SPRINGER REFERENCE

Vinood B. Patel
Victor R. Preedy
Editors

Handbook of Nutrition, Diet, and Epigenetics

Springer

Handbook of Nutrition, Diet, and Epigenetics

Vinood B. Patel • Victor R. Preedy
Editors

Handbook of Nutrition, Diet, and Epigenetics

With 416 Figures and 143 Tables

Springer

Editors
Vinood B. Patel
School of Life Sciences
University of Westminster
London, UK

Victor R. Preedy
Diabetes and Nutritional Sciences Research Division
Faculty of Life Sciences and Medicine
King's College London
London, UK

ISBN 978-3-319-55529-4 ISBN 978-3-319-55530-0 (eBook)
ISBN 978-3-319-59052-3 (print and electronic bundle)
https://doi.org/10.1007/978-3-319-55530-0

Library of Congress Control Number: 2018953716

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The well-being of humankind is not only dependent upon individuals receiving adequate nutrition but also upon their genetic makeup. Genes may encode proteins responsible for structural components (e.g., membranes, subcellular organelles) and dynamics (e.g., enzymes, receptor–postreceptor cascades). Many of these components will require, from the outset, an adequate diet. For example, some antioxidant enzymes are critically dependent on the diet. This is illustrated by the role of dietary selenium which is necessary for glutathione peroxidase activities, while copper and zinc are necessary for superoxide dismutase activities. However, there is an increasing body of evidence to suggest that nutrition itself may alter the way in which genes are expressed via the process of epigenetics. Definitions of epigenetics vary and include modifications in the functional expression of DNA. This may involve changes in, or the influence of, DNA methylation, noncoding RNA, chromatin, histone acetylation or methylation, genomic imprinting, and other processes. There are many dietary components that impose epigenetic changes including folate, B vitamins, betaine, choline, and other extracts from plants, foods, and beverages. In fact, the knowledge base of how dietary components impact epigenetic processes has increased markedly over the past few years. As a prelude to understanding the role of epigenetics, it is also necessary to understand the basics of cellular and molecular biology, as well as the clinical basis of health and disease. However, marshaling all the information on the complex relationships between cellular and molecular biology, diet and nutrition, health and disease, and epigenetic processes is somewhat difficult due to the myriad of material. To address this, the editors have compiled the *Handbook of Nutrition, Diet, and Epigenetics*.

The book is divided into the following parts:

Part I. Introductory Material and Foundations
Part II. Organs, Disease, and Life Stages
Part III. Influence of Diet and Nutrition on Epigenetics
Part IV. Practical Techniques and Applications

Part I Introductory Material and Foundations covers biology of the cell, overviews, and comparative epigenetics. **Part II Organs, Disease, and Life Stages** covers weight control, metabolic syndrome and obesity, diabetes, insulin and

glucose, the cardiovascular system, the nervous system, cancers and immune function, the intestinal tract, kidney, muscle and bone, life stages, pregnancy, development and programming, transgenerational effects, and aging. **Part III Influence of Diet and Nutrition on Epigenetics** covers energy, general treatments and nutritional modifications, lipids and proteins as macronutrients and their components, vitamins and minerals, combinations (mixtures of components), specific foods and nutraceuticals, and nutritional toxicology and adverse effects. **Part IV Practical Techniques and Applications** covers multilocus methylation assays, beadchips, bioinformatics databases, microRNAs, mass spectrometry, embryonic stem cells, and molecular pathways and resources.

It is difficult to list all the chapters as there are just over 120, and some cover numerous analytical or disease-based domains. The editors recognize the difficulties in assigning chapters to specific parts of the book as some chapters may well be suitable for two or more sections. Nevertheless, there is a wide breadth of material available. There are also unique features in this handbook, whereby each of the chapters includes the following sections:

- Dictionary of Terms
- Key Facts
- Summary Points

These features enable the transdisciplinary and transintellectual divides to be bridged.

