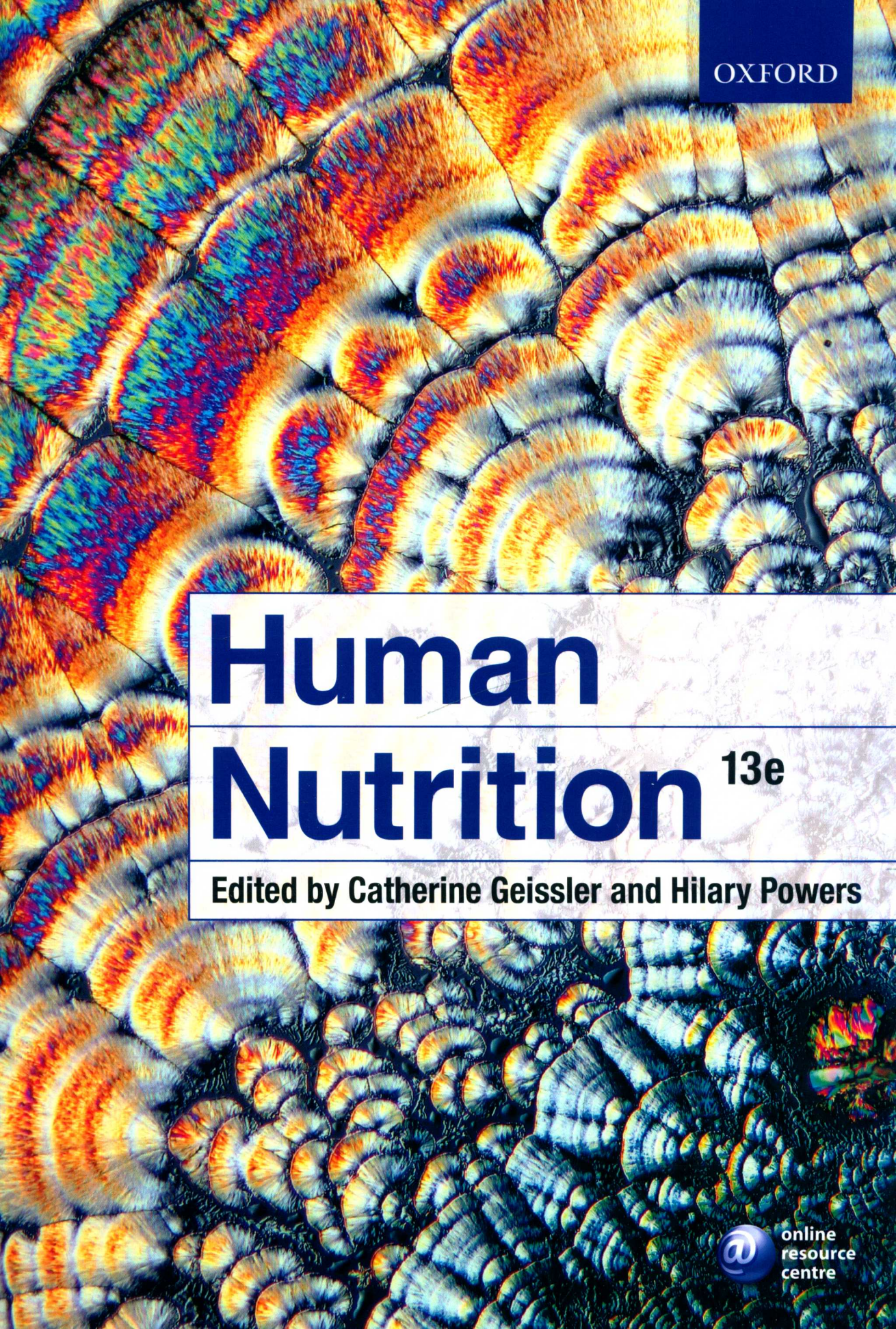
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Human
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Human Nutrition

THIRTEENTH EDITION

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OXFORD
UNIVERSITY PRESS

OXFORD
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Great Clarendon Street, Oxford, OX2 6DP,
United Kingdom

Oxford University Press is a department of the University of Oxford.
It furthers the University's objective of excellence in research, scholarship,
and education by publishing worldwide. Oxford is a registered trade mark of
Oxford University Press in the UK and in certain other countries

Tenth edition 2000
Eleventh edition 2005
Twelfth edition 2011

Impression: 1

Published in the United States of America by Oxford University Press
198 Madison Avenue, New York, NY 10016, United States of America

British Library Cataloguing in Publication Data
Data available

Library of Congress Control Number: 2017932600

ISBN 978–0–19–876802–9

Printed in Great Britain by
Bell & Bain Ltd., Glasgow

Human Nutrition

Preface

This 13th edition of Human Nutrition covers a wide range of topics in the science of nutrition from the chemistry of food components and physiology of digestion, through nutrient requirements and effects of deficiencies and excesses, specific needs and food habits in differing age groups and physiological conditions, nutrition related diseases and their epidemiology, to clinical and public health measures designed to confront nutritional problems. It is intended as a textbook for undergraduate and graduate nutrition students and as a reference text for practitioners and researchers.

In the 7 years since publication of the 12th edition of this work, the world has experienced significant changes in the extent of malnutrition, both under-nutrition and over-nutrition, and also in the science of nutrition. Whilst the format of our previous editions remains largely unchanged, the authors have extensively updated the content, and several new chapters have been added to give more prominence to the topics of food safety, the relationship between nutrition and the nervous system, and diet and epigenetics.

Some of the significant changes in nutrition that have occurred over the intervening period include an increase in the prevalence of obesity and associated health conditions, as well as world-wide documentation of measures used to prevent or improve these conditions. Various bodies encourage healthy eating and some governments work with industry to explore ways of reducing fat, sugar and salt intake, others have imposed taxation or other legislation to curb excessive consumption of those food constituents. There is now a much greater awareness globally of the adverse effects of overconsumption, but more needs to be done to reduce the burden of obesity. Nutritionists are working much more closely with scientists from other professions, to broaden our understanding of the metabolic, socio-economic and environmental causes. Never before have nutritional issues been so prominent in the media.

On the other hand, undernutrition remains a stark reality for many low and middle income countries, for refugees, and for the poorest in high income countries. Many countries now have a 'double burden' of under and over-nutrition, which complicates the development of relevant policies and actions. Much has been done, but more needs to be done, to elucidate the causes and impact of chronic low intakes of energy or micronutrients, and how best to address dietary inadequacies worldwide. New methods of collaboration are being developed between the various contributors to the international nutrition system, including academics, international agencies, governments, civil society, donors, food industry and others, in an attempt to speed up improvements in the wide prevalence of malnutrition.

This new edition of Human Nutrition is intended to keep the reader abreast of developments in our understanding of food and nutrition, from molecular mechanisms to nutrition policies designed to address under-nutrition as well as over-consumption. We are most grateful to our many authors for sharing so lucidly their expertise and insight in contributing to this new edition.We are also grateful to authors of chapters in the previous edition who have not contributed directly to the new edition.

Catherine Geissler
Hilary Powers

July 2016

New to this edition

- Three new chapters explore food safety, nutrition and the nervous system, and diet and epigenetics.
- A completely new and enhanced design and layout ensures that information is easy to navigate.

For extended coverage on the topics included in this textbook, in addition to further reading and weblinks for each chapter, visit the dedicated Online Resource Centre at **www.oxfordtextbooks.co.uk/orc/geissler13e/.**

