Contents

The Chemical Element: Chemistry's Contribution to Our Global Future V Introduction XIII List of Contributors XVII

1	Chemistry for Development 1
	Stephen A. Matlin and Berhanu M. Abegaz
1.1	Chemistry, Innovation and Impact 1
1.2	Poverty and Disparities in Life Expectancy 8
1.3	The Millennium Development Goals 9
1.3.1	Goal 1: Reducing Poverty and Hunger 10
1.3.2	Goal 2: Achieving Universal Primary Education 12
1.3.3	Goal 3: Promoting Gender Equality and Empowering Women 12
1.3.4	Goals 4 and 5: Reducing Maternal and Under-Five Child Mortality 13
1.3.5	Goal 6: Combating HIV/AIDS, Malaria and Other Diseases 13
1.3.6	Goal 7: Ensuring Environmental Sustainability 13
1.3.7	Goal 8: Developing a Global Partnership for Development 15
1.4	Science, Technology and Development 15
1.5	Chemistry and Development 19
1.5.1	Chemical Research Applied to World Needs 19
1.5.2	International Organization for Chemical Sciences in Development 20
1.6	Science and Technology for National Development 22
1.6.1	Investments in Research and Development 22
1.6.2	Outputs from Investments in Research and Development 25
1.6.3	Connecting Science, Technology and Innovation 30
1.7	Capacity Building: Some Key Requirements for Chemistry's Role in
	Development 32
1.7.1	Evolution of Capacity Building Approaches in LMICs 32
1.7.2	National Policies for S&T 33
1.7.3	Responsibilities 34
1.7.4	Professional Associations and Cooperative Networks for Chemistry
	and Development 36
1.7.5	National Funding for Research 42
176	Gender Issues 43



1.7.7	Open Access 44
1.7.8	Technology Transfer 44
1.8	Chemistry and Future Challenges to Health, Wealth and Wellbeing 46
1.8.1	"Glocal" – Thinking and Acting from Global to Local 46
1.8.2	Agriculture, Food and Nutrition 47
1.8.3	Climate Change 49
1.8.4	Energy 50
1.8.5	Environment and Sustainable Development 50
1.8.6	Health 51
1.8.7	Intellectual Property 53
1.8.8	Natural Resources Exploitation 54
1.8.9	Water 56
1.9	Conclusions 56
	Acknowledgments 58
	References 58
2	The Role of Chemistry in Addressing Hunger and Food Security 71
_	Jessica Fanzo, Roseline Remans, and Pedro Sanchez
2.1	Chemistry is the Backbone of Food and Nutrition 71
2.2	Global Hunger and Malnutrition in the World Today 73
2.2.1	Progress on the Proportion of Children Who are Underweight 73
2.2.2	Progress on the Proportion of the Population Who are
	Undernourished 74
2.3	Hunger, Nutrition, and the Food Security Mandate 74
2.4	Chemistry's Influence on the Pillars of Food Security 76
2.4.1	Food Availability 76
2.4.2	Chemistry and the Green Revolution 76
2.4.3	Genetically Engineered Crops and Food Production 80
2.4.4	Food Access 82
2.4.4.1	Post-Harvest Treatment and Storage 82
2.4.5	Food Utilization 85
2.4.5.1	Balanced Diets and Utilization of Nutrients: The Chemical
	Components 85
2.4.5.2	Antinutrients 88
2.4.5.3	Fortification of Food Vehicles: One Chemical at a Time 89
2.4.5.4	Improving Utilization through Modern Medicine: The Contribution of
	Chemistry to Basic Medicines 90
2.5	Conclusion 92
	References 94
3	Poverty 99
	Mari-Carmen Gomez-Cabrera, Cecilia Martínez-Costa, and Juan Sastre
3.1	Contribution of Chemistry to Social and Economic Development 99
3.2	Concept and Historical Evolution of Poverty 102

