



# INTRODUCTION TO



# FOOD SCIENCE & FOOD SYSTEMS

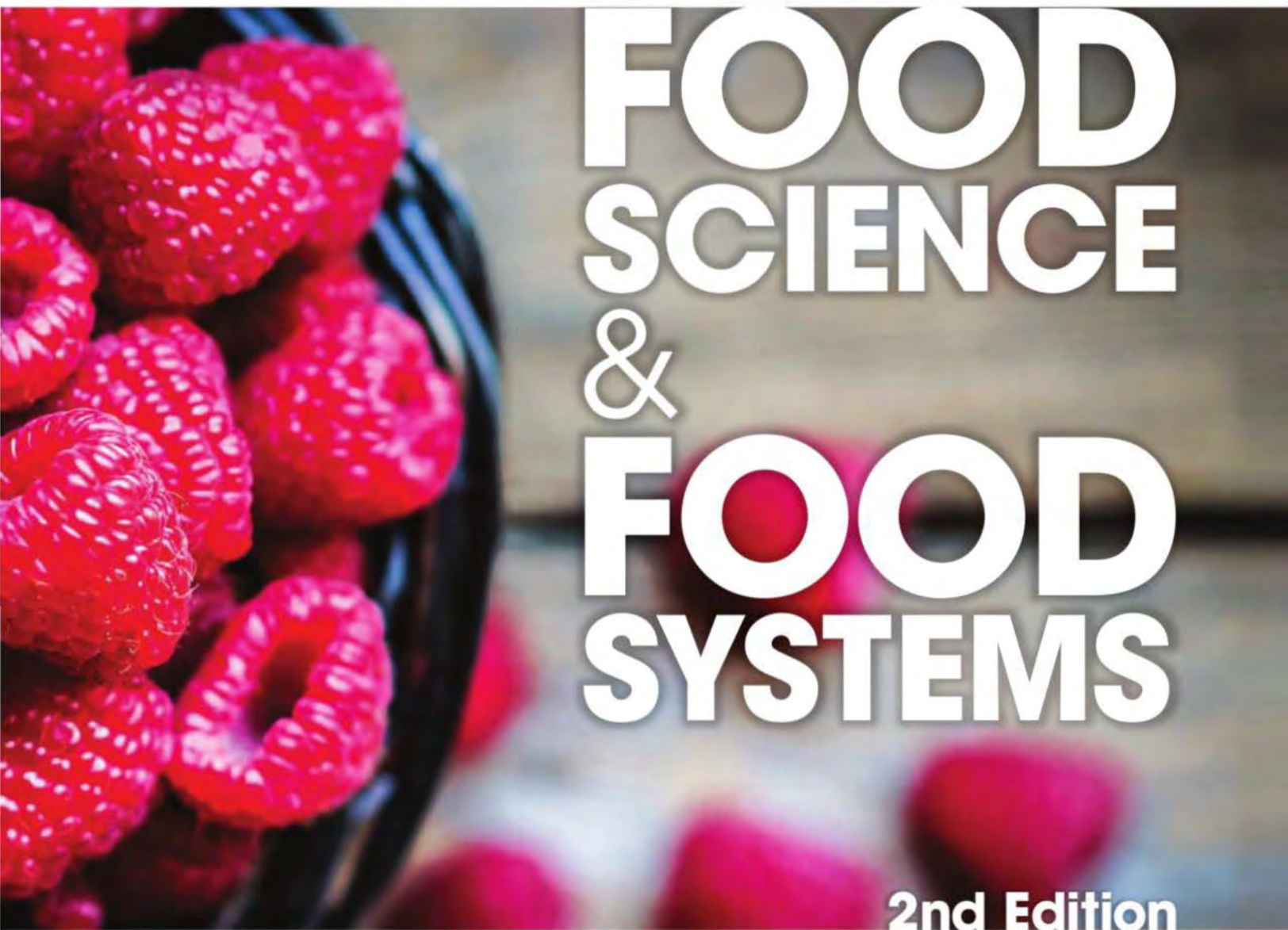
2nd Edition



Rick Parker and Miriah Pace



# INTRODUCTION TO



# FOOD SCIENCE & FOOD SYSTEMS

2nd Edition

Rick Parker and Miriah Pace



Australia • Brazil • Mexico • Singapore • United Kingdom • United States

**Introduction to Food Science &  
Food Systems, Second Edition**  
Rick Parker and Miriah Pace

Senior Vice President, GM Skills & Global  
Product Management: Dawn Gerrain

Product Team Manager: Erin Brennan

Product Manager: Nicole Robinson

Senior Director Development:  
Marah Bellegarde

Senior Product Development Manager:  
Larry Main

Senior Content Developer: Jennifer Starr

Product Assistant: Maria Garguilo

Vice President Marketing Services:  
Jennifer Baker

Market Manager: Jonathan Sheehan

Senior Production Director: Wendy A. Troeger

Senior Content Project Manager: Betsy Hough

Senior Art Director: Benj Gleeksman

Software Development Manager:  
Pavan Ethakota

**Cover Image Credits:**

© Zeljko Radojko/Shutterstock

© Zigzag Mountain Art/Shutterstock

© inacio pires/Shutterstock

© Alena Haurlyik/Shutterstock

© symbiot/Shutterstock

● Gayvoronskaya\_Yana/Shutterstock

© Grisha Bruev/Shutterstock

**Interior Design Image Credits:**

© Elina Li/Shutterstock

© Sasha\_Ivv/Shutterstock

© 2017, 2003 Cengage Learning

WCN: 02-200-208

ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced or distributed in any form or by any means, except as permitted by U.S. copyright law, without the prior written permission of the copyright owner.

For product information and technology assistance, contact us at  
**Cengage Learning Customer & Sales Support, 1-800-354-9706**

For permission to use material from this text or product,  
submit all requests online at [www.cengage.com/permissions](http://www.cengage.com/permissions).  
Further permissions questions can be e-mailed to  
[permissionrequest@cengage.com](mailto:permissionrequest@cengage.com)

Library of Congress Control Number: 2015943892

[Book Only] ISBN-13: 978-1-4354-8939-4

**Cengage Learning**

20 Channel Center Street  
Boston, MA 02210  
USA

Cengage Learning is a leading provider of customized learning solutions with employees residing in nearly 40 different countries and sales in more than 125 countries around the world. Find your local representative at [www.cengage.com](http://www.cengage.com)

Cengage Learning products are represented in Canada by Nelson Education, Ltd.

To learn more about Cengage Learning, visit [www.cengage.com](http://www.cengage.com)

Purchase any of our products at your local college store or at our preferred online store [www.cengagebrain.com](http://www.cengagebrain.com)

**Notice to the Reader**

Publisher does not warrant or guarantee any of the products described herein or perform any independent analysis in connection with any of the product information contained herein. Publisher does not assume, and expressly disclaims, any obligation to obtain and include information other than that provided to it by the manufacturer. The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities described herein and to avoid all potential hazards. By following the instructions contained herein, the reader willingly assumes all risks in connection with such instructions. The publisher makes no representations or warranties of any kind, including but not limited to, the warranties of fitness for particular purpose or merchantability, nor are any such representations implied with respect to the material set forth herein, and the publisher takes no responsibility with respect to such material. The publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or part, from the readers' use of, or reliance upon, this material.





