FUNDAMENTALS OF HUMAN HEALTH AND NUTRITION

Prakash Shetty
London School of Hygiene and Tropical Medicine, UK

Keywords: Food, diet, vegetarians, macronutrients, dietary energy, micronutrients, water, protein-energy imbalance, malnutrition, obesity, osteoporosis, dietary deficiencies, energy metabolism, heat regulation

Contents

Summary

Metabolism is the sum total of all chemical reactions within a body. It is a key factor in human nutrition. It can be divided into (a) energy release and breakdown and (b) energy input for building compounds. Metabolic rate is the energy used by a body per unit of time. Energy is provided by the food that is consumed but energy intake is not constant and so energy must be stored, usually either as lipids (or fat) or as carbohydrates. Body

size (body weight and body surface area) affects metabolic rate, and body weight is often used in practice to predict metabolic rates of individuals.

Energy sources vary and this is important to our understanding of how energy is released in the body. Energy is derived by oxidation (burning). Fats yield more energy than carbohydrates and proteins. For example, lipids can yield 9 calories/gram while carbohydrates and proteins yield about 4 calories/gram.

Body temperature is a result of internal heat production plus heat absorption from the ambient air less radiation losses. Water plays an important role in this temperature regulation. Thermoregulation involves physiological and behavioral adjustments. Nerve cells in the skin and other parts of the body monitor temperature. There are warm receptors and cold receptors in the skin that can sense changes in skin and blood temperature. Cooling mechanisms include sweating, vasodilation (increasing blood flow to the extremities), and panting. Warming mechanisms include vasoconstriction (constricting blood flow to the extremities), shivering, and chemical reactions within the body to produce heat instead of adenosine triphosphate (ATP).

ATP is a high-energy compound considered to be the universal currency of biological energy. The synthesis of ATP is a central process in human nutrition. The energy in the food we ingest is converted into ATP. Each day every one of us of makes, breaks down, and remakes in the mitochondria in our bodies an amount of ATP that is about the same as our body weight. The energy in the ATP molecule powers all biological processes. Thus, the synthesis of ATP is essential for life.

The mechanisms involved in body weight regulation in humans include genetic, physiological, and behavioral factors. Stability of body weight and body composition requires that energy intake matches energy expenditure and that nutrient balance is achieved.

Nutrients both macro- and micro- (the latter include vitamins and minerals) play an important function in the body's metabolism.

This article briefly reviews the fundamental nutrition of humans and the constituents of their habitual diets and the foods they consume. A brief outline of some of the common nutritional disorders is also presented and thus provides an overview for the more specialist articles in this the topic area.

1. Introduction

Food is something we eat to keep us alive and healthy, and the subject of nutrition largely deals with this aspect of food. Food means all sorts of different things to different people. The primitive tribes people uses the term *food* for familiar and edible substances such as flesh, fruits, roots, tubers, and so on, which satisfy their hunger when they eat them (see *Ethnographic Aspects of Human Nutrition*). In an advanced industrialized society the concept of food can be sophisticated and can vary a great deal between individuals (see *Regional and Cultural Differences in Nutrition*). In scientific terms, food is defined as that which is essential for the growth, normal functioning, and health of living organisms (be they unicellular or multicellular). Food is essentially a collection of substances which are needed to keep the organism alive and functioning in a normal and healthy manner.

Food is a mixture of chemicals, and each class of chemical substance in food has a chemical name, i.e. carbohydrates, proteins or amino acids, fats, fibers, vitamins, minerals, and water. Apart from the minerals and water that are present in foods, which are termed inorganic, the rest of the chemical matter is said to be organic. The three principal constituents of food, also called the proximate principles, are carbohydrates, proteins, and fats. They are made up of the elements carbon, hydrogen, and oxygen, with proteins having nitrogen (and in some cases sulfur) in addition. These proximate principles are important sources of dietary or food energy but also fulfill a number of other important roles. As opposed to vitamins and minerals that are referred to as *micronutrients*, carbohydrates, proteins, and fats that constitute the bulk of the nutrients in the daily diet are referred to as *macronutrients*.

2. Functions of Food

2.7 Food as a Source of Energy

One of the important functions of food within the body is to produce energy, both mechanical and heat energy. The products of digestion are absorbed into the bloodstream and are oxidized by oxygen to release the energy required by the body. Macronutrients are the important source of energy in the food although their relative contributions vary, with fats contributing the highest and protein in the diet contributing less than the others. The chemical energy contained in foods in the macronutrients can be determined in a bomb calorimeter. The energy determined by bomb calorimetry is termed the gross energy (GE) of a food or of the specific macronutrient. However, not all the energy in the food is available to the animal or human that eats the food. There is an important reason for that: Not all the food eaten is absorbed from the digestive tract to become available as fuel for metabolism or for use by the body.