3.4	Causes of Poverty 106
3.4.1	Geopolitics 107
3.4.2	Geography 107
3.4.3	Lack of Economic Growth 107
3.4.4	Deficient Governance 108
3.4.5	Deficient Health 108
3.4.6	Failures of Effective and Sufficient Development Aid 108
3.5	Poverty, Malnutrition, and Life Expectancy 109
3.6	Strategies against Poverty: A General Approach with Context-Specific Solutions 112
3.6.1	Renewable Energy Sources and Sustainable Development 112
3.6.2	Infrastructure, Science, and Technological Progress 114
3.6.3	Microcredits and Inclusive Business Models 116
3.6.4	Health Promotion and Malnutrition Prevention 117
3.6.5	Involvement of the Local Government: The Ijebu-Ode Experiment 119
3.6.6	UN, CSOs, and Governments from Developed Countries: a Joint Crucial Effort 120
3.6.7	Additional Efforts towards Eradication of Poverty 121
3.7	Chemistry is Essential for Poverty Alleviation 122
3.7.1	Nanotechnology and Nanochemistry 122
3.7.2	Industrial Biotechnology and Biofuels 126
3.7.3	Combinatorial Chemistry 127
	References 128
4	The Human Element: Chemistry Education's Contribution to Our
4	Global Future 131
	Global Future 131 Peter Mahaffy
4.1	Global Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131
4.1 4.2	Global Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132
4.1 4.2 4.3	Global Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135
4.1 4.2	Global Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137
4.1 4.2 4.3	Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives
4.1 4.2 4.3 4.4	Global Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137
4.1 4.2 4.3 4.4	Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1—An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138
4.1 4.2 4.3 4.4	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1—An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139
4.1 4.2 4.3 4.4	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of
4.1 4.2 4.3 4.4 4.4.1	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1—An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn
4.1 4.2 4.3 4.4 4.4.1	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn Chemistry 140
4.1 4.2 4.3 4.4 4.4.1	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn Chemistry 140 Provide Education about Chemistry, and through Chemistry, as well as
4.1 4.2 4.3 4.4 4.4.1 4.4.2 4.4.3	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn Chemistry 140 Provide Education about Chemistry, and through Chemistry, as well as in Chemistry 142
4.1 4.2 4.3 4.4 4.4.1 4.4.2 4.4.3	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1—An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn Chemistry 140 Provide Education about Chemistry, and through Chemistry, as well as in Chemistry 142 Move beyond the Fractionation of Knowledge 144
4.1 4.2 4.3 4.4 4.4.1 4.4.2 4.4.3	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1–An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn Chemistry 140 Provide Education about Chemistry, and through Chemistry, as well as in Chemistry 142 Move beyond the Fractionation of Knowledge 144 Show the Integral Connection between Chemical Reactivity and
4.1 4.2 4.3 4.4 4.4.1 4.4.2 4.4.3 4.4.4 4.4.5	Clobal Future 131 Peter Mahaffy The International Year of Chemistry Educational Challenge 131 Scene 1 – Chemistry to the Rescue of Threatened Communities 132 Sequel to Scene 1—An Education in Chemistry 135 Equipping the Human Element with Relevant Education in, about, and through Chemistry 137 Identify the Learners, Understand Their Overall Learning Objectives and Career Goals, and Ensure Education in Chemistry Meets Their Needs 138 Build and Support Active Learning Communities 139 Engage Students with Curriculum and Pedagogy that Takes Account of Research about How They Best Learn and How They Best Learn Chemistry 140 Provide Education about Chemistry, and through Chemistry, as well as in Chemistry 142 Move beyond the Fractionation of Knowledge 144