**To Marilyn**, *wife, mother, partner, friend,  
and one true love for more than 47 years, through  
good times and bad, helping me enjoy the journey.*



# CONTENTS

## SECTION ONE INTRODUCTION AND BACKGROUND

3

### Chapter 1

#### Overview of Food Science

4

Parts of the Food Industry	5
Trends	6
Allied Industries	14
International Activities	15
Responsiveness to Change	19
Interrelated Operations	19
Summary	20
Review Questions	20
Student Activities	21
Additional Resources	21
References	21

### Chapter 2

#### Food Systems and Sustainability

22

Food-System Definitions	23
Allied Industries	24
International Activities	24
Interrelated Operations	25
Food-System Trends	25
Retail Trends	26
Defining Sustainability	27
Standards of Sustainable Food Production	28
Standard 1: Base Direction and Changes Based on Science	28
Standard 2: Follow Market Principles	30
Standard 3: Increase Profitability and Reduce Risks	30

Standard 4: Satisfy Human Need for Fiber and Safe, Nutritious Foods	31
Standard 5: Conserve and Seek Energy Resources	32
Standard 6: Create and Conserve Healthy Soil	33
Standard 7: Conserves and Protects Water Resources	34
Standard 8: Recycle and Reduce Waste Products	36
Standard 9: Select Animals and Crops Appropriate for an Environment and Available Resources	37
Standard 10: Manage Pests with Minimal Environmental Impact	38
Standard 11: Encourage Strong Communities	38
Standard 12: Use Appropriate Technology	39
Standard 13: Promote Social and Environmental Responsibility	39
Sustainable Standards Score Card	40
Summary	40
Review Questions	41
Student Activities	41
Additional Resources	42
References	42

### Chapter 3

#### Chemistry of Foods

44

Carbohydrates	45
Function in Food	46
Monosaccharide	46
Disaccharides	49
Sugars in Food	50
Polysaccharides	52



Proteins	54	References	67
Functions of Proteins in Foods	57	Endnotes	67
Lipids	57	<b>Chapter 4</b>	
Role of Fats in Food	58	<b>Nutrition and Digestion</b>	<b>68</b>
Fatty Acids	59	Nutrient Needs	69
Double Bonds	59	Water	69
Triglycerides	60	Energy	69
Phospholipids	60	Carbohydrates	71
Cholesterol	60	Fiber	71
Vitamins	60	Protein	72
Fat-Soluble Vitamins	60	Lipids	74
Water-Soluble Vitamins	61	Vitamins	74
Minerals	61	Minerals	75
Calcium	61	MyPlate	75
Phosphorus	61	Food Groups	75
Potassium	62	Digestive Processes	81
Sodium	62	Ingestion	81
Chloride	62	Digestion	81
Magnesium	62	Absorption	81
Sulfur	62	Elimination	81
Chromium	62	Components of the Human	
Cobalt	62	Digestive System	81
Copper	62	Vegetarian Diets	83
Fluorine	62	Bioavailability of Nutrients	83
Iodine	62	Stability of Nutrients	83
Iron	62	Diet and Chronic Disease	84
Manganese	63	Summary	84
Molybdenum	63	Review Questions	84
Nickel	63	Student Activities	85
Selenium	63	Additional Resources	85
Silicon	63	References	85
Tin	63	Endnotes	86
Vanadium	63	<b>Chapter 5</b>	
Zinc	63	<b>Food Composition</b>	<b>88</b>
Water	64	Determining the Composition of Foods	89
Biotin	64	Energy in Food	89
Choline	64	Food-Composition Tables	90
Phytochemicals	64	Summary	91
Summary	65	Review Questions	92
Review Questions	65	Student Activities	92
Student Activities	66		
Additional Resources	66		

Additional Resources	93	Mixing	117
References	93	Heat Exchanging	117
<b>Chapter 6</b>		Concentration	119
<b>Quality Factors in Foods</b>	<b>94</b>	Drying	120
Sensory Evaluation	96	Forming	120
Appearance Factors	96	Packaging	120
Textural Factors	97	Controlling	121
Flavor Factors	98	Overlapping Operations	121
Additional Quality Factors	101	Conserving Energy	122
Proteins	101	Other Processes	122
Lipids	101	Summary	124
Carbohydrates	101	Review Questions	124
Vitamins	102	Student Activities	124
Chemicals and Microbiological Characteristics	102	Additional Resources	125
Quality Standards	102	References	125
Quality Standards: USDA and the AMS	102	Endnotes	125
Grading and Certification	104		
Mission	105	<b>Chapter 8</b>	
Food Quality Assurance	106	<b>Food Deterioration</b>	<b>126</b>
Commercial Item Descriptions	106	Types of Food Deterioration	127
Quality Control	106	Shelf Life and Dating of Foods	127
Summary	108	Causes of Food Deterioration	129
Review Questions	109	Bacteria, Yeast, and Mold	129
Student Activities	109	Food-Borne Disease	130
Additional Resources	110	Insects	130
References	110	Food Enzymes	130
Endnotes	110	Heat and Cold	132
		Oxygen	132
		Postharvest Biochemical Changes	133
<b>Chapter 7</b>		Postslaughter Biochemical Changes	133
<b>Unit Operations in Food</b>		Principles of Food Preservation	133
<b>Processing</b>	<b>112</b>	Heat	133
Materials Handling	113	Cold	133
Cleaning	113	Drying	134
Separating	114	Acid	134
Cream Separator	114	Sugar and Salt	134
Clarification	114	Smoke	134
Membrane Processes	115	Atmosphere	135
Size Reduction	115	Chemicals	135
Pumping (Fluid Flow)	115	Radiation	135
		Summary	136
		Review Questions	136

Student Activities	136
Additional Resources	137
References	137

## SECTION TWO PRESERVATION

**139**

### Chapter 9 Heat

**140**

Heat	141
Degrees of Preservation	141
Sterilization	141
Commercial Sterility	141
Pasteurization	142
Blanching	142
Selecting Heat Treatments	142
Heat Resistance of Microorganisms	142
Heat Transfer	142
Convection-Conduction	143
Conduction-Convection	143
Radiation	143
Protective Effects of Food Constituents	144
Different Temperature-Time	
Combinations	144
Organisms	144
Thermal Death Curves	145
D Value	145
Z Value	145
Time-Temperature Combinations	145
Low-Acid Foods	145
Heating Before or After Packaging	145
Still Retort	146
Agitating Retort	146
Hydrostatic Retort	146
Aseptic Packaging	147
Home Canning	148
Food Acidity and Processing	
Methods	148
Process Adjustments at	
High Altitudes	149
Summary	149
Review Questions	149

Student Activities	150
Additional Resources	150
References	151

### Chapter 10

#### Cold

**152**

Refrigeration Versus Freezing	153
Refrigeration and Cool Storage	153
Requirements of Refrigerated	
Storage	154
Changes in Food During	
Refrigerated Storage	154
Freezing and Frozen Storage	155
Chemical Changes During Freezing	157
Textural Changes During Freezing	157
Microbial Growth in the Freezer	158
Freezing Methods	158
Packaging	158
New Developments	159
Home Freezing	159
Rigid Containers	159
Flexible Bags or Wrappings	160
Freezer Pointers	160
Foods to Freeze for Quality	160
Effect of Freezing on Spices	
and Seasonings	160
Freezer Management	161
Summary	162
Review Questions	162
Student Activities	163
Additional Resources	163
References	163

### Chapter 11

#### Drying and Dehydration

**164**

Dehydration	165
Drying Curve	167
Solute Concentration	167
Binding of Water	167
Chemical Changes	168
Drying Methods	169
Food Concentration	169
Reduced Weight and Volume	170