Abbreviations

AA	arachidonic acid
ACE	angiotensin-converting enzyme
ACH	arm–chest–hip index
AD	Alzheimer's disease
ADH	alcohol dehydrogenase
ADHD	attention deficit hyperactivity disorder
ADI	acceptable daily intake
ADP	adenosine diphosphate
AIDS	acquired immune deficiency syndrome
ALD	alcoholic liver disease
ALDH	aldehyde dehydrogenase
ALP	atherogenic lipoprotein phenotype
AMC	arm muscle circumference
AMDR	acceptable macronutrient distribution range
AMP	adenosine monophosphate
AN	anorexia nervosa
ANGPLT	angiopoietin-like proteins
ANLS	astrocyte–neuron lactate shuttle
APT	atopy patch test
AR	attributable risk
ARBD	alcohol-related birth defect
ARFID	avoidant/restrictive food intake disorder
ART	anti-retroviral therapy, assisted reproductive technology
ASP	animal source protein
ATP	adenosine triphosphate
AUDIT	Alcohol Use Disorder Identification Test
BAPEN	British Association for Parental and Enteral Nutrition
BAT	brown adipose tissue
BCAA	branched-chain amino acids (leucine, isoleucine, valine)
BED	binge eating disorder
BER	base excision repair
BF	body fat
BFH	baby-friendly hospital
BIA	bio-impedance analyser
BIE	bioelectrical impedance
BMC	bone mineral content
BMD	bone mineral density
BMI	body mass index
BMR	basal metabolic rate
BN	bulimia nervosa
bp	base pair
BSE	bovine spongiform encephalopathy
BSID	Bayley Scores of Infant Development
BSF	biceps skinfold thickness
BV	biological value
cAMP	cyclic adenosine monophosphate
CAC	Codex Alimentarius Commission
CAGE	Cut, Annoyed, Guilty, Eye-Opener
CAT	computer-assisted tomography
CBT	cognitive behavioural therapy
CCK	cholecystokinin
CD	Crohn's disease, cluster of differentiation
CDC	Centers for Disease Control and Prevention (USA)
cDNA	complementary DNA
cds	coding sequence
CED	chronic energy deficiency
CEL	carboxyl ester lipase
CETP	cholesterol ester transfer protein
CGI	comparative gene identification
CHD	coronary heart disease
CI	confidence interval
CMAM	Community Management of Acute Malnutrition
CMPI	cow's milk protein intolerance
CMV	cytomegalovirus
CNS	central nervous system
CoA	coenzyme A
COMA	Committee On Medical Aspects of Food Policy
COPD	chronic obstructive pulmonary disease
COUP	chicken ovalbumin upstream promoter
COX	cyclo-oxygenase
CRP	C-reactive protein
CRD	component-resolved diagnostics
CSF	cerebrospinal fluid
CUG	catch-up growth
CVA	cerebrovascular accident
CVD	cardiovascular disease
CYP	cytochrome P450 mono-oxygenase
DA	dopamine
DALY	disability-adjusted life years
DAS	diallyl sulfide
DADS	diallyl disulfide
DBPCFC	double-blind placebo-controlled food challenge
DCCT	Diabetes Control and Complications Trial
DEFRA	Department of the Environment, Food and Rural Affairs (UK)
DES	dietary energy supply
DEXA	dual-energy X-ray absorptiometry
DFE	dietary folate equivalents
DHA	docosahexaenoic acid, dehydroascorbic acid

DPA	docosapentaeonic acid
DHSS	Department of Health and Social Security (UK)
DIAAS	digestible indispensable amino acid score
DIT	diet-induced thermogenesis, di-iodotyrosine
DMFT	index of decayed, missing, and filled teeth (permanent)
Dmft	index of decayed, missing, and filled teeth (deciduous)
DNA	deoxyribonucleic acid
DNL	de novo lipogenesis
DNMT1	DNA methyltransferase 1
DNSBA	Diet and Nutrition Survey of British Adults
DoH	Department of Health (UK)
DRI	dietary reference intake (USA)
DRV	dietary reference value (UK)
dUMP	deoxyuridine monophosphate
EAA index	essential amino acid index
EAR	estimated average daily requirements (UK)
ECF	extracellular fluid
ED	elemental diet, eating disorder
EDD	estimated date of delivery
EDI	estimated daily intake
EDTA	ethylene diamine tetra-acetic acid
EFA	essential fatty acid
EFS	Expenditure and Food Survey
EFSA	European Food Safety Authority
EGF	epidermal growth factor
EGRAC	erythrocyte glutathione reductase activation coefficient
eLENA	eLibrary of Evidence for Nutrition Actions – WHO
ELISA	enzyme-linked immunosorbent assay
ENS	enteric nervous system
EoE	eosinophilic oesophagitis
EPA	eicosapentaenoic acid, Environmental Protection Agency (USA)
ER	endoplasmic reticulum, oestrogen receptor
ERP	event-related potential
ESPEN	European Society for Parenteral and Enteral Nutrition
EU	European Union
FA	fatty acid
FABP	fatty acid binding protein
FACS	fluorescence activated cell sorter
FAD	flavin adenine dinucleotide, fatty acid desaturase
FAEE	fatty acid ethyl ester
FAO	Food and Agriculture Organization of the United Nations
FAS	fetal alcohol syndrome
FAT	fatty acid translocase
FATP	fatty acid transport protein
FBS	food balance sheet
FDA	US Food and Drug Administration
FDG-PET	fluorodeoxyglucose positron emission tomography
Fe	iron
FES	Family Expenditure Survey
FFA	free fatty acid
FFM	fat-free mass
FFQ	food frequency questionnaire
FH	familial hypercholesterolaemia
FIGLU	formiminoglutamic acid
FODMAP	fermentable oligosaccharides, disaccharides, monosaccharides, and polyols
FOSHU	foods for specified health use
FPG	fasting plasma glucose
FSA	Food Standards Agency
FSIS	Food Safety and Inspection Service (USA)
FTT	failure to thrive
FXr	farnesyl X receptor
GAIN	Global Alliance for Improved Nutrition
GALT	gut-associated lymphatic tissue
GATT	General Agreement on Tariffs and Trade
GAVI	Global Vaccine Alliance
GDP	guanosine diphosphate
GI	gastrointestinal, glycaemic index
GINA	Global Database on the Implementation of Nutrition Action
GIP	gastric inhibitory peptide
GLP	Good Laboratory Practice
GLP-1	glucagon-like peptide 1
GM	genetically modified
GPx	glutathione peroxidase
GRAS	generally regarded as safe
GWAS	genome-wide association studies
GTF	glucose tolerance factor
GTP	guanosine triphosphate
H^+	hydrogen ions
HACCP	Hazard Analysis Critical Control Point
Hb	haemoglobin
HBV	hepatitis B virus
HCG	human chorionic gonadotrophin
HDL	high density lipoproteins
HEP	high energy phosphate
HFA	height for age
HFCS	high-fructose corn syrup
HIV	human immunodeficiency virus
HL	hepatic lipase
HLA	human leucocyte antigen

HPLC	high-performance or high-pressure liquid chromatography
HPV	human papillomavirus
HSL	hormone-sensitive lipase
IAA	indispensable amino acid
IAP	intracisternal A particle
IARC	International Agency for Research on Cancer
IBS	irritable bowel syndrome
ICC	interstitial cells of Cajal
ICF	intracellular fluid
IDA	iron-deficiency anaemia
IDD	iodine deficiency disorder
IDDM	insulin-dependent diabetes mellitus
IDL	intermediate density lipoproteins
IF	intestinal failure
IFG	impaired fasting glucose
IFN-γ	interferon-gamma
IFPRI	International Food Policy Research Institute
Ig	immunoglobulin
IGF-1	insulin-like growth factor 1
IGT	impaired glucose tolerance
IHD	ischaemic heart disease
IHS	Integrated Household Survey
IL	interleukin
ILSI	International Life Sciences Institute
IMTG	intramyocellular triacylglycerol
IOC	International Olympic Committee
IOM	Institute of Medicine
IOTF	International Obesity Task Force
IP_3	inositol-1,4,5-triphosphate
IPM	integrated pest management
IU	international unit
IUGR	intra-uterine growth retardation
JECFA	Joint Expert Committees on Food Additives
JEMRA	Joint Expert Meeting on Microbial Risk Assessment
JMPR	Joint Meetings on Pesticide Residues
K	potassium
LA	linoleic acid
LBM	lean body mass
LBW	low birthweight
LCAT	lecithin-cholesterol acyltransferase
LCD	low calorie diet
LCPUFA	long-chain polyunsaturated fatty acid
LCTG	long-chain triglyceride
LDL	low density lipoproteins
LLNA	large neutral amino acid
LMICs	low and middle income countries
LMP	last menstrual period
LNS	lipid-based nutritional supplement
LOFFLEX	low-fat fibre-limited exclusion diet
LOX	lipoxygenase
LPL	lipoprotein lipase
LPS	lipopolysaccharide
LRNI	lower reference nutrient intake
LTI	lower threshold intake
MAC	mid-arm circumference
MAFF	Ministry of Agriculture, Fisheries and Food (UK)
MAM	moderate acute malnutrition
MAST	Michigan Alcohol Screening Tool
MCT	medium-chain triglycerides
MDG	Millennium Development Goal
ME	metastable epiallele
Mg	magnesium
MHC	major histocompatibility complex
MIT	mono-iodotyrosine
MJ	megajoule
MMA	methylmalonic acid
MMC	migrating motor complex
MNA	Mini Nutritional Assessment
MODY	maturity-onset diabetes of the young
MPR	minimum protein requirement
MRI	magnetic resonance imaging
mRNA	messenger RNA
miRNA	microRNA
MRS	magnetic resonance spectroscopy
MSI	minimum safe intake
MTCT	mother-to-child transmission
MUAC	mid-upper arm circumference
MUFA	mono-unsaturated fatty acid
MUST	Malnutrition Universal Screening Tool
MZ	monozygotic
N4G	nutrition for growth
Nac	nucleus accumbens
NAD	nicotinamide adenine dinucleotide
NAADP	nicotinic acid adenine dinucleotide phosphate
NADP	nicotinamide adenine dinucleotide phosphate
NAFLD	non-alcoholic fatty liver disease
$NaHCO_3$	sodium bicarbonate
NCD	non-communicable disease
NCGS	non-coeliac gluten sensitivity
ncRNA	non-coding RNA
NDNS	National Diet and Nutrition Survey
NEAT	non-exercise activity thermogenesis
NEC	necrotizing enterocolitis
NEFA	non-esterified fatty acids
NFS	National Food Survey
NHANES	National Health and Nutrition Examination Survey
NK	natural killer
NMN	*N*-methyl nicotinamide
NMR	nuclear magnetic resonance

NOAEL	no adverse effect level
NR-NCD	nutrition-related non-communicable disease
NSP	non-starch polysaccharide
NSAID	non-steroidal anti-inflammatory drug
NTD	neural tube defect
ODA	official development assistance
ODS	Office of Dietary Supplements
OGTT	oral glucose tolerance test
ONL	obligatory nitrogen loss
ONS	oral nutritional supplements, Office of National Statistics
OR	odds ratio
OSFED	other specified feeding and eating disorders
Pi	inorganic phosphate
PAH	polycyclic aromatic hydrocarbon
PAL	physical activity level
PAT	Paddington Alcohol Test
PBM	peak bone mass
PBB	polybrominated biphenyl
PCB	polychlorinated biphenyl
PCI	protein C inhibitor
PCOS	polycystic ovary syndrome
PDCAAS	protein digestibility corrected amino acid score
PEM	protein–energy malnutrition
PER	protein efficiency ratio
PEU	protein–energy undernutrition
PFK	phosphofructokinase
PGC	primordial germ cell
PHE	Public Health England
PHV	peak height velocity
PIVKA	protein induced by vitamin K absence or antagonism
PLRP	pancreatic lipase-related protein
PPAR	peroxisome proliferation activated receptor
PPU	postprandial protein utilization
PRI	population reference intake (of nutrients)
PRSL	potential renal solute load
P/S ratio	polyunsaturated/saturated fatty acid ratio
PSD	psychosocial deprivation
PSP	plant source protein
PT	preterm
PTH	parathyroid hormone
PTL	pancreatic triacylglycerol lipase
PUFA	polyunsaturated fatty acids
PVC	polyvinyl chloride
PWS	Prader–Willi syndrome
PYY	peptide YY
RAE	retinoid activity equivalent
RAR	retinoic acid receptor
RAST	radio-allergosorbent test (food allergy)
RBC	red blood cell
RBP	retinol binding protein
RCT	randomized controlled trial
RDA	recommended daily allowance
RDI	recommended daily intake
rDNA	recombinant DNA
RDR	relative dose response
RE	retinol equivalence
REACH	Resource for Advancing Children's Health
REE	resting energy expenditure
RfD	reference dose
RISK	RNA-induced silencing complex
RMR	resting metabolic rate
RNA	ribonucleic acid
RNI	reference nutrient intake (UK)
ROS	reactive oxygen species
RQ	respiratory quotient
RR	relative risk
RS	resistant starch
RTF	ready to feed (infant formula)
RUTF	ready to use therapeutic foods
RXR	retinoic X receptor
SAA	sulfur amino acids
SAC	*S*-allylcysteine
SACN	Scientific Advisory Committee on Nutrition
SADQ	Severity of Alcohol Dependence Questionnaire
SAM	*S*-adenosylmethionine, severe acute malnutrition
SAMC	*S*-allylmercaptocysteine
SCF	Scientific Committee on Food (EU)
SCFA	short-chain fatty acid
SCID	severe combined primary immunodeficiencies
SD	standard deviation
SENECA	Survey in Europe on Nutrition and the Elderly
SFA	saturated fatty acid
SGA	small for gestational age, subjective global assessment
SGLT	sodium glucose-linked transporter
SIBO	small intestinal bacterial overgrowth
SMR	standardized mortality ratio
SNP	single nucleotide polymorphism
SOD	superoxide dismutase
SPA	spontaneous physical activity
SR	sarcoplasmic reticulum (complex)
T_3	tri-iodothyronine
T_4	tetra-iodothyronine
TAG	triacylglycerol