Contributors are authors of international and national standing, leaders in the field, and trendsetters. Emerging fields of epigenetics in relation to diet and nutrition are also incorporated in the *Handbook of Nutrition, Diet, and Epigenetics*. This represents essential reading for nutritionists, dietitians, health care professionals, research scientists, molecular and cellular biochemists, physicians, general practitioners, public health practitioners, as well as those interested in health in general.

Vinood B. Patel
Victor R. Preedy

Contents

Volume 1

Volume 3

About the Editors

Vinood B. Patel
School of Life Sciences
University of Westminster
London, UK

Vinood B. Patel (B.Sc., Ph.D., FRSC) is a Reader in Clinical Biochemistry at the University of Westminster and honorary Fellow at King's College London. Dr. Patel graduated from 1992 the University of Portsmouth with a Degree in Pharmacology and completed his Ph.D. in protein metabolism from King's College London in 1997. His postdoctoral work was carried out at Wake Forest University Baptist Medical School studying structural-functional alterations to mitochondrial ribosomes, where he developed novel techniques to characterize their biophysical properties. Dr. Patel is a nationally and internationally recognized scientist, and in 2014 he was elected as a Fellow to the Royal Society of Chemistry. He presently directs studies on metabolic pathways involved in diabetes and liver disease, particularly related to mitochondrial energy regulation and cell death. He is currently conducting research to study the role of nutrients, antioxidants, phytochemicals, iron, alcohol, and fatty acids. His other areas of interest include identifying new biomarkers that can be used for the diagnosis and prognosis of liver disease and understanding mitochondrial oxidative stress in Alzheimer's disease and gastrointestinal dysfunction in autism. Dr. Patel has edited biomedical books in the areas of nutrition and health prevention and biomarkers and has published over 150 articles.

Victor R. Preedy (B.Sc., Ph.D., D.Sc., FRSB, FRSPH, FRCPath, FRSC) is a senior member of King's College London, where he is also Director of the Genomics Centre and a member of the Faculty of Life Sciences and Medicine.

Professor Preedy graduated in 1974 with an Honors Degree in Biology and Physiology with Pharmacology. He gained his University of London Ph.D. in 1981. In 1992, he received his Membership of the Royal College of Pathologists, and in 1993 he gained his second doctoral degree for his outstanding contribution to protein metabolism in health and disease. Professor Preedy was elected as Fellow to the Institute of Biology in 1995 and to the Royal College of Pathologists in 2000. Since then, he has been elected as Fellow to the Royal Society for the Promotion of Health (2004) and the Royal Institute of Public Health (2004). In 2009, Professor Preedy became Fellow of the Royal Society for Public Health and, in 2012, Fellow of the Royal Society of Chemistry. In his career, Professor Preedy has carried out research at the National Heart Hospital (part of Imperial College London), the School of Pharmacy (now part of University College London), and the MRC Centre at Northwick Park Hospital. He has collaborated with research groups in Finland, Japan, Australia, the USA, and Germany. He is a leading expert in the science of health and has a long-standing interest in food and nutrition for over 30 years, especially related to tissue pathology and cellular and molecular biology. He has lectured nationally and internationally. To his credit, Professor Preedy has published over 600 articles, which include peer-reviewed manuscripts based on original research, abstracts and symposium presentations, reviews, and numerous books and volumes.

Contributors

Rosita Aitoro Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Aftab Alam Chromatin and Disease Biology Lab (# 08), National Centre for Cell Science, NCCS Complex, Savitribai Phule Pune University Campus, Pune, Maharashtra, India

Luigi Albano Department of Translational Medical Sciences, University of Naples "Federico II", Naples, Italy

David Albuquerque Department of Life Sciences, Research Centre for Anthropology and Health (CIAS), University of Coimbra, Coimbra, Portugal

Nezam Altorok Division of Rheumatology, Department of Internal Medicine, University of Toledo Medical Center, Toledo, OH, USA

Fawaz Alzaïd Sorbonne Universités, Université Pierre et Marie-Curie, Institut National de la Santé et de la Recherche Médicale (INSERM), UMR_S 1138 Cordeliers Research, Paris, France