Solar Evaporation	170	Uses of Fermentation	188
Open Kettles	171	Fermented Dairy Products	188
Flash Evaporators	171	Bread Making	189
Thin-Film Evaporators	171	Pickling	189
Vacuum Evaporators	172	Processed Meats	190
Freeze Concentration	172	Vinegar	190
Ultrafiltration and Reverse Osmosis	172	Wine Making	191
Home Drying	173	Brewing	191
Food Dehydrators	173	Microorganisms as Foods	192
Oven Drying	173	Genetic Engineering and	
Room Drying	173	Biotechnology	192
Sun Drying	173	Chymosin (Rennin)	193
Summary	175	Bovine Somatotropin (BST)	193
Review Questions	175	Tomatoes	193
Student Activities	175	Cloning	193
Additional Resources	176	GMO Debate	193
References	176	The Future	194
<b>Chapter 12</b>		Summary	195
<b>Radiant and Electrical Energy</b>	<b>178</b>	Review Questions	195
Food Irradiation	179	Student Activities	195
Food Irradiation Process	179	Additional Resources	196
Approved Uses for Food Irradiation	180	References	196
Applications for Food Irradiation	180	Endnotes	196
Nutritional Quality of Irradiated		<b>Chapter 14</b>	
Foods	181	<b>Food Additives</b>	<b>198</b>
Regulation of Food Irradiation	181	Reasons for Use	199
Microwave Heating	181	Preservatives	203
Food-Processing Applications	183	Nutritional Additives	204
Ohmic (Electrical) Heating	183	Color Modifiers	205
Summary	184	Flavoring Agents	207
Review Questions	184	Texturing Agents	207
Student Activities	185	Acidulants	208
Additional Resources	185	Fat Replacers	208
References	185	Irradiation	208
Endnote	185	Hazards	209
<b>Chapter 13</b>		Summary	209
<b>Fermentation, Microorganisms,</b>		Review Questions	210
<b>and Biotechnology</b>	<b>186</b>	Student Activities	210
Fermentations	187	Additional Resources	211
Benefits	187	References	211
Control	187	Endnote	211

## Chapter 15

### Packaging

212

Types of Containers	213
Food-Packaging Materials and Forms	213
Metals	213
Glass	214
Paper	214
Plastics	215
Laminates	215
Retortable Pouches	216
Edible Films	216
Package Testing	216
Packages with Special Features	218
Environmental Considerations	218
Innovations in Packaging	219
Summary	220
Review Questions	220
Student Activities	221
Additional Resources	221
References	221
Endnote	221

## SECTION THREE FOODS AND FOOD PRODUCTS

223

### Chapter 16

#### Milk

224

Fluid Milk	225
Legal Description	225
Production Practices	225
Grades and Classes of Milk	226
Factors Necessary to Produce Quality Milk	226
Mastitis Detection and Control	227
Quality Control on the Farm	227
Milk Pricing Economics and Trends	229
Processing	229
Pasteurizing	229
Identifying Diseases Transmitted to Consumers Through Milk	230
Butterfat	230

Homogenization	231
Beverage Milk	231
Nutritional Qualities	231
Quality Control During Processing	232
Packaging	232
Milk Products and By-Products	232
Butter	233
Concentrated and Dried Dairy Products	235
Condensed Buttermilk	236
Cheese	238
Yogurt	240
Ice Cream	241
Quality Products	242
Milk Substitutes	243
Reduced Fat Products	244
Milk Quality Evaluation and Flavor Defects	244
FFA Milk Quality and Products Career Development Event	244
Summary	245
Review Questions	245
Student Activities	246
Additional Resources	246
References	246
Endnotes	247

### Chapter 17

#### Meat

248

Meat and Meat Products	249
Government Oversight	250
Grading	250
Grading Formulas	251
Value-Based Beef Pricing	251
Dressing Percentage	252
Slaughtering Practices	252
Wholesale and Retail Cuts of Meat	253
Structure and Composition of Meat	256
Meat Products Formulations	256
Chilling	257
Aging of Meat	257
Tenderizing	258
Muscle Identification	258

Curing	261	Review Questions	285
Color	262	Student Activities	285
Smoking	262	Additional Resources	286
Meat Specialties	262	References	286
Freezing	262		
Storage	263		
Cooking	263		
FFA Meats Evaluation and Technology Career Development Event	263	<b>Chapter 19</b>	
Meat Substitutes	265	<b>Fish and Shellfish</b>	<b>288</b>
Summary	265	Fish and Shellfish: Saltwater and Freshwater	289
Review Questions	265	Fishing Versus Culture	289
Student Activities	266	Aquaculture	289
Additional Resources	266	Composition, Flavor, and Texture	290
References	267	Spoilage	290
		Processing	292
		Aquaculture Processing	292
		Inspection	293
		Quality	293
		Grading	294
		Products	295
		Preservation	295
		Shellfish	296
		Fish By-Products	296
		Roe	296
		Storage	296
		New Products	297
		Summary	298
		Review Questions	298
		Student Activities	298
		Additional Resources	299
		References	299
		Endnote	299
		<b>Chapter 20</b>	
		<b>Cereal Grains, Legumes, and Oilseeds</b>	<b>300</b>
		Cereal Grains	301
		General Structure and Composition	301
		Starch	302
		Properties of Starch	302
		Factors Requiring Control	303
		Handling of Cooked Starch	304
		Weeping	304
<b>Chapter 18</b>			
<b>Poultry and Eggs</b>	<b>268</b>		
Poultry Production	269		
Processing	270		
Processing Steps	271		
Meat Properties	272		
Grading	274		
Products	276		
EGGS	278		
Caged Layers in California	278		
Processing	278		
Formation and Structure	278		
Composition	279		
Grading	280		
FFA Poultry Evaluation Career Development Event	281		
Quality Factors of Eggs	282		
Evaluation of Egg Interior and Exterior Quality	283		
FFA Meats Evaluation and Technology Career Development Event	283		
Storage	284		
Fertile Eggs	284		
Organic Eggs	284		
Egg Substitutes	284		
Summary	285		

Milling of Grains	304	Soy Nuts	322
Classes of Wheat	306	Soy Oil and Products	322
Grades of Flour	307	Soy Sprouts	322
Types of White Flour	307	Tempeh	322
Enriched Flour	308	Tofu and Tofu Products	322
Gluten	308	Soy-Based Whipped Toppings	323
Other Flours	309	Summary	323
Rice	310	Review Questions	323
Corn Refining	310	Student Activities	324
Inspection and Cleaning	310	Additional Resources	324
Steeping	310	References	324
Germ Separation	311	Endnote	325
Fine Grinding and Screening	311		
Starch Separation	311	<b>Chapter 21</b>	
Syrup Conversion	311	<b>Fruits and Vegetables</b>	<b>326</b>
Fermentation	312	Types of Fruit	327
Bioproducts	312	Vegetable Properties and Structural Features	327
Breakfast Cereals	312	General Composition	328
Principles of Baking	313	Fresh Vegetable Labels	328
Legumes	314	Fresh Fruit Labels	328
Nutritional Composition	317	Activities of Living Systems	329
Legume Products	317	Plant Tissues	330
Soybeans	318	Harvesting	331
Green Vegetable Soybeans	318	Ripening	331
Hydrolyzed Vegetable Protein	318	Appearance	332
Infant Formulas, Soy-Based	320	Texture	332
Lecithin	320	Flavor	333
Meat Alternatives (Meat Analogs)	320	Quality Grades for Fresh Vegetables	334
Natto	320	Quality Grades for Canned and Frozen Vegetables	334
Nondairy Soy Frozen Dessert	320	Quality Grades for Fresh Fruit	335
Soy Cheese	320	Quality Grades for Canned and Frozen Fruits	335
Soy Fiber (Okara, Soy Bran, and Soy Isolate Fiber)	321	Country of Origin Labeling	336
Soy Flour	321	Post-Harvest	337
Soy Grits	321	Processing Fruits	338
Soy Protein Concentrate	321	Canned Fruits	344
Soy Protein Isolates (Isolated Soy Protein)	321	Frozen Fruits	344
Soy Protein, Textured	321	Fruit Juices	344
Soy Sauce	322	Processing Vegetables	344
Soy Yogurt	322	Canned Vegetables	351
Soy Milk and Soy Beverages	322	Frozen Vegetables	351
Soy Nut Butter	322		