TBW	total body water
TCA cycle	tricarboxylic acid cycle
TDI	tolerable daily intake
TEE	total energy expenditure
tHcy	total homocysteine
TIBC	total iron-binding capacity
TMAO	trimethylamine oxide
TMP	thymidine monophosphate
TNF	tumour necrosis factor
TNF-α	tumour necrosis factor alpha
TPN	total parenteral nutrition
TRL	triacylglycerol-rich lipoprotein
tRNA	transfer RNA
TSF	triceps skinfold thickness
TSH	thyroid-stimulating hormone
TUL	tolerable upper limit
UC	ulcerative colitis
UCP-1	uncoupling protein 1
UDP	uridine diphosphate
UF	uncertainty factor
UL	upper tolerable intake level
UNICEF	United Nations Children's Fund
UNSCN	United Nations Standing Committee on Nutrition (also SCN)
UNU	United Nations University
USDA	United States Department of Agriculture
USRDA	United States Recommended Daily Allowance
UTP	uridine triphosphate
UTR	untranslated region
VAD	vitamin A deficiency
VAS	visual analogue scale
vCJD	new variant Creutzfeldt–Jakob disease
VDR	vitamin D receptor
VKDB	vitamin K deficiency bleeding
VLBW	very low birthweight
VLCD	very low calorie diet
VLDL	very low density lipoproteins
Vo_2max	maximal oxygen uptake
WBC	white blood cell
WCRF	World Cancer Research Fund
WFA	weight for age
WFH	weight for height
WFP	World Food Programme
WFS	World Food Summit
WHO	World Health Organization
WIC	Women, Infants and Children – Food and Nutrition Service, USA
WIN	Weight Control Information Network
WOF	World Obesity Federation (formerly IOTF)
WTO	World Trade Organization
Zn	zinc

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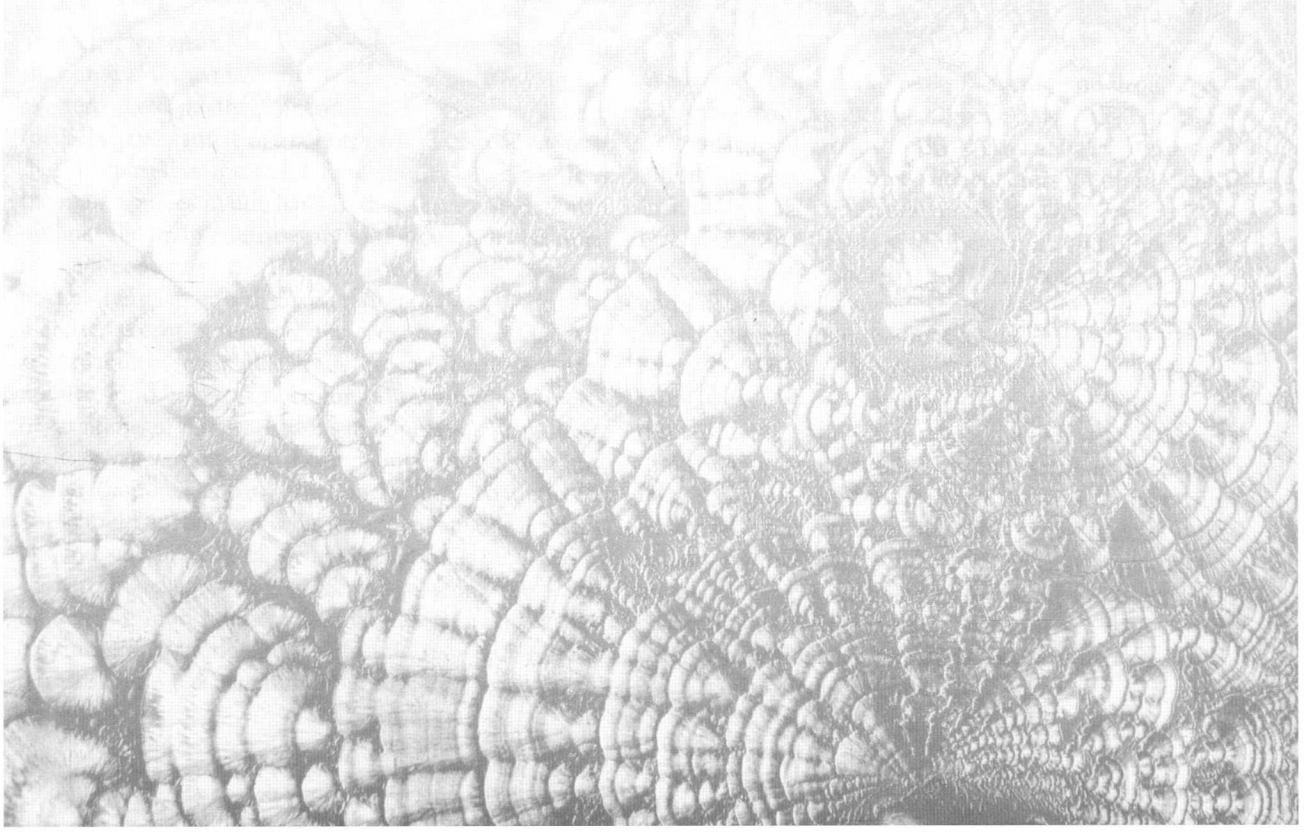
Contents

PART 1

Food and nutrients



1 Food and nutrient patterns

John Kearney and Gerda Pot

OBJECTIVES

By the end of this chapter you should be able to:

- identify the main sources of nutrients in Western diets
- understand the social, psychological, geographic, and economic factors determining food choices and diet patterns
- appreciate the similarities and variability in food and nutrient patterns in different population groups and countries
- be aware of changing trends over time, including novel foods.

1.1 Introduction

This chapter examines food and nutrient patterns in the context of the major foods and food products in the Western diet and their nutritional importance. Taking the UK as an example of a country with a typical Western diet, it considers the main food groups and identifies the main sources of nutrients in the Western diet. It also outlines the main contributors to the nutrient and non-nutrient content of the UK diet. Another important aspect of this chapter is the exploration of the variations in dietary patterns in terms of the causes of variation such as availability (geographic, trade, demand) as well as economics, food beliefs, and cultural differences. Examples of variations in dietary patterns in population subgroups, such as vegetarians and those defined by religion and region (national and international), are also outlined. This should enable the reader to appreciate the similarities and variability in different population groups and to clarify the social, psychological, and geographical factors influencing food intake patterns. The variability in the consumption of foods, nutrients, and non-nutrients, in terms of time (secular trends) and place (geographical differences—between developing and developed countries as well as between different developed countries), is described. This highlights the ability of different diets (foods consumed) to provide optimal nutrient intake. The wide diversity in the quantities of foods consumed between different countries and the changes with nutritional transition will serve to illustrate this.

In summary, in this chapter the major food groups in the diet are examined in terms of their nutrient and non-nutrient contribution, and their variability between countries and between subgroups in the population, as well as changing trends in food intake patterns, including novel foods, over time.

1.2 Major food groups in the western diet

Western diets are composed of several food groups collectively providing the nutritional needs of the body. The particular food groups in the Western diet that provide all the nutrients and non-nutrients for optimum health include cereals and cereal products (e.g. bread), vegetables and fruit, roots and tubers, milk and other dairy products, meats, fish, eggs, and other sources of protein, and fats and oils. A typical pattern of the Western diet may be illustrated in the food intake patterns for British adults (DEFRA 2013a) (see Table 1.1). How these patterns vary between countries (i.e. geographically) is discussed in Section 1.3, while changes over time are discussed in Section 1.4. The non-nutrients discussed in this chapter are those believed to have a potentially beneficial effect on human health. They include both dietary fibre and phytoprotectants such as flavonoids and phytoestrogens. Other non-nutrients in foods, such as contaminants, allergens, and food additives, do not have specific nutritional benefits and are not discussed here (see Chapters 2 and 3).