2.8 Energy Metabolism

Energy is defined as the potential to perform work. Energy is an abstraction that can be measured only in reference to defined standard conditions. Thus all defined units to measure energy are equally absolute. All forms of energy can be converted into heat energy, and food energy can also be expressed as heat energy. The joule is the preferred unit for expressing electrical, mechanical, or chemical energy. The joule is defined as the amount of energy used when 1 kilogram is moved a distance of 1 meter by 1 newton of force. The joule can be converted to ergs, watt-seconds, and calories. Calorie [or Kilocalorie (Kcal)] is the unit of heat energy. A calorie is defined as the heat required to raise the temperature of one gram of water through one degree centigrade, e.g. from 16.5 ºC to 17.5 ºC. Most nutritionists work in calories, or rather multiple units such as Kcal (= 1000 calories) which is equal to 4.184 kiloJoules (kJ). Increasingly the scientific literature in nutrition tends to prefer the use of joules over calories.

Energy is required by all living creatures to perform the "work" of living. To live and to carry out our normal day-to-day activities, every body produces a lot of heat every day. Body tissues must be metabolized to produce this heat. Two key points emerge: (1) to supply energy to a body is more costly, both biologically and economically, than supplying any other nutrient. (2) the primary factors that determine the efficiency of utilization of food energy are the amounts lost largely as heat and in feces.

A number of abbreviations are used to describe energy fractions in the body. The first measurement in a nutritional evaluation of energy exchange is gross energy. Gross energy (GE) or heat of combustion is the energy released as heat when an organic substance is completely oxidized to carbon dioxide and water. Briefly, the intake of food energy (IE) is the gross energy of food consumed. A substantial portion of IE is lost as fecal energy (FE), and the difference (IE-FE) is termed apparent digestible energy (DE). Portions of this are lost as urinary energy (UE) and gaseous energy (GE). The remainder (IE–FE–UE–GE) is termed metabolizable energy (ME). ME may be recovered as a useful product (RE) such as tissue energy (TE), milk energy for lactating females (LE), and so on, or may be lost as heat energy (HE). Energy lost as HE may be the result of a variety of functions including basal metabolism (H_eE), digestion and absorption activity (H_jE), thermal regulation (H_cE), and waste formation and excretion (H_wE). An increase in heat production following the intake of food is termed heat increment (H_jE) and includes (H_dE, H_fE, H_rE, and H_wE).

The laws of thermodynamics and the Law of Hess state the fundamental principles on which bioenergetics (the study of energy transformations in biological systems) is based. Simply stated, these laws assert that (a) energy can be neither created nor destroyed but may be converted from one form to another, (b) all forms of energy can be quantitatively converted to heat, and (c) heat generated in a net transformation is independent of the path of conversion. The basis of bioenergetics as defined by these laws and application to human nutritional energetics may be stated by use of the terminology defined earlier: IE=FE + GE UE + HE + RE. This identity partitions the food energy consumed into the major components associated with bioenergetics. It can be expanded to include a few or many of the intermediate steps involved, and each component can be subdivided into components. The details of this are probably outside the scope of this overview but the reader is referred to the more specialized articles in this volume (see *Nutritional Deficiency and Imbalances*).

All bodies derive energy from carbohydrates, fats, and protein. Most of this energy is obtained from carbohydrates, however. The relative amount from carbohydrates versus fats varies depending on the daily diet of the individual. All bodies require amino acids derived from proteins in their diet, at the tissue level, for protein synthesis.

It has been estimated that, of the macronutrients from a typical diet, 99% of ingested carbohydrate, 95% of fat, and 92% of protein is absorbed. Nitrogen-containing compounds (chiefly proteins) are not completely oxidized by the body. They are converted to urea and excreted in urine; urea retains about 25% cent of the chemical energy of the original protein. Energy lost through feces (unabsorbed macronutrients) and through urine (mainly as urea) needs to be subtracted from the gross energy of a food to estimate the available energy to the body. This value is termed the metabolizable energy (ME) of the food. In ideal situations, the metabolizable energy intakes of individuals on a mixed diet can be determined by performing bomb calorimetry on food, feces, and urine. To simplify the determination of the ME content of foods, Atwater estimated separately the ME content of the macronutrients. The ME content of foods or diets can then be estimated from the amounts of these individual macronutrients in the diets (see Table 1).