By-Products	351	Invert Sugar	375
Biotechnology	352	Caramelization	376
Summary	352	Corn Syrups and Other Sweeteners	377
Review Questions	353	Fructose and Fructose Products	378
Student Activities	353	Chocolate and Cocoa Products	378
Additional Resources	353	Cocoa	378
References	354	Milk Chocolate	379
		Confectionery Manufacturing Practices	379
		Enrobing	381
		Standards	381
		Sugar Substitutes	381
		Labeling	382
		Summary	383
		Review Questions	383
		Student Activities	383
		Additional Resources	384
		References	384
		Endnotes	385
<b>Chapter 22</b>		<b>Chapter 24</b>	
<b>Fats and Oils</b>	<b>356</b>	<b>Beverages</b>	<b>386</b>
Effects of Composition on Fat Properties	357	Carbonated Nonalcoholic Beverages	387
Sources of Fats and Oils	360	Sweeteners	388
Functional Properties of Fats	360	Flavors	388
Production and Processing Methods	360	Colors	388
Degumming	362	Acid	388
Alkali Refining	362	Water	388
Bleaching	362	Carbon Dioxide	389
Winterization (Fractionation)	362	Mixing	389
Hydrogenation	362	Noncarbonated Herbal and Healthful	
Deodorization	362	Beverages	389
Interesterification	363	Hi-C®	389
Products Made from Fats and Oils	363	Gatorade®	390
Monoglycerides and Diglycerides	364	SoBe®	390
Fat Substitutes	364	Snapple®	391
Protein-Based Fat Replacers	365	Bottled Water	392
Carbohydrate-Based Fat Replacers	365	Alcoholic Beverages	393
Fat-Based Fat Replacers	365	Beer	393
Lipid (Fat and Oil) Analogs	367	Wine	394
Tests on Fats and Oils	368	Coffee	396
Summary	369	Coffee Substitutes	396
Review Questions	369	Tea	397
Student Activities	369		
Additional Resources	370		
References	370		
Endnotes	371		
<b>Chapter 23</b>			
<b>Candy and Confectionery</b>	<b>372</b>		
Sources of Sugar	373		
Sugar-Based Confectionery	374		
Composition	374		
Ingredients	374		



Processing	397	Bacteria	421
Blended and Unblended Varieties	397	Factors Affecting Microbial Growth	421
Instant Tea and Bottled Tea	397	Food	422
Herbal Tea	398	Acidity	422
Summary	400	Temperature	422
Review Questions	400	Time	422
Student Activities	400	Oxygen	422
Additional Resources	401	Moisture	422
References	401	Fat Tom	422
Endnote	402	Microbiological Methodology	425
		Processing and Handling	425
		Good Manufacturing Practices	426
		Rodents, Birds, and Insects	427
		Cleaning and Sanitizing	428
		Cleaning	428
		Sanitation	428
		Regulatory Considerations	430
		HACCP and Food Safety	430
		Biotechnology	433
		Genetically Modified Foods	434
		FFA Food Science and Technology	
		Career Development Event	437
		Summary	437
		Review Questions	437
		Student Activities	438
		Additional Resources	438
		References	439
		Endnotes	439
		<b>Chapter 27</b>	
		<b>Regulation and Labeling</b>	<b>440</b>
		Federal Food, Drug, and Cosmetic Act	441
		Additional Food Laws	441
		Legal Categories of Food Substances	442
		Testing for Safety	442
		Quality Assurance	443
		Food Labeling	443
		Foods Affected	444
		Exemptions	444
		Restaurant Nutritional Labeling	447
		Nutrition Panel Title	449
		Serving Sizes	449
<b>SECTION FOUR</b>			
<b>RELATED ISSUES</b>	<b>405</b>		
<b>Chapter 25</b>			
<b>Environmental Concerns</b>			
<b>and Processing</b>	<b>406</b>		
Water In Food Production	407		
Properties and Requirements			
of Processing Waters	407		
Environmental Concerns	407		
Disposal of Solid Wastes	408		
Properties of Wastewaters	410		
Wastewater Treatment	411		
Lowering Discharge Volumes	411		
Responsibility	412		
Summary	412		
Review Questions	413		
Student Activities	413		
Additional Resources	413		
References	414		
<b>Chapter 26</b>			
<b>Food Safety</b>	<b>416</b>		
Safety, Hazards, and Risks	417		
Food-Related Hazards	417		
Cross-Contamination	418		
High-Risk Foods and Individuals	418		
Microorganisms	421		
Viruses	421		
Parasites	421		
Fungi	421		

Nutrition Information	450	Review Questions	477
Nutrition Panel Format	450	Student Activities	478
Daily Values—DRVs	453	Additional Resources	478
Nutrient Content Descriptions	453	References	478
Other Definitions	455	Endnotes	479
Proposed Revisions to the Nutritional Facts Label	456		
USDA’s Meat Grading Program	458	<b>Chapter 29</b>	
Health Claims	458	<b>Food and Health</b>	<b>480</b>
Ingredient Labeling	458	Food and Disease	481
Formulation and Costing	460	Obesity	482
Factors in Packaging Design	460	Possible Cancer Prevention	486
FFA Food Science Career Development Event	461	Type 2 Diabetes	489
Summary	462	Sleep Problems	491
Review Questions	462	Digestive Disorders	493
Student Activities	462	Gas	493
Additional Resources	463	Heartburn	494
References	463	Lactose Intolerance	494
Endnotes	463	Peptic Ulcer Disease	495
		Diarrhea	496
		Constipation	497
		Diverticular Disease, Celiac Disease, Crohn’s Disease, and Pancreatitis	497
<b>Chapter 28</b>		Eating Disorders	500
<b>World Food Needs</b>	<b>464</b>	Anorexia Nervosa	501
World Food Hunger and Malnutrition	465	Bulimia Nervosa	501
Causes of Hunger	466	Binge-Eating Disorder	501
Fighting the Problem	469	Food Allergies	502
Step 1: More Self-Sufficiency	470	Dental Caries or Tooth Decay	502
Step 2: Check Farming Regulations	470	Phytonutrients	503
Step 3: Proper Storage	471	Nutraceuticals	503
Step 4: Check Food Aid	471	Herbs	504
Step 5: Work Together	471	What Are Herbs?	504
Step 6: Prevent Waste	471	Research on Herbs	504
Step 7: Pay Off Debt	471	Regulation of Herbal Supplements	507
Roles of Technology	471	Using Caution	507
Resource Management	471	Nutrigenomics	508
Protection of Crops	472	Components of Food	509
Genetic Improvement	472	Fruits and Vegetables	509
Global Action	473	Whole Grains	509
World Food Summit	473	Protein	510
World Food Summit Plan of Action	473	Fats and Oils	510
Hunger Agencies and Organizations	474		
Summary	477		

Bad Diets, Good Diets	511	Food-Industry Supervised Agricultural Experience	532
What to Eat	511	Getting a Job	532
Balancing Calories	512	Application Forms	532
Summary	512	Letters of Inquiry and Application	533
Review Questions	514	Résumé or Data Sheet	534
Student Activities	514	The Interview	534
Additional Resources	515	Follow-Up Letters	535
References	515	Occupational Safety	536
<b>Chapter 30</b>		Summary	538
<b>Careers in Food Science</b>	<b>516</b>	Review Questions	538
General Skills and Knowledge	517	Student Activities	538
Basic Skills	517	Additional Resources	539
Thinking Skills	518	References	540
General Workplace Competencies	519	Endnotes	540
Information Technology	520	<b>Appendix A</b>	
Personal Qualities	521	<b>Review of Chemistry</b>	<b>542</b>
Entrepreneurship	521	<b>Appendix B</b>	
Jobs and Courses in the Food Industry	522	<b>Reference Tables</b>	<b>552</b>
Education and Experience	523	<b>Appendix C</b>	
Identifying a Job	523	<b>Harvesting and Storing Fruits, Nuts, and Vegetables</b>	<b>630</b>
Food Inspection and Safety	523	<b>Glossary/Glosario</b>	<b>636</b>
Food-Service Industry	524	<b>Index</b>	<b>670</b>
Food Retail and Wholesale Industry	528		
Research and Development	529		
Food Scientist and Related Scientists	530		
Marketing and Communications	530		
Others	531		



# Preface

*Introduction to Food Science & Food Systems*, Second Edition, is designed for high school agriscience and consumer science programs and for postsecondary students enrolled in a food science course. It is an excellent overview for anyone interested in attaining a basic understanding of food science.

As the title suggests, science is an important component of the book. Food science as understood by humans represents a specific body of knowledge that approaches and solves problems by the scientific method—a continuous cycle of observations, hypotheses, predictions, experiments, and results. The *science* of food science is emphasized throughout the book.

## HOW THIS TEXT IS ORGANIZED

*Introduction to Food Science & Food Systems* makes teaching easy. The information is divided into four basic sections, and chapters are based on a thorough, easy-to-follow outline.

- **Section I: Introduction and Background** provides the necessary background information for understanding the science of foods. This includes an introduction to the industry, a new chapter on food systems and sustainability, the chemistry of foods, nutrition and digestion, food composition and quality, unit operations, and food deterioration. These chapters are the foundation.
- **Section II: Preservation** groups the chapters that relate to methods of food preservation, including heat, cold, drying, radiant and electrical energy, fermentation, microorganisms, biotechnology, chemicals, and packaging. These chapters are the basics of food science.
- **Section III: Foods and Food Products** includes chapters on milk, meat, poultry and eggs, fish and shellfish, cereal grains, legumes and oilseeds, fruits and vegetables, fats and oils, candies and sweets, and beverages. These chapters are the application of food science.

- **Section IV: Related Issues** includes chapters that cover environmental concerns, food safety, regulations and labeling, world food needs, and career opportunities as well as a new chapter on food as it relates to health. These chapters represent the challenges of food science.

## FEATURES OF THIS EDITION

Each chapter is designed to provide students with features that enhance learning and a learning pathway that enables them to easily navigate through food-science topics:

**LOGICALLY ORGANIZED**, the text is divided into four sections, including content in context so that information is presented in a relevant and meaningful way that reinforces learning.

**LEARNING FEATURES** such as **Learning Objectives** and **Key Terms** set the stage for the chapter and help learners identify key concepts and information. Also included are **National Agricultural Education Standards Correlations** that highlight the specific core competency that is met through successful completion of each chapter.

**APPLICATION** is emphasized throughout with engaging **Math and Science Connection** activities integrated into each chapter and a set of **Review Questions and Student Activities** to conclude each chapter.

**FURTHER LEARNING** is encouraged, with engaging articles highlighting interesting tidbits about the industry—whether historical insights, fun facts, or a synopsis of an emerging food trend—and a list of **Additional Resources** at the end of each chapter to inspire students to learn more about specific topics.

**HIGHLY ILLUSTRATED**, and now in full color, the text is accompanied by many tables, charts, graphs, photos, and illustrations to assist further understanding of the topics under discussion.

**ROBUST APPENDICES** reinforce topics learned in the chapters and offer valuable reference materials. **Appendix A** contains a review of the chemistry behind food science for those students who require additional learning in this area. **Appendix B** includes a multitude of reference tables, in particular the Food Composition Table, which provides specific nutrient information of different foods. It also features another list of Internet resources so that students can expand on their learning of specific food-science topics. **Appendix C** covers the details of harvesting and storing fruits, nuts, and vegetables. Also included is a combined **Glossary and Glosario** that provides terms and definitions in both English and Spanish.

**OBJECTIVES**

After reading this chapter, you should be able to:

- Describe food systems
- List five major segments of a food system
- Discuss the concept of sustainability
- Identify three allied industries of a food system
- List three effects of urbanization on a food system
- List 13 standards for sustainability
- Discuss why changes in the food system need to be science-based
- Identify three trends in global food demand that affect food systems
- Name two social or political aspects of a food system
- Identify three renewable energy sources that could be used in a food system

**KEY TERMS**

- agribusiness
- agribusiness
- beneficial
- bio-intensive
- biosecurity
- entomophagy
- food structure
- food system
- genomics
- market niche
- nutraceuticals
- probiotics
- rice
- the cashmere
- science
- sustainable
- urbanization

---

**NATIONAL AGRICULTURE STANDARD**  
100-04

**MATH CONNECTION**

Compare the mass of two objects. Compare their sizes. How do they compare to each other in the United States?

**SCIENCE EVALUATION**

Compare the mass of two objects. Compare their sizes. How do they compare to each other in the United States?

**SCIENCE CONNECTION!**

Compare the mass of two objects. Compare their sizes. How do they compare to each other in the United States?

**Appearance Factors**

The Modified atmosphere also called the Modified atmosphere when the demand grows on the surface of the crop with respect to its growth. The modification creates the most favorable and change in color. The reaction occurs between the CO<sub>2</sub> and the O<sub>2</sub>. Other reactions in plant metabolism for protein and formation of a sugar. The Modified atmosphere is used for ripening and storage of fruits and vegetables.

**Quality** Color and appearance is a consumer's primary concern. Color and appearance is a consumer's primary concern. Color and appearance is a consumer's primary concern.

---

**Table 2.1.3 Common Fruits**

Fruit	Notes
Apple	The many varieties of apples differ widely in appearance. Most characteristics, however, including size and shape, are common.
Apricot	Apricots develop their flesh as if sometimes of the tree and sometimes of the ground when the fruit is picked.
Avocado	Avocados vary greatly in color, size, and shape. Most have a thin skin, a large pit, and a smooth, buttery flesh. Some have a thin, leathery skin, whereas others have a smooth skin. The skin color of most varieties is some shade of green, but certain varieties turn brown, orange, or purple when ripe.
Banana	Bananas develop their fruit during the night. They are harvested when they are green and ripen during the day. The ripening process is controlled by ethylene gas. The color of the fruit changes from green to yellow to red as it ripens.
Blueberry	Large berries are cultivated varieties, and smaller berries are wild varieties. A dark blue color with a white bloom is the best indicator of quality. The bloom is a natural and protective waxy coating.
Cherry	Cherry comes from bright green, showing bright red, and dark red varieties. A black, dark color is the most important indicator of good fruit and quality in most cherries.

xx

PREFACE

## NEW TO THIS EDITION

**CURRENT INFORMATION**, including new chapters on the food system and sustainability and food and health, along with a new section on genetically engineered foods, will keep students in the know about significant industry trends.

**ALL-NEW, FULL-COLOR DESIGN** featuring photos, charts, graphs, and illustrations that visually demonstrate food production and process techniques to engage students. **National Agricultural Education Standard Correlations** are highlighted at the start of each chapter to address core competencies, while **MATH** and **SCIENCE CONNECTION ACTIVITIES** throughout the chapters encourage students to demonstrate these skills in the context of food science.

**ALIGNED to FFA CAREER DEVELOPMENT EVENTS (CDEs)**, where applicable, to help students focus on important job skills

**ADDITIONAL RESOURCES**, including a list of valuable and relevant Web sites in each chapter, encourage students to further explore specific food-industry topics.

**GLOSSARY and GLOSARIO** provides terms and definitions in English and Spanish.

## EXTENSIVE TEACHING AND LEARNING PACKAGE

### NEW! COMPANION SITE

Instructor Resources are available on the Companion Site to accompany *Food Science & Food Systems*, Second Edition, to facilitate teaching and learning. This site offers FREE, secure access to the following resources:

**ANSWERS TO QUESTIONS** includes the answers to all end-of-chapter questions to validate learning.

**LESSON PLANS** that outline the key concepts in each chapter, along with correlations to the corresponding PowerPoint® presentations, provide tools for classroom instruction.

**POWERPOINT® PRESENTATIONS** map the Lesson Plans and include photos and illustrations to reinforce learning. This feature is only also available to students for important self-review.

**COGNERO ONLINE TESTING** system includes quiz questions for each chapter, providing the ability to:

- Author, edit, and manage test-bank content from multiple resources
- Create multiple test versions in an instant
- Deliver tests from instructor- or institution-specific LMS or classrooms

**IMAGE GALLERY**, containing all the images from the book, enables instructors to enhance classroom presentations or review key concepts and information.

# NEW! MINDTAP FOR INTRODUCTION TO FOOD SCIENCE & FOOD SYSTEMS, SECOND EDITION

The MindTap for *Introduction to Food Science & Food Systems, Second Edition*, features an integrated course offering a complete digital experience for both students and teachers. This MindTap is highly customizable and combines assignments, videos, interactivities, lab exercises and quizzes along with the enhanced e-book to enable students to directly analyze and apply what they are learning as well as allow teachers to measure skills and outcomes with ease.

- **A Guide:** Relevant interactivities combined with prescribed readings, featured multimedia, and quizzing to evaluate progress will guide students from basic knowledge and comprehension to analysis and application.
- **Personalized Teaching:** Teachers are able to control course content—hiding, rearranging existing content, or adding and creating their own content to meet the needs of their specific programs.
- **Promote Better Outcomes:** Through relevant and engaging content, assignments, and activities, students are able to build the confidence they need to ultimately chart a course to success. Likewise, teachers are able to view analytics and reports that provide a snapshot of class progress, time in course, engagement, and completion rates.



# Acknowledgments

Without the support of my wife Marilyn, any of the writing I have done would still be a dream or idea. As I have discovered, writing requires the goodwill and support of an understanding spouse. Our marriage has thrived for 47 years, and it continues strong. Marilyn is a friend who critiques ideas, types parts of the manuscripts, writes questions and answers, organizes artwork, takes photographs, and checks format. She is a partner in the production of a text and in all other aspects of my life.

Finally, I appreciate the support, understanding, help, and encouragement of Nicole Robinson, Jennifer Starr, and the rest of the Cengage team.

As always, we wish to express our sincere appreciation to those who have contributed to the development of this and past editions:

Daniel Andrews  
Wauneta-Palisade High School  
Wauneta, Nebraska

Roy Crawford  
Lancaster High School  
Lancaster, Texas

Diane Ryberg  
Eau Claire North High School  
Eau Claire, Wisconsin

Dr. Janelle Walter  
Baylor University  
Waco, Texas



# About the Authors



## RICK PARKER

R. O. (Rick) Parker grew up on an irrigated farm in southern Idaho. His love of agriculture guided his education. Starting at Brigham Young University, he received his bachelor's degree and then moved to Ames, Iowa, where he finished his PhD in animal physiology at Iowa State University. After completing his PhD, he and his wife, Marilyn, and their children moved to Edmonton, Alberta, Canada,

where he completed a postdoctorate at the University of Alberta. His next move was to Laramie, Wyoming, where he was a research and teaching associate at the University of Wyoming. After Wyoming, he moved to Clovis, California, where he wrote with Dr. M. E. Ensminger, author of numerous early animal science textbooks.

Returning to Idaho, the author served as division director and instructor at the College of Southern Idaho for 19 years. He then worked as director for AgrowKnowledge, the National Center for Agriscience and Technology Education, a project funded by the National Science Foundation. Currently, he is president of the National Agricultural Institute and the director of the North American Colleges and Teachers of Agriculture (NACTA). In addition, he is the editor of the peer-reviewed *NACTA Journal*, which focuses on the scholarship of teaching and learning, and he teaches biology, food science, and animal science for the College of Southern Idaho. Dr. Parker is also the author of the following Cengage Learning texts: *Aquaculture Science*, *Introduction to Plant Science*, *Fundamentals of Plant and Soil Science*, and *Equine Science*. He is also the co-author of *Fundamentals of Plant Science*.

## MIRIAH PACE



Miriah Pace is currently a board member and assistant editor at the National Agricultural Institute. Her role includes developing and maintaining Web sites, developing curriculum and editing the peer-reviewed *NACTA Journal* for the North American Colleges and Teachers of Agriculture. She also serves as a teaching assistant for a College of Southern Idaho class, Food Systems and

Science. Miriah joined the staff of the National Agricultural Institute in July 2012 and is currently working toward her bachelor's degree.

## CONTRIBUTING AUTHORS

For the second edition, we were fortunate to find two talented individuals to assist in revising the content. We gratefully acknowledge their contributions.

### FARRAH JOHNSON

Farrah Johnson is the Agriscience Educator at Deltona High School in Deltona, Florida. Ms. Johnson earned her BS in Agricultural Education from the University of Florida and her MS from Mississippi State University also in Agricultural Education. Ms. Johnson began working with food-science curriculum through a grant project with Cornell University, the University of Florida, and the University of California—Davis early in her teaching career. She now teaches food-science courses as part of the agriculture program at Deltona High School. Farrah is active in the professional organizations for agricultural education and works with new agriculture teachers in Florida. She served as president of the National Association of Agricultural Educators in 2012–2013 and served a 2-year term on the National FFA Board of Directors as a stakeholder. She has served in numerous roles for the Florida Association of Agricultural Educators during her teaching career.

### LEVI CAHAN

Levi Cahan has a distinguished background in livestock production from years of training and educating others as well as being self-employed as a farmer. He is the lead Agriculture Educator at Schuylerville High School in upstate New York, where he instructs and manages student learning in several agricultural subjects with a focus on animal science. He received his BS in Animal Science and his MS in Agricultural Education from Cornell University. He also studied abroad in New Zealand at Lincoln University, specializing in animal science and rotational grazing practices. Mr. Cahan stays active in agriculture and education as an FFA advisor; he has served on the New York State FFA Governing Board as a trustee, as a trustee for the NYAAE, and currently as the chairman of the NYS FFA Foundation board, and he is a member of the NYS Beef Council. He has also contributed to other Cengage titles, including serving as author of the *Modern Livestock and Poultry Production Lab Manual*, Ninth Edition.





# **SECTION** *One*





# Introduction and Background

- Chapter 1 **Overview of Food Science**
- Chapter 2 **Food System and Sustainability**
- Chapter 3 **Chemistry of Foods**
- Chapter 4 **Nutrition and Digestion**
- Chapter 5 **Food Composition**
- Chapter 6 **Quality Factors in Foods**
- Chapter 7 **Unit Operations  
in Food Processing**
- Chapter 8 **Food Deterioration**

# CHAPTER 1

# Overview of Food Science

## OBJECTIVES

*After reading this chapter, you should be able to:*

- Name the four parts of the food industry
- Describe consumer food buying trends
- Divide the food industry by major product lines
- Compare spending for food in the United States to that in other countries
- List four consumption trends
- Discuss trends in consumer meal purchases
- Identify allied industries
- Explain the international scope of the food industry

## NATIONAL AFNR STANDARD

### FPP.04

Explain the scope of the food industry and the historical and current developments of food product and processing.

## KEY TERMS

allied industry  
consumer  
distribution  
expenditures  
manufacturing  
marketing  
per capita  
production  
tariffs  
trends

# CHAPTER 1

# Overview of Food Science

## OBJECTIVES

*After reading this chapter, you should be able to:*

- Name the four parts of the food industry
- Describe consumer food buying trends
- Divide the food industry by major product lines
- Compare spending for food in the United States to that in other countries
- List four consumption trends
- Discuss trends in consumer meal purchases
- Identify allied industries
- Explain the international scope of the food industry

## NATIONAL AFNR STANDARD

### FPP.04

Explain the scope of the food industry and the historical and current developments of food product and processing.

## KEY TERMS

allied industry  
consumer  
distribution  
expenditures  
manufacturing  
marketing  
per capita  
production  
tariffs  
trends

No matter where people live or what they do, they are food consumers. We consume food on a daily basis so we make choices every day about what foods to purchase and consume based on a variety of needs and wants. Consumers vote every day in the marketplace with their dollars, and the market listens carefully to their votes. A continuous feedback exists from consumers responding to offerings by marketers who are trying to meet the perceived wants of consumers. Price, availability, health, and convenience are all factors that affect personal purchasing choices. Changes in the makeup of the population, lifestyles, incomes, and attitudes on food safety, health, and convenience have drastically altered the conditions facing the producers and marketers of food products. Food manufacturers and distributors work hard to meet changing consumer demands.

## PARTS OF THE FOOD INDUSTRY

The food industry is divided into four major segments:

1. Production
2. Manufacturing and processing
3. Distribution
4. Marketing

**Production** is the raising or growing of plant and animal products for food consumption. It includes such industries as farming, ranching, orchard management, fishing, and aquaculture. Technologies involved in the production of raw materials include the selection of plant and animal varieties; their cultivation, growth, harvest, and slaughter; and the storage and handling of raw materials. **Manufacturing** converts raw agricultural products to more refined or finished products. For example, peanuts are manufactured into hundreds of different products, only one of which is peanut butter. Manufacturing requires many unit operations and processes that are at the core of food technology.

As many foods are being processed into ready-to-eat products, more specialized manufacturing is required. **Distribution** deals with those aspects conducive to product sales, including product formation, weighing and bulk, transportation, and storage requirements and stability. **Marketing** is the selling of foods and involves wholesale, retail, institutional, and restaurant sales (Figure 1-1). Marketing is the segment that consumers are most involved with. Advertising through television, print, and social media is a multibillion-dollar effort that food companies use to reach consumers.

These four divisions are not clear-cut and often overlap one another. For example, when farmers take their crops to a farmer's market, distribution and marketing merge into the same category. Nevertheless, the food industry requires planning



**FIGURE 1-1** School meals are just another example of consumer products that are influenced by food industry marketers.



and synchronization in all its divisions to be successful. When the entire food system is analyzed, additional divisions are often included. These are discussed in more detail in Chapter 2.

Another way to divide the food industry is along major product lines:

- Cereals and bakery products
- Meats, fish, and poultry
- Dairy products
- Fruits and vegetables
- Sugars and other sweets
- Fats and oils
- Nonalcoholic beverages
- Alcoholic beverages

These divisions are typically where **consumer** consumption is measured and reported.

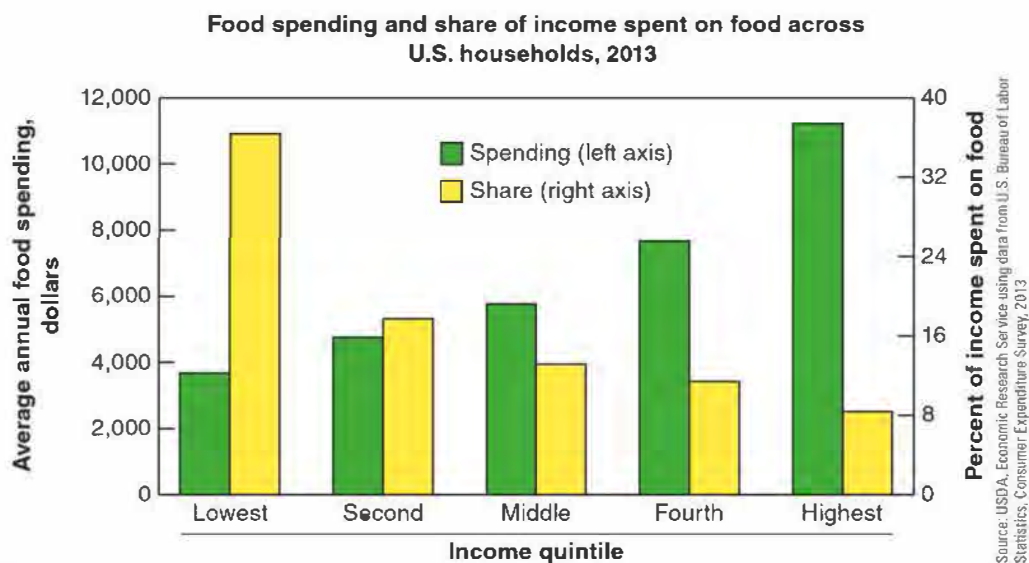
## TRENDS

Although consumers' food spending has increased considerably over the years, the increase has not matched the gain in disposable income. As a result, the percentage of income spent for food has declined. The decline is the direct result of the income-inelastic nature of the aggregate demand