Gerard Aragonès Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Juan Arguelles Departamento de Biología Funcional, Área de Fisiología, Facultad de Medicina y Ciencias de la Salud, Universidad de Oviedo, España, Oviedo, Asturias, Spain

Takahiro Arima Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Lluís Arola Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Nutrition and Health Research Group, Technological Center for Nutrition and Health (EURECAT-CTNS), Tecnio, Campus of International Excellence Southern Catalonia (CEICS), Reus, Spain

Anna Arola-Arnal Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Stella Aslibekyan Department of Epidemiology, University of Alabama at Birmingham, Birmingham, AL, USA

Paulo Pimentel Assumpção Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belém, Pará, Brazil

Susana Astiz Comparative Physiology Group. SGIT-INIA, Avda. Puerta de Hierro s/n, Madrid, Spain

Aneta Balcerczyk Faculty of Biology and Environmental Protection, Department of Molecular Biophysics, University of Lodz, Lodz, Poland

Donatella Barisani School of Medicine and Surgery, University of Milano Bicocca, Monza, Italy

Nicolas Barnich M2iSH, Université Clermont Auvergne, Inserm U1071, USC-INRA 2018, Clermont-Ferrand, France

Emma L. Beckett School of Medicine and Public Health, The University of Newcastle, Ourimbah, NSW, Australia

Megan Beetch Land and Food Systems, Food, Nutrition and Health, University of British Columbia, Vancouver, BC, Canada

Jomer Bernardo Texas A&M Irma Lerma Rangel College of Pharmacy, Kingsville, TX, USA

Cinta Bladé Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Priscilla Boccia Department of Technological Innovation and Safety of Plants, Product and Anthropic Settlements (DIT), Italian Workers' Compensation Authority (INAIL), Rome, Italy

Loys Bodin GenPhySE, Université de Toulouse, INRA, INPT, ENVT, Castanet Tolosan, France

Tiziana Bonaldi Department of Experimental Oncology, European Institute of Oncology, Milan, Italy

Nikolay M. Borisov Centre for Convergence of Nano-, Bio-, Information and Cognitive Sciences and Technologies, National Research Centre "Kurchatov Institute", Moscow, Russia

Department of Personalized Medicine, First Oncology Research and Advisory Center, Moscow, Russia

John D. Bowman Texas A&M Irma Lerma Rangel College of Pharmacy, Kingsville, TX, USA

Sofia Braverman Department of Immunology, Weizmann Institute of Science, Rehovot, Israel

Francisca I. Bravo Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Jean-Michel Brun GenPhySE, Université de Toulouse, INRA, INPT, ENVT, Castanet Tolosan, France

Gunnar Brunborg Department of Molecular Biology, Infection Control and Environmental Health, Norwegian Institute of Public Health, Oslo, Norway

Scott J. Bultman Department of Genetics, Lineberger Comprehensive Cancer Center, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Rommel Rodríguez Burbano Laboratório de Biologia Molecular, Hospital Ophir Loyola, Belém, Pará, Brazil

Markus Burkard Department of Vegetative and Clinical Physiology, Institute of Physiology, University Hospital Tuebingen, Tuebingen, Germany

Anton A. Buzdin Centre for Convergence of Nano-, Bio-, Information and Cognitive Sciences and Technologies, National Research Centre "Kurchatov Institute", Moscow, Russia

OmicsWay Corporation, Walnut, CA, USA

Group for Genomic Regulation of Cell Signaling Systems, Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry, Moscow, Russia

Lars Olov Bygren Department of Biosciences and Nutrition, Karolinska Institutet, Huddinge, Sweden

Demin Cai Key Laboratory of Animal Physiology and Biochemistry, Ministry of Agriculture, College of Veterinary Medicine, Nanjing Agricultural University, Nanjing, China

Danielle Queiroz Calcagno Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belém, Pará, Brazil

Luísa Camacho Division of Biochemical Toxicology, National Center for Toxicological Research, Food and Drug Administration, Jefferson, AR, USA

Roberto Berni Canani Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

European Laboratory for the Investigation of Food Induced Diseases (ELFID), University of Naples "Federico II", Naples, Italy

CEINGE Advanced Biotechnologies, University of Naples "Federico II", Naples, Italy

Andres Cardenas Department of Population Medicine, Harvard Medical School, Boston, MA, USA

Emily Chapman Department of Environmental Medicine and Public Health, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Sybil Charriere Claude Bernard University, Lyon, France

Department of Endocrinology, Diabetology, Metabolic Diseases and Nutrition, Cardiovascular Hospital Louis Pradel, Bron Cedex, France

Samit Chattopadhyay Indian Institute of Chemical Biology, Kolkata, West Bengal, India

Chromatin and Disease Biology Lab (# 08), National Centre for Cell Science, NCCS Complex, Savitribai Phule Pune University Campus, Pune, Maharashtra, India

Qiao Yi Chen Department of Environmental Medicine, New York University School of Medicine, Tuxedo, NY, USA

Elizabeth Suchi Chen Division of Genetics, Department of Morphology and Genetics, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil

Guohua Chen Department of Pathology, Wayne State University School of Medicine, Detroit, MI, USA

Jia Chen Department of Environmental Medicine and Public Health, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Department of Pediatrics, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Department of Oncological Sciences, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Department of Medicine, Hematology and Medical Oncology, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Jin-Ran Chen Arkansas Children's Nutrition Center and the Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, AR, USA

Alfred Sze-Lok Cheng School of Biomedical Sciences, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong

Wen-Hsing Cheng Department of Food Science, Nutrition and Health Promotion, Mississippi State University, Mississippi State, MS, USA

Arpankumar Choksi Chromatin and Disease Biology Lab (# 08), National Centre for Cell Science, NCCS Complex, Savitribai Phule Pune University Campus, Pune, Maharashtra, India

Mahua Choudhury Department of Pharmaceutical Sciences, Irma Lerma Rangel College of Pharmacy, Texas A&M Health Science Center, College Station, TX, USA

Sayantani Chowdhury Division of Molecular Medicine, Bose Institute, Kolkata, India

Sabrina Chriett INSERM U1060, Oullins, France

Steven A. Claas College of Public Health, University of Kentucky, Lexington, KY, USA

Juan Francisco Codocedo CARE UC Biomedical Research Center, Faculty of Biological Sciences, Pontificia Universidad Católica de Chile, Santiago, Chile

Anne Collin INRA – URA, INRA, Nouzilly, France

Linda Cosenza Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Max Costa Department of Environmental Medicine, New York University School of Medicine, Tuxedo, NY, USA

Vincent Coustham INRA – URA, INRA, Nouzilly, France

Anna Crescenti Nutrition and Health Research Group, Technological Center for Nutrition and Health (EURECAT-CTNS), Tecnio, Campus of International Excellence Southern Catalonia (CEICS), Reus, Spain

Juan Cui Department of Computer Science and Engineering, University of Nebraska-Lincoln, Lincoln, NE, USA

Alessandro Cuomo Department of Experimental Oncology, European Institute of Oncology, Milan, Italy

Lidia Daimiel Nutritional Genomics of the Cardiovascular Disease and Obesity, Foundation IMDEA Food CEI UAM + CSIC, Madrid, Spain

Department of Nutrition and Bromatology, Facultad de Farmacia, Universidad San Pablo-CEU, CEU universities, Boadilla del Monte, Madrid, Spain

Aline de Conti Division of Biochemical Toxicology, National Center for Toxicological Research, Food and Drug Administration, Jefferson, AR, USA

Flávia Ramos de Siqueira Department of Internal Medicine, Laboratory of Experimental Hypertension, School of Medicine, University of Sao Paulo, Sao Paulo, SP, Brazil

Department of Internal Medicine, University of São Paulo School of Medicine, Butantã, São Paulo, SP, Brazil

Department of Internal Medicine, Nephrology Division, School of Medicine, University of São Paulo, São Paulo, SP, Brazil

Stefanie Braga Maia de Sousa Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belém, Pará, Brazil

Christiana A. Demetriou Neurology Clinic D, The Cyprus Institute of Neurology and Genetics, Ayios Dhometios, Nicosia, Cyprus

The Cyprus School of Molecular Medicine, The Cyprus Institute of Neurology and Genetics, Ayios Dhometios, Nicosia, Cyprus

Jérémy Denizot M2iSH, Université Clermont Auvergne, Inserm U1071, USC-INRA 2018, Clermont-Ferrand, France

Maya A. Deyssenroth Department of Environmental Medicine and Public Health, Icahn School of Medicine at Mount Sinai, New York, NY, USA

Margherita Di Costanzo Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Carmen di Scala Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Svetlana Dinić Department of Molecular Biology, Institute for Biological Research Siniša Stanković, University of Belgrade, Belgrade, Serbia

Cristina Domenichelli Largo Alessandria del Carretto, Rome, Italy

Daoyin Dong Department of Obstetrics, Gynecology and Reproductive Sciences, University of Maryland School of Medicine, Baltimore, MD, USA

Jörg Dötsch Department of Pediatrics, University of Cologne, Cologne, Germany

Nur Duale Department of Molecular Biology, Infection Control and Environmental Health, Norwegian Institute of Public Health, Oslo, Norway

Thomas Eggermann Institute of Human Genetics, University Hospital, RWTH Technical University Aachen, Aachen, Germany

Eran Elinav Department of Immunology, Weizmann Institute of Science, Rehovot, Israel

Eduard Escrich Multidisciplinary Group for the Study of Breast Cancer, Department of Cell Biology, Physiology and Immunology, Physiology Unit, Faculty of Medicine, Universitat Autònoma de Barcelona, Barcelona, Spain

Dyfed Lloyd Evans School of Life Sciences, University of KwaZulu-Natal, Westville Campus, Durban, KwaZulu Natal, South Africa

Mingzhu Fang Department of Environmental and Occupational Health, School of Public Health Environmental and Occupational Health Sciences Institute, Rutgers, The State University of New Jersey, Piscataway, NJ, USA

Maria Rosaria Faraone-Mennella Department of Biology, University of Naples "Federico II", Naples, Italy

Yannick Faulconnier Herbivore Research Unit -Biomarkers Team, French Institut of Agricultural Research (INRA), St Genès-Champanelle, France

Christopher D. Faulk Department of Animal Sciences, University of Minnesota, St. Paul, MN, USA

Robert Feil Institute of Molecular Genetics (IGMM), Centre National de Recherche Scientifique (CNRS), UMR-5535, University of Montpellier, Montpellier, France

Michael Fenech CSIRO Health and Biosecurity, Personalised Nutrition and Healthy Ageing, Adelaide, SA, Australia

Carla Ferreri Institute of Organic Synthesis and Photoreactivity (ISOF), CNR, Bologna, Italy

Maxime François CSIRO Health and Biosecurity, Personalised Nutrition and Healthy Ageing, Adelaide, SA, Australia

Department of Molecular and Cellular Biology, School of Biological Sciences, University of Adelaide, Adelaide, SA, Australia

Laure Frésard Department of Pathology, Stanford University, Stanford, CA, USA

Luzia Naôko Shinohara Furukawa Department of Internal Medicine, Laboratory of Experimental Hypertension, School of Medicine, University of Sao Paulo, Sao Paulo, SP, Brazil

Department of Internal Medicine, University of São Paulo School of Medicine, Butantã, São Paulo, SP, Brazil

Andrea Fuso Department of Surgery "P. Valdoni", Sapienza University of Rome, Rome, Italy

Uma Gaur Institute of Animal Genetics and Breeding, Sichuan Agricultural University, Chengdu, Sichuan, China

Bruce German Department of Food Science and Technology, University of California Davis, Davis, CA, USA

Meenu Ghai School of Life Sciences, University of KwaZulu-Natal,Westville Campus, Durban, KwaZulu Natal, South Africa

Jyotirmoy Ghosh Department of Chemistry, Banwarilal Bhalotia College, Ushagram Asansol, West Bengal, India

Carolina Oliveira Gigek Division of Genetics, Department of Morphology and Genetics, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil

Division of Surgical Gastroenterology, Department of Surgery, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil

Elodie Gimier M2iSH, Université Clermont Auvergne, Inserm U1071, USC-INRA 2018, Clermont-Ferrand, France

Silvia Gioiosa Institute of Biomembranes and Bioenergetics, National Research Council, Bari, Italy

Toshinao Goda Graduate School of Nutritional and Environmental Sciences, University of Shizuoka, Shizuoka, Japan

Department of Nutrition, School of Food and Nutritional Sciences, The University of Shizuoka, Shizuoka, Japan

Xiaoming Gong Department of Pediatrics, Paul L. Foster School of Medicine, Texas Tech University Health Sciences Center El Paso, El Paso, TX, USA

Antonio Gonzalez-Bulnes Comparative Physiology Group. SGIT-INIA, Avda. Puerta de Hierro s/n, Madrid, Spain

Viviana Granata Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Steven G. Gray Thoracic Oncology Research Group, Trinity Translational Medical Institute, St James's Hospital, Dublin, Ireland

Nevena Grdović Institute for Biological Research, University of Belgrade, Belgrade, Serbia

Michael Paul Greenwood School of Clinical Sciences, University of Bristol, Bristol, UK

Harvest F. Gu Department of Clinical Science, Intervention and Technologies, Karolinska Institutet, Karolinska University Hospital, Stockholm, Sweden

Center for Molecular Medicine, Karolinska Institutet, Karolinska University Hospital, Stockholm, Sweden

Sandrine Le Guillou Génétique Animale et Biologie Intégrative, French Institut of Agricultural Research (INRA), Jouy-en-Josas, France

Daniel B. Hardy Departments of Obstetrics and Gynecology and Physiology and Pharmacology, The Children's Health Research Institute and The Lawson Health Research Institute, The University of Western Ontario, London, ON, Canada

Natsuyo Hariya Department of Nutrition, Faculty of Health and Nutrition, Yamanashi Gakuin University, Kofu, Yamanashi, Japan

Hiromitsu Hattori Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Trine B. Haugen Faculty of Health Sciences, Oslo and Akershus University College of Applied Sciences, Oslo, Norway

Christine Heberden Micalis Institute, INRA, AgroParisTech, Université Paris-Saclay, Jouy-en-Josas, France

Renato Heidor Laboratory of Diet, Nutrition and Cancer, Department of Food and Experimental Nutrition, Faculty of Pharmaceutical Sciences, University of São Paulo, São Paulo, SP, Brazil

Joel Claudio Heimann Department of Internal Medicine, Laboratory of Experimental Hypertension, School of Medicine, University of Sao Paulo, Sao Paulo, SP, Brazil

Hitoshi Hiura Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Tara L. Hogenson Schulze Center for Novel Therapeutics, Mayo Clinic, Rochester, MN, USA

Kazue Honma Graduate School of Nutritional and Environmental Sciences, University of Shizuoka, Shizuoka, Japan

Department of Nutrition, School of Food and Nutritional Sciences, The University of Shizuoka, Shizuoka, Japan

Dave S. B. Hoon Department of Translational Molecular Medicine, John Wayne Cancer Institute at Providence Saint John's Health Center, Santa Monica, CA, USA

Willie Hsu Department of Chemistry, Texas A&M University, College Station, TX, USA

Yun Hu Key Laboratory of Animal Physiology and Biochemistry, Ministry of Agriculture, College of Veterinary Medicine, Nanjing Agricultural University, Nanjing, China

Kun Huang Tongji School of Pharmacy, Huazhong University of Science and Technology, Wuhan, China

Tyler C. Huff Dr. John T. Macdonald Foundation Department of Human Genetics, John P. Hussman Institute for Human Genomics, University of Miami Miller School of Medicine, Miami, FL, USA

Yuko Ibuki Graduate Division of Nutritional and Environmental Sciences, University of Shizuoka, Shizuoka, Japan

Nibaldo C. Inestrosa CARE UC Biomedical Research Center, Faculty of Biological Sciences, Pontificia Universidad Católica de Chile, Santiago, Chile

Centre for Healthy Brain Ageing, School of Psychiatry, Faculty of Medicine, University of New South Wales, Sydney, NSW, Australia

Centro de Excelencia en Biomedicina de Magallanes (CEBIMA), Universidad de Magallanes, Punta Arenas, Chile

Tomas Jakobsson Department of Laboratory Medicine, Karolinska Institutet, Huddinge, Sweden

Gopabandhu Jena Facility for Risk Assessment and Intervention Studies, Department of Pharmacology and Toxicology, National Institute of Pharmaceutical Education and Research (NIPER), Mohali, Punjab, India

Yuqian Jiang Department of Biochemistry and Molecular Medicine, University of California at Davis, Sacramento, CA, USA

Jordi Jiménez-Conde Department of Neurology, Hospital del Mar; Neurovascular Research Group, IMIM (Institut Hospital del Mar d'Investigacions Mèdiques), Barcelona, Spain

Ruta Jog Department of Pathology, Wayne State University School of Medicine, Detroit, MI, USA

Bjorn Johansson Centre of Molecular and Environmental Biology (CBMA), Department of Biology, University of Minho, Braga, Portugal

Joan Jory Guelph, ON, Canada

Sadhana Joshi Department of Nutritional Medicine, Interactive Research School for Health Affairs, Bharati Vidyapeeth Deemed University, Pune, India

Shailesh Joshi School of Life Sciences, University of KwaZulu-Natal,Westville Campus, Durban, KwaZulu Natal, South Africa

Bonnie R. Joubert Population Health Branch, National Institute of Environmental and Health Sciences, Durham, NC, USA

Jelena Arambašić Jovanović Department of Molecular Biology, Institute for Biological Research Siniša Stanković, University of Belgrade, Belgrade, Serbia

Tomasz P. Jurkowski Institute of Biochemistry, University of Stuttgart, Stuttgart, Germany

Gunnar Kaati Department of Biosciences and Nutrition, Karolinska Institutet, Huddinge, Sweden

Bashar Kahaleh Division of Rheumatology, Department of Internal Medicine, University of Toledo Medical Center, Toledo, OH, USA

Foteini Kakulas School of Medicine and Pharmacology, The University of Western Australia, Crawley, WA, Australia

Neerja Karnani Singapore Institute for Clinical Sciences (SICS), A*STAR, Brenner Centre for Molecular Medicine, Singapore, Singapore

Yukihiko Kato Department of Dermatology, Tokyo Medical University Hachioji Medical Center, Tokyo, Japan

Jaspreet Kaur Department of Biotechnology, University Institute of Engineering and Technology, Panjab University, Chandigarh, India

Pushpinder Kaur USC Keck School of Medicine, University of Southern California, Los Angeles, CA, USA

Sabbir Khan Facility for Risk Assessment and Intervention Studies, Department of Pharmacology and Toxicology, National Institute of Pharmaceutical Education and Research (NIPER), Mohali, Punjab, India

Yong Jin Kim Department of Obstetrics and Gynecology, Korea University Medical College, Korea University Guro Hospital, Seoul, South Korea

Yoon Young Kim Department of Obstetrics and Gynecology, Seoul National University College of Medicine, Seoul National University Hospital, Seoul, South Korea

Anna K. Kiss Department of Pharmacognosy and Molecular Basis of Phytotherapy, Faculty of Pharmacy, Medical University of Warsaw, Warsaw, Poland

Akane Kitamura Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Jelena Knežević-Vukčević Microbiology, Center for Genotoxicology and Ecogenotoxicology, Faculty of Biology, University of Belgrade, Belgrade, Serbia

Norio Kobayashi Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Robert A. Koza Center for Molecular Medicine, Maine Medