conditions i.e. white, green, yellow, red and black corresponding to heat conditions.

Table 18.10: Fluid Replacement and Work/Rest Guidance for Warm Weather Training Conditions and Refilling Frequency

Heat Category	Easy work				Moderate Work			Hard Work		
	WBGT Index (°F)	Work: Rest (min)	Water Intake (ml/hr)	Refilling Frequency (hr)	Work: Rest (min)	Water Intake (ml/hr)	Refilling Frequency (hr)	Work: Rest (min)	Water Intake (ml/hr)	Refilling Frequency (hr)
1 (White)	78-81.9	NL	475	4	NL	710	4	40:20	710	4
2 (Green)	82-84.9	NL	475	4	50:10	710	4	30:30	950	3
3 (Yellow)	85-87.9	NL	710	4	40:20	710	4	30:30	950	3
4 (Red)	88-89.9	NL	710	4	30:30	710	4	20:40	950	3
5 (Black)	>90	50:10	950	3	20:40	950	3	10:50	950	3

Source for classification of Heat Category: Institute of Medicine, 2005 and WHO, 2004

*NL- No limit for work; WBGT- Wet-Bulb Globe Temperature; Rest- Minimal physical activity like sitting or standing in the shade.

Conditions assumed are clothing, tropical fatigues, heat acclimatized subjects, wind speed 2 m/s. To prevent hypohydration, fluid should be taken periodically whether one is thirsty or not.

Let us now have to look at the energy expenditure patterns and nutrient requirements.

Energy Expenditure in Hot Environments

Energy expenditure in hot environments is increased by a small but significant amount because of additional work of ventilation and increased sweat gland activity. There is a rise of ~ 10% in energy requirement at 38°C. Very few studies exist for energy determinations using doubly labeled water technique during heat exposure; energy expenditure is reported to be 4750 Kcal/day in hot and humid jungle environment and 4000 Kcal/day for hot wet and 4200 kcal/day for hot dry desert conditions. Excessive nitrogen losses are reported in perspiration of unacclimatized people but not in acclimatized persons. The nitrogen concentration in perspiration is small and decreases with an increase in perspiration rate; as 90% of the excretion of nitrogen is in faeces and urine and it is not significant enough to warrant extra protein in the diet in tropics

We shall now proceed with nutrient requirements.

Vitamin and Mineral Requirements

There is no extra need of vitamins. Although loss of water-soluble B-vitamins is minimal, a deficiency could occur over time from profuse sweating coupled with an insufficient dietary intake.

Because thiamin, riboflavin, niacin and vitamin B₆ are important to energy metabolism, the level of these vitamin intakes should be related to amount of food consumed. Role of vitamin B₆ in carbohydrate metabolism was established in 1990. As much as 80% of the body's vitamin B₆ is present in muscle, as coenzyme of glycogen phosphorylase, that is first enzyme in glycogenolysis. If calorie intake is not sufficient to meet the demands of work in heat, then vitamin intake will be compromised as well and supplementation would be required. Ascorbic acid may have some unexplained benefits when consumed above the usual dietary requirements during work in heat.

Minerals and Electrolyte Requirements: It was found that no extract intake of iron is needed and NaCl requirements increase due to loss in sweat; 15 to 16 gm of salt normally taken in diet is quite adequate for acclimatized people. With acclimatization for three days, the sodium losses in sweat get reduced. However, body is not able

to conserve for potassium losses. Therefore, supplementation of potassium in drinks may enhance the process of acclimatization. Coconut water is a good source of potassium.

Fluid Requirements: Nutrient requirements for Indians, 2020, ICMR-NIN data suggests fluid requirement are calculated based on the energy expenditure estimated using indirect calorimetry and doubly labeled water. An intake of 1.5ml was considered per each calorie expended. The fluid requirements are shown in Table 18.11.

Table 18.11: Estimation of Fluid Requirements for Indian Troops based on their Energy Expenditure in hot Environments

Type of troops and environment	Total Energy Expenditure (kcal/day)	Average Fluid Intake from Foods (ml/day)	Average Fluid Intake from Beverages (ml/day)	Average Total Fluid Requirement (ml/day)
Army				
Desert -Combat	3304	1500	3450	4950

Source: RDA and EAR- Nutrient Requirements for Indians, ICMR (2020), NIN

Finally, let us study about the nutritional requirements for astronauts involved with space missions.

18.4.6 Nutritional Requirements for Space Missions

Space exploration represents a new frontier in the nutritional sciences and humans are eating in space since Cosmonaut *Yuri Gagarin's* 108 min flight in 1961. Human presence in space has been almost continuous since these early flights. Missions have ranged from about 15 minutes to 14 months. Until the beginning of the International Space Station, all human habitable spacecrafts were built by Soviet Union or the United States, and both countries have made enormous contributions to the human space flight capabilities, sciences and technology. Throughout the history of human space flight, life sciences research has been an integral part of the missions. As the mission duration increased, the framework of nutrition/research has expanded dramatically. Defence Food Research Laboratory (DFRL), Mysore developed foods for *Sqdn. Ldr. Rakesh Sharma* for his 7-day space voyage in joint Indo-Soviet manned space mission in April 1984 under programme named 'Pavan'.

Varied environmental conditions away from the planet earth are bound to bring certain changes in the body composition of astronauts which might influence the nutrient needs. So before we move on to the nutrient needs, let us study about these changes in the body composition.

Changes in Body Composition

Major stress in space is *microgravity*. Microgravity refers to *an environment in which there is very little net gravitational force, as of a free-falling object, an orbit, or interstellar space*. Now let us look at the effects of microgravity, which are listed in Table 18.10.

Table 18.10: Effects of microgravity on humans

Space motion sickness	Experienced by 60-70% of astronauts and cosmonauts; produces malaise, headache, anorexia, nausea and vomiting. Symptoms appear early in flight and last about 2-7 days.
Cardiovascular deconditioning	Cephalad shift of fluid estimated at 1.5 to 2.0 litres from lower extremities, decreased orthostatic tolerance, increased heart rate, decrease in pulse pressure, tendency towards spontaneous syncope.
Haematological changes	Reduction in plasma volume and red blood cell mass.
Bone mineral loss	Loss of total body calcium in both humans, as well as, animals flown to space from 1 week to more than 237 days.
Muscle deconditioning	Loss of lean tissue and decreased muscle strength.

Several of the pathophysiological changes associated with space flight manifest themselves as the changes in body composition. Space flight presents a unique challenge for quantifying body composition changes since fluid, bone, muscle and adipose tissue levels all vary independently of one another in space, and body weight loss does not follow classical pattern. The body mass measurements were taken for the first time during 28 to 84 day Skylab mission and revealed 0.91 to 3.64 kg losses of preflight body weight. Analysis of component of the weight loss was based on both direct whole body measurements and on indirect metabolic balance data. A conclusion from the analysis was that more than half of the weight loss was from fat free mass and remaining from the fat stores. About half of the total weight loss that occurred within the first two days of flight was due to water loss. All studies of fluid balance during microgravity have indicated a decrease in total body fluids of approximately 500-900 ml.

Most important is muscle loss and limited resistive exercise by crewmembers have been helpful in prevention upto some extent. Skeletal losses unlike muscle losses do appear to be related to the length of flight. About 0.4% to 1.0% of bone minerals are lost per month during space-flight. The role of nutrition in musculoskeletal losses during space flight has not been clearly defined, but data from Skylab missions demonstrate negative nitrogen and potassium balance despite supposedly adequate ingestion of energy and protein. Return to earth poses a major concern. Stress fractures, muscle pulls, ligament stress and inability to ambulate occur and may take 2-8 weeks to resolve. Although experience with long-term space flight has provided considerable confidence in the ability of human body to recover from space flight and readapt to the earth environment, effects observed on the long Sky lab, Mir and Shuttle-Mir missions have convinced the researchers that countermeasures and monitoring are essential to success of space flight.

Now with this basic knowledge about changes in the body composition, let us find out the nutritional requirements meant for space flight. Review the nutritional recommendations given in Table 18.11 to find out how these are different from the normal recommendations.

Nutrient Requirements

The nutritional recommendations for space flight are listed in Table 18.11.

Table 18.11: Nutritional recommendations for space flights

• Men	18 - 30 yrs.	Kcal/d = 1.7 (15.3 w + 679)
	> 30 yrs	Kcal/d= 1.7 (11.6 w + 879)
• Women	18 - 30y	Kcal/d= 1.6 (14.7 w + 496)
	>30 y	Kcal/d= 1.6 (8.7 w + 829)
• Fluid	~2 lit/d	

- **Macronutrients**

Protein	12 - 15% of total calories and animal to plant ratio 60:40
Fat	30 - 35%
	(PUFA:MUFA:SFA1: 1.5 - 2.0 :1
CHO	50 - 58%
Sodium	1.5 - 3.5 g/d
Potassium	3.5 g/d
Calcium	1.2 g/d
Phosphorous-	not more than 1.5 times of calcium
Magnesium	350 mg/d

- **Micronutrients**

Vitamins

Vitamin A	1000 µg RE/d
Vitamin D	10 µg/d
Vitamin E	20 mg/d
Vitamin K	80 µg/d (men), 65 µg/d (women)
Vitamin C	100 mg
Folate	400 µg
Vitamin B ₁₂	2.5 µg
Thiamin	1.5 mg
Riboflavin	1.5 mg
Niacin	20 NE
Vitamin B ₆	2.0 mg
Biotin	50 µg
Pantothenic Acid	5.0 mg

Trace Elements

Iron	10 mg
Manganese	2-5 mg
Zinc	15 mg
Chromium	100-200 µg
Copper	15-3.0 mg
Iodine	150 µg

Now that we have learnt about the nutrient needs, let us get to know how to meet these requirements through food systems. Space food systems are unique. Why these are unique from our normal day-to-day life and the modifications and are essential to meet altered requirements, are highlighted next. We shall begin our study with a review on how these space food systems got introduced. Interestingly, these food systems were faced with a few drawbacks and then improved with each space programme and got into present shape, meeting nutritional demands and food preferences of consumers. So then let us get started.

Space Food System

Mercury (1961-1963) astronauts had to eat bite-sized cubes, freeze dried powders, and semi liquids stuffed in aluminium tubes. For most astronauts, the foods were unappetizing and squeezing the tubes was disliked. Moreover, it was difficult to rehydrate freeze-dried foods and crumbs had to be prevented.

Further, during the Gemini missions (1964-1967), eating improved somewhat. The first things to go were the squeeze tubes. Bite-sized cubes were coated with gelatin to reduce crumbling, and the freeze-dried foods were encased in a special plastic container to make reconstituting easier. With improved packaging came improved food

quality and menus. Gemini astronauts had food choices as shrimp cocktail, chicken and vegetables, butterscotch pudding, and apple sauce, and crew was able to select meal combinations.

By the time of the Apollo programme (1968-1972), the quality and variety of food increased. Apollo astronauts were the first to have hot water, which made rehydration of foods easier and improved the taste of food. Astronauts were also first to use the “spoon bowl,” a plastic container that could be opened and its contents eaten with a spoon.

The task of eating in space improved to a great extent in Skylab (1973-1974). Unlike previous space vehicles for astronauts, Skylab featured a large interior area where space was available for a dining room and a table. Eating for Skylab’s three-member teams was a fairly normal operation: footholds allowed them to situate themselves around the table and “sit” to eat. Added to the conventional knife, fork and spoon, was a pair of scissors for cutting open plastic seals. Because Skylab was relatively large and had ample storage area, it could feature an extensive menu: 72 different food items. It had a freezer and a refrigerator also.

Shuttle (1981 onwards) astronauts have a variety of food items to choose from. They may eat from a standard menu designed around a typical Shuttle mission of 7 days, or may substitute items to accommodate their own tastes. Astronauts can design their own menus. But a dietitian has to ensure balanced supply of nutrients from these astronaut-designed menus.

The standard Shuttle menu repeats after 7 days. It supplies each member with three balanced meals plus snacks. Each astronaut’s food is stored aboard the Shuttle and is identified by a coloured dot affixed to each package.

On the Space Shuttle, food is prepared at a galley installed on the orbiter’s mid-deck. The galley is *a modular unit that contains a water dispenser and an oven*. The water dispenser is used for rehydrating foods and the galley oven is available for warming foods.

Conventional eating utensils are used in space. Astronauts use knife, fork and spoon. The only unusual eating utensil is pair of scissors used for cutting open the packages. Following the meal, food containers are discarded in the trash compartment below the mid-deck floor. Eating utensils and food trays are cleaned at the hygiene station with premoistened towelettes.

Shuttle food system functions well in space. It consists of familiar, appetizing, well-accepted food items that can be prepared quickly and easily. A full meal for a crew of four can be set up in about 5 minutes. Reconstituting and heating the food takes an additional 20 to 30 minutes about the time it takes to fix a snack at home, and far less than it takes to cook a complete meal.

Let us find out the different types of foods that are included in the space food system next.

Types of Foods

Weight and volume have always been the primary design factors for every piece of hardware launched into space. The shuttle is no exception. Weight allowed for food is limited to 1.72 kg per person per day, which includes the 0.45 kg of packaging weight. This as you would realize, require special processing and packaging technique. What are these? Let us see.

Foods are individually packaged and stored for easy handling in the zero gravity of space. All food is precooked or processed so it requires no refrigeration and is either

ready-to-eat or can be prepared simply by adding water or by heating. The only exceptions are the fresh fruits and vegetables stored in the fresh food locker. Without refrigeration, the carrots and celery must be eaten within the first two days of the flight.

The various types of foods are enumerated herewith. Figure 18.2, illustrates space food items.

Thermostabilized (T): Heat processed foods (“off-the-shelf” items) in aluminium or bimetallic tins and retort pouches.

Irradiated (I): Foods preserved by exposure to ionizing radiation and packed in flexible foil-laminated pouches.

Intermediate Moisture (IM): Dried foods with a low moisture content such as dried apricots, which are packed in flexible pouches.

Freeze Dried (FD): Foods that are prepared to the ready-to-eat stage, frozen and then dried in a freeze dryer which removes the water by sublimation. Freeze dried foods such as fruits may be eaten as it is while others require the addition of hot or cold water before consumption.

Rehydratable (R): Dried foods and cereals that are rehydrated with water produced by the Shuttle Orbiter’s fuel cell system, packed in a semi-rigid plastic container with septum for water injection.

Natural Form (NF): Foods such as nuts, crunch bars and cookies. Packed in flexible plastic pouches.

Beverages (B): Dry beverage powder mixes packed in rehydratable containers.



Figure 18.2: Space food items

Another aspect which requires mention while talking about space nutrition is space crop and bioregenerative system. What is this concept? Read the subsequent discussion and find out.

Space Crops and Bioregenerative System

What is a bioregenerative system? Why is it essential?

Nutritional requirements for long flights have been refined, placing more demands on food development. Despite the technological advances and increased variety, most space crews, with the exception of Sky labs Astronauts have not met the nutritional requirements. This problem must be solved. An integrated approach for various studies has been proposed during the meeting at Bad Honnef, Germany in September 1998. Biotechnology holds great promise for devising specific foods that would meet many of the stringent mission requirements. The use of plants in combination of physicochemical technologies for supply of fresh food, water and oxygen has shown to be promising for human life support during planetary exploration. The bioregenerative system for growing food in hydroponic plant growth chambers may be advantageous. However, this will require an additional training of growing and harvesting of crops and selection of various plant species and even use of genetically modified ones for high yields. A primary concern in use of plants is requirement of high light intensity for better yield. Various studies on plants growth under controlled environments have been carried out and some of the plants selected are wheat, lettuce, soybean, potato, sweet potato, tomato, radish, spinach and strawberry. Significant research and development is still required using ground based models and real flight before a bioregenerative food system can be chosen for the sojourn on the Moon or Mars.

Check Your Progress Exercise 4

- 1) Mention the names of a few plants which has been selected for space crops and bioregenerative system.

.....

.....

.....

- 2) Mention briefly the effects of microgravity on humans.

.....

.....

.....

- 3) How does an intermediate moisture food item differ from a rehydrated food item?

.....

.....

.....

- 4) NASA provides 1.2 g calcium in diet to an astronaut in a space shuttle. Why?

.....

.....

.....

- 5) Tick the correct answer:

- i) More than half of the weight loss in space was from

- a) fat free mass
- b) fat reserves
- c) water
- ii) The amount of estimated bone mineral loss per month in space flight is
 - a) 0.1% - 0.4%
 - b) 0.4% - 1.0%
 - c) 1.0% - 4.0%
- iii) Microgravity effect on humans can cause
 - a) decreased plasma volume and decrease in RBC mass
 - b) decreased plasma volume and increase in RBC mass
 - c) increased plasma volume and decrease in RBC mass
- iv) Galley is a modulator unit which contains
 - a) a water dispenser and combustion fuel chamber
 - b) a toaster and water dispenser
 - c) a water dispenser and an oven
- v) The nutritional recommendation for vitamin D in space flight is
 - a) 10 mcg/day
 - b) 100 mcg/day
 - c) 20 mcg/day
- 6) Match the following:

A	B
a) Freeze dried food	i) Stress factor
b) Natural form food	ii) Increases taste of food
c) Hot water	iii) Semi-rigid plastic containers
d) Microgravity	iv) Crunch bars
e) Rehydrated foods	v) Fruits

18.5 LET US SUM UP

This unit discussed important aspects of nutritional needs during emergency situations and under environmental extremes.

Under emergency situation, energy intake of 2100 Kcal along with safe protein intake of 46 g is required. To prevent micronutrient deficiencies, variety of food items should be included in emergency ration for general feeding programme. On the basis of nutritional assessment, the supplementary feeding and therapeutic feeding programmes should be conducted.

For successful adaptation to environmental extremes such as hot, cold, hypoxic (high altitudes) and microgravity (space travel), nutrient requirements are different from normal condition. Various physiological changes take place as adaptive response to such environments. Proper planning, adequate intake of nutrients and fluids is a must for successful acclimatization during expeditions and stay under extreme environments.

18.6 GLOSSARY

Acclimatization	: physiological and metabolic changes response to particular environment which help in adaptation to individual.
Acute Mountain Sickness:	a general term referring o a combination of symptoms, including headache, anorexia, nausea, vomiting and malaise.
Anorexia	: loss of appetite.
Calamity	: any great misfortune or cause of misery which is generally applied to events or disasters.
Cardiac output	: total amount of blood being pumped by the heart over a particular period of time.
Chill blains	: inflammation of the hands and feet caused by exposure to cold and moisture.
Cosmonaut	: a person trained to travel in a spacecraft.
Diuresis	: is the production of urine by the kidneys.
Emergency	: an unforeseen occurrence or a combination of circumstances which calls for an immediate action.
Extreme environment	: an environment where basic needs, like acquisition of food, shelter and protection, require extraordinary efforts.
Famine	: a widespread lack of access to food due to disaster that causes a collapse in the food production and marketing system.
Frostbite	: damage to the skin from freezing due to prolonged exposure to cold temperatures, usually below 32°F.
Galley	: a modular unit that contains a water dispenser and an oven
Homeothermy	: regardless of the environmental temperature, the normal body temperature must be maintained within a relatively narrow range.
Heat stroke	: elevated body temperature as a result of fluid loss and failure of temperature regulatory center in hypothalamus.
High altitude	: terrestrial heights above 2700 m, characterized by decreased barometric pressure resulting in hypobaric hypoxia.
Hydroponic	: growing of plants without soil.
Hypohydration	: decreased water intake induced by high altitude exposure.
Hypoxia	: decreased availability of oxygen at tissue level. Four types are 1) hypoxic hypoxia or hypobaric hypoxia when PO ₂ is reduced 2) anaemic hypoxia is due to low haemoglobin 3) ischemic hypoxia due to decreased flow of blood 4) histotoxic hypoxia is due to toxic chemicals.
Kwashiorkor	: a form of protein energy malnutrition in which only protein is deficient.

Marasmus	: a form of protein energy malnutrition in which a deficiency of energy in the diet causes severe body wasting.
Microgravity	: reduced gravity to near zero due to lack of gravitational force in space.
Monitoring	: an intermittent (regular or irregular) series of observations in time, carried out to sow the extent of compliance with a formulated standard or degree of deviation from an expected norm.
Protein-energy malnutrition (PEM)	: a condition characterized by wasting and increased susceptibility to infection that result from the long term consumption of insufficient energy and protein to meet needs.
Respiratory Quotient	: the ratio of the volume of carbon dioxide expired to the volume of oxygen consumed by an organism or cell in a given period of time.
Stroke volume	: the amount of blood pushed into the aorta with each beat of the heart.
Surveillance	: a repeated survey raising a standard methodology undertaken to provide a series of observations over time.
Syncope	: Partial or complete loss of consciousness with interruption of awareness of oneself and ones surroundings. When the loss of consciousness is temporary and there is spontaneous recovery, it is referred to as syncope
Thermogenesis	: the process of heat production.
Thermoregulation	: the ability of an organism to keep its body temperature within certain boundaries, even when temperature surrounding is very different.
Vasodilation	: the expansion of a blood vessel or capillaries of the skin in response to warm temperature, thus increasing the flow of blood to the surface.

18.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

- 1) Calamity is any great misfortune or cause of misery which is generally applied to events or disasters. Emergency is an unforeseen occurrence or a combination of circumstances which calls for immediate action or remedy. The major nutritional deficiency diseases effecting individuals include underweight, anaemia and marasmus. The cases of vitamin deficiency diseases i.e. blindness, scurvy, beriberi, pellagra and other deficiency diseases are also observed.
- 2) The factors which need to be considered are given in section 18.3. Read them and answer on your own.
- 3) The basic assumptions on which per capita energy requirements are recommended include:
 - The age/sex distribution of the population is a characteristic of developing countries

- The mean height of adult men and women are 169 cm and 155 cm respectively, which is the approximate value in sub-Saharan Africa
 - The body mass index (BMI) (kg/m^2) is between 20-22
 - Physical activity is light
 - All infants are breast-fed from birth to 6 months, and half of the infants of 6-11 months are still breast-feeding and deriving half of their energy and protein requirement from breast milk
- 4) There are several approaches for preventing the onset of micronutrient deficiencies in emergency situations affecting large populations. These include: increasing the daily ration, varying the composition of food basket, including micronutrient fortified foods in ration, and providing supplementation when there is likely to be a specific deficiency based on dietary assessment and overt signs and symptoms. The general ration must provide for a minimum intake of 2100 Kcal per person per day.
- 5) a) - v)
b) - iii)
c) - iv)
d) - i)
e) - ii)
- 6) i) - a)
ii) - b)
iii) - b)
iv) - b)
v) - b)

Check Your Progress Exercise 2

- 1) An environment where basic needs, like acquisition of food, shelter and protection, require extraordinary efforts.
- 2) Any three of the following: decrease oxygen availability and barometric pressure, decrease in haemoglobin saturation, increased energy expenditure, hypoxia, and altered taste thresholds.
- 3) Refer to the micronutrient requirements given in sub-section 18.4.3 and answer the question on your own.
- 4) i) - b)
ii) - a)
iii) - a)
iv) - a)
v) - b)
- 5) a) - ii)
b) - v)
c) - iv)
d) - i)
e) - iii)
- 6) a) True
b) True

- c) False
- d) False
- e) True

Check Your Progress Exercise 3

- 1) The factors responsible for the increased energy requirements in cold and polar environment include:
 - a) The increased energy requirements are due to the 'hobbling' effect of the clothing weight (7-10 kg) and are associated with the efforts of locomotion.
 - b) Energy expenditure in hot environments is increased by a small but significant amount because of additional work of ventilation and increased sweat gland activity.
- 2) An important modifying factor on the thermoregulatory response to cold is the individual's provision of subcutaneous fat, since fat reduces thermal conductance from the core to the body surfaces. The effect of the mechanisms used to protect against heat loss depends on the body surface area in comparison with body mass.
- 3) Individual variations in body size and fatness, acclimatization, and external factors such as air currents, heat gain due to radiation, intensity of work, clothing and relative humidity increases food intake in Antarctica.
- 4)
 - i) - a)
 - ii) - a)
 - iii) - a)
 - iv) - c)
- 5)
 - a) - iii)
 - b) - i)
 - c) - ii)

Check Your Progress Exercise 4

- 1) Wheat, lettuce, soybean, potato, sweet potato, tomato, radish, spinach and strawberry.
- 2) Refer to Table 18.10 in sub-section 18.4.6 and answer the question on your own.
- 3) Intermediate moisture food items are those with low moisture content such as dried apricots, which are packed in flexible pouches. Rehydrated foods are dried foods rehydrated with water, packed in a semi-rigid plastic container with septum for water injection.
- 4) NASA provides 1.2 g calcium in diet to an astronaut in a space shuttle because about 0.4% to 1.0% of bone minerals are lost per month during space-flight.
- 5)
 - i) - a)
 - ii) - b)
 - iii) - a)
 - iv) - c)
 - v) - a)
- 6)
 - a) - v)
 - b) - iv)
 - c) - ii)
 - d) - i)
 - e) - iii)