Macronutrient absorbed	**%**	**ME (kJ/g)**	**Atwater factor (kCal/g)**
Carbohydrates			
Glucose	99	15.4	4
Starch	99	17.3	4
Protein	92	15.9	4
Fat	95	37.1	9

Table 1. Metabolizable energy of macronutrients

2.2.1 Energy Balance

Energy balance is the difference between energy intake and energy expenditure. Positive energy balance occurs when either energy intake exceeds the energy expenditure or when expenditure is lower than the habitual energy intake. Positive energy balance leads to storage of excess energy largely as fat and is indicated by a gain in body weight—body weight changes being a simple but crude measure of changes in energy balance. In negative energy balance, weight loss occurs since the intake is unable to match the level of energy expended by the individual. Overweight and obesity are conditions associated with positive energy balance while under-nutrition signalled by loss of weight is often the result of continued negative energy balance (See Malnutrition, Hunger and Satiety, Obesity and Anorexia).

-
-
-

Bibliography

Langley L.L. et al. (1974). *Dynamics, Anatomy and Physiology*. Fourth Edition. 1974. New York: McGraw-Hill Book Company. [An encyclopedic treatment of these important relationships.]

Latham M.C. (1997). Human Nutrition in the Developing World. Rome: Food and Agriculture Organization. [A comprehensive introduction to nutritional problems of the developing world.]

National Research Council (1989). *Recommended Dietary Allowances*, Tenth Edition, Washington, DC, US: National Academy of Sciences [This is the main accepted source on nutrient allowances for the maintenance of good health.]

Tsang R.C. and Nichols B.L. (1988). *Nutrition During Infancy*, 440 pp. Philadelphia, US: Hanley and

Belfus, Inc. [This is a nutrition book that is informative, readable, entertaining, and, at times, provocative.]

Underwood E.J. (1977). Trace *elements in Human and Animal Nutrition*, Fourth Edition. New York: Academic Press. [A classic account of the work on trace elements and their role and functions.]

Biographical Sketch

Dr Prakash Shetty is currently Professor of Public Health Nutrition at the Institute of Human Nutrition, University of Southampton, UK and Editor in Chief of the European Journal of Clinical Nutrition. Until 2005 he served as Chief, Nutrition Planning, Assessment & Evaluation Service, in the Food & Nutrition Division of the Food & Agriculture Organisation of the UN (FAO) in Rome, Italy. Before joining the FAO he was Professor of Human Nutrition at the London School of Hygiene & Tropical Medicine (London University). Since his appointment in 1993 to the Chair of Human Nutrition at London University he has been Head of the Public Health Nutrition Unit, Department of Epidemiology & Population Health at the London School. He graduated from Madras University with an MBBS degree (1968) and an MD (1972), both from the Christian Medical College, Vellore, India. He was awarded his PhD in Medicine from Cambridge University, UK while working at the MRC Dunn Nutrition Laboratory in Cambridge and was elected Fellow of the Faculty of Public Health (FFPH) and of the Royal College of Physicians of London (FRCP). Prior to moving to the UK, he was Professor and Chairman of the Department of Physiology at St Johns Medical College in Bangalore from 1980 to 1993 and established a Nutrition Research Centre of which he was the Director with research interests in energy and protein metabolism. He has over 150 peer reviewed publications, chapters in textbooks and has edited several books and monographs in nutrition. He has served on several Expert Committees, both nationally and on International Committees and Consultations of the FAO, WHO, UNU and IAEA as well as on scientific taskforces and advisory committees of funding agencies and charities. At FAO he has been the principal focal point and led the FAO Secretariat for the FAO/WHO/UNU Joint Expert Consultations on Energy in human nutrition; and Protein & Amino acids in human nutrition; and more recently the WHO/FAO Joint Expert Consultation on Diet, nutrition and the prevention of non-communicable diseases. He has been a member of the International Dietary Energy Consultancy group (IDECG) and also serves as a member of the International Reference Group for WHO's global strategy on diet, physical activity and health and Chaired the IUNS Taskforce on Evidence Based Nutrition. He has served and continues to serve on the Editorial Boards of several international journals in nutrition like Public Health Nutrition, and Journal of Food Science & Nutrition and was until 2005 the Deputy Editor of the British Journal of Nutrition. He currently serves as a Governor of the British Nutrition Foundation and on the Scientific Council of the Nestle Foundation, Lausanne, Switzerland.