	The state of the s
4.5	An Example of Integrating Sustainability and Chemistry Education
	Curriculum: Visualizing the Chemistry Underlying Climate
	Change 149
4.6	Scene 2-Chemistry Education and Our Global Future 152
	References 154
5	The Impacts of Synthetic Chemistry on Human Health 159
•	René Roy
5.1	The Molecules at the Origin of Drug Discoveries 159
5.2	From Bench to Market Place 162
5.3	General Concepts of Drug Design 169
5.3.1	Tasks and Bottlenecks in Medicinal Chemistry 170
5.3.2	Lead Validation 171
5.4	Patent Protection Issues 172
5.5	Drug Metabolism and Drug Resistance or Why Make
	Big Pills? 173
5.5.1	Drug Metabolism 174
5.5.1.1	Phase I Transformations 174
5.5.1.2	Phase II Transformations 174
5.5.2	Drug Resistance 174
5.6	Antibacterial Agents 176
5.7	Antiviral Agents: The Flu Virus Story: The Naissance of a Sugar-based
	Flu Drug 177
5.8	The Viagra Story-Serendipity Leading to a Blockbuster Drug 180
5.9	Human Vaccines as a Prophylactic Health Remedy 182
5.9.1	Carbohydrate-based Vaccines 182
5.9.2	The Role of Chemistry in Synthetic Vaccines 183
5.9.3	Bacterial Capsular Polysaccharide Vaccines 183
5.10	Conclusion 185
5.10	
	References 186
_	
6	The Greening of Chemistry 189
	Pietro Tundo, Fabio Aricò, and Con Robert McElroy
6.1	Introduction 189
6.1.1	The History of Green Chemistry 189
6.1.2	Green Chemistry in the Economy: the Chinese Circular Economy
	(CE) 197
6.1.3	Award for Green Chemistry Research 199
6.1.3.1	The Presidential Green Chemistry Challenge 199
6.1.3.2	Award for Green Products and Processes 200
6.1.3.3	The European Sustainable Chemistry Award 200
6.1.3.4	The Institution of Chemical Engineers Award 200
6.1.3.5	Green and Sustainable Chemistry Network Award
J. 1.J.J	•
6126	(Japan) 200
6.1.3.6	RACI Green Chemistry Challenge Award 200

6.2	Areas of Green Chemistry 202
6.2.1	Alternative Feedstocks 203
6.2.2	Use of Innocuous Reagents 206
6.2.2.1	Less Hazardous Reagent 206
6.2.2.2	Generate Less Waste 210
6.2.2.3	High Conversion and Selectivity 213
6.2.2.4	Catalyst 213
6.2.3	Employing Natural Processes 215
6.2.4	Use of Alternative Solvents 217
6.2.5	Design of Safer Chemicals 220
6.2.6	Developing Alternative Reaction Conditions 222
6.2.7	Minimizing Energy Consumption 222
6.3	Metrics in Green Chemistry 226
6.4	Conclusions and Future Perspectives 227
	References 229
7	Water: Foundation for a Sustainable Future 235
-	Maya A. Trotz, James R. Mihelcic, Omatoyo K. Dalrymple, Arlin Briley,
	Ken D. Thomas, and Joniqua A. Howard
7.1	Introduction 235
7.2	Water Pollution and Water Quality 239
7.2.1	Biochemical Oxygen Demand 239
7.2.2	Nutrients (Nitrogen and Phosphorus) 239
7.2.3	Global Cycling of Carbon in Water 245
7.2.4	Turbidity and Pathogens 246
7.2.5	Arsenic and Fluoride 247
7.2.6	Global Cycling of Mercury 249
7.2.7	Emerging Chemicals of Concern 251
7.3	Water Treatment Technologies 254
7.3.1	Point of Use Treatment and Advanced Oxidation Processes 254
7.3.2	Membranes 256
7.3.3	Arsenic 256
7.3.4	Water Reuse 259
7.3.5	Carbon Sequestration 261
7.4	Conclusions 262
	References 263
8	Facing the Energy Challenges through Chemistry in a
	Changing World 269
	Gabriele Centi and Siglinda Perathoner
8.1	Introduction 269
8.2	Chemistry and the Role for Development of Society 272
8.3	Chemistry and Sustainable Energy 275
8.4	Sustainable Energy Scenarios and Climate Changes 282
8.5	Nanomaterials for Sustainable Energy 283

8.6 8.7 8.8	Biofuels 290 Towards Solar Fuels 296 Conclusions 304 References 305
9	Ozone Depletion and Climate Change 311
	Glenn Carver
9.1	Introduction 311
9.2	Ozone in the Atmosphere 312
9.2.1	Chapman Reactions 314
9.2.2	Catalytic Cycles 315
9.2.3	How Ozone is Measured 316
9.3	The Antarctic Ozone Hole 317
9.3.1	The Steps to the Ozone Hole 321
9.4	Arctic Ozone 324
9.5	Montreal Protocol and Beyond 327
9.6	Ozone and Climate Change 330
9.6.1	The World Avoided 332
9.7	Perspectives 333
9.8	Resources 334
	Acknowledgments 335
	References 335
	Epilogue 337 Jeffrey Sachs

Color Plates 341

Index 371