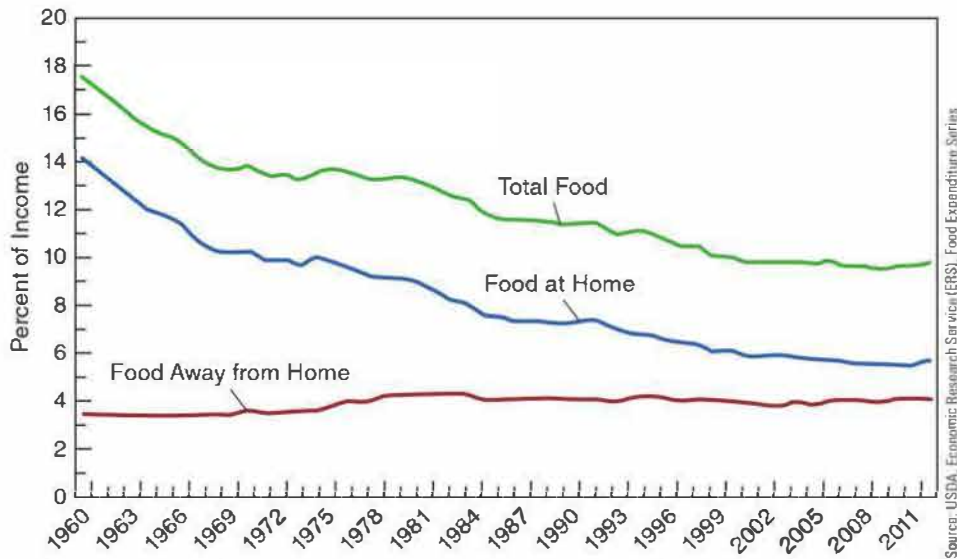
for food: As income rises, the proportion spent for food declines (Figure 1-2). The **expenditures** for food require a large share of income when income is relatively low—in any country.

Americans spent only about 6% of their personal consumption expenditures for food eaten at home (Figure 1-3). This compares with 10% for Canada and 11% for Switzerland. In less developed countries, such as Kenya and the Philippines, at-home food expenditures often account for more than 40% of a household's budget (Table 1-1).

Americans do not have the highest **per capita** income (the average Swiss income is higher). In relation to total per capita personal consumption expenditures, however, Americans spend the lowest percentage on food. Factors other than income alone influence food expenditures in developed nations. Thanks to abundant arable land and a varied climate, Americans do not have to rely as heavily on imported foods as do some other nations. The American farm-to-consumer distribution system is highly successful at moving large amounts of perishable food over long distances with a minimum of spoilage or delay. Finally, American farmers use a tremendous wealth of agricultural information and state-of-the-art farming equipment. This allows them to produce food more efficiently.



**FIGURE 1-2** As income rises the proportion spent on food declines.



**FIGURE 1-3** Percent of Disposable Income Spent on Food, 1960–2011. The percentage of income spent on food at home has steadily declined in recent years.

## MATH CONNECTION!

Track your food consumption for a day. What is the average cost of your consumption in the United States? Research and compare those costs with another country. How much would it cost for the same food in that other country?

**TABLE 1-1** Percent of Consumer Expenditures Spent on Food, Alcoholic Beverages, and Tobacco Consumed at Home, by Selected Countries, 2012<sup>1</sup>

COUNTRY/TERRITORY	SHARE OF CONSUMER EXPENDITURES			
	FOOD <sup>2</sup>	ALCOHOLIC BEVERAGES AND TOBACCO	CONSUMER EXPENDITURES <sup>3</sup>	EXPENDITURE ON FOOD <sup>2</sup>
	PERCENT		U.S. DOLLARS PER PERSON	
United States	6.6	1.9	34,541	2,273
ERS estimate	6.4	1.9	34,541	2,215
Singapore	7.3	2.1	19,398	1,422
United Kingdom	9.1	3.8	24,260	2,214
Canada	9.6	3.4	27,761	2,679
Austria	10.1	3.3	25,908	2,617
Ireland	10.1	5.4	20,093	2,037

(Continues)

**TABLE 1-1** Percent of Consumer Expenditures Spent on Food, Alcoholic Beverages, and Tobacco Consumed at Home, by Selected Countries, 2012<sup>1</sup>

COUNTRY/TERRITORY	SHARE OF CONSUMER EXPENDITURES			
	FOOD <sup>2</sup>	ALCOHOLIC BEVERAGES AND TOBACCO	CONSUMER EXPENDITURES <sup>3</sup>	EXPENDITURE ON FOOD <sup>2</sup>
	PERCENT		U.S. DOLLARS PER PERSON	
Australia	10.2	3.6	37,492	3,814
Germany	10.9	3.0	22,762	2,481
Switzerland	11.0	3.5	44,899	4,943
Denmark	11.1	3.8	27,306	3,036
Netherlands	11.6	3.3	20,625	2,388
Finland	12.0	4.7	24,927	3,001
Qatar	12.1	0.3	11,199	1,361
Sweden	12.2	3.7	26,146	3,193
South Korea	12.2	2.2	12,002	1,468
Norway	13.2	4.3	37,146	4,885
France	13.2	3.3	22,945	3,037
Czech Republic	13.3	9.3	9,643	1,279
Hong Kong, China	13.4	1.0	24,060	3,224
Taiwan	13.5	2.1	12,247	1,657
Japan	13.8	2.5	27,761	3,818
Belgium	13.8	3.8	22,208	3,075
Bahrain	13.9	0.4	10,200	1,422
Spain	14.0	3.0	17,713	2,483
Italy	14.2	2.8	20,362	2,892
United Arab Emirates	14.3	0.2	21,206	3,024
New Zealand	14.6	3.0	22,448	3,284
Slovenia	15.3	5.6	13,858	2,125
Brazil	15.9	1.4	7,063	1,123
Israel	15.9	2.6	17,491	2,783
Hungary	16.2	7.5	6,972	1,127

(Continues)

**TABLE 1-1** Percent of Consumer Expenditures Spent on Food, Alcoholic Beverages, and Tobacco Consumed at Home, by Selected Countries, 2012<sup>1</sup>

COUNTRY/TERRITORY	SHARE OF CONSUMER EXPENDITURES			
	FOOD <sup>2</sup>	ALCOHOLIC BEVERAGES AND TOBACCO	CONSUMER EXPENDITURES <sup>3</sup>	EXPENDITURE ON FOOD <sup>2</sup>
	PERCENT		U.S. DOLLARS PER PERSON	
Chile	16.2	3.0	9,566	1,546
Greece	16.5	4.4	16,652	2,740
Portugal	16.5	3.0	13,473	2,225
Slovakia	16.8	4.9	9,556	1,603
Uruguay	18.3	3.4	10,272	1,878
Colombia	18.4	3.3	4,744	872
Kuwait	18.6	0.5	7,284	1,352
Venezuela	18.6	3.6	7,421	1,378
Latvia	18.8	6.8	8,612	1,619
South Africa	19.4	6.1	4,524	877
Malaysia	19.5	2.5	5,557	1,084
Poland	19.6	6.5	7,773	1,521
Estonia	19.6	8.6	8,923	1,753
Argentina	20.9	4.5	6,595	1,381
Bulgaria	21.2	4.0	4,718	999
Ecuador	21.9	0.9	3,526	771
Turkey	22.2	4.6	7,705	1,708
Costa Rica	23.3	0.4	6,754	1,577
Turkmenistan	23.5	2.0	2,503	589
Dominican Republic	24.5	4.2	5,192	1,272
Mexico	24.9	2.2	6,518	1,625
India	25.2	3.0	871	220
Iran	25.5	0.4	2,744	699
Lithuania	25.7	8.5	9,067	2,331
Saudi Arabia	25.8	0.6	6,220	1,607
China	26.9	3.6	2,149	577

(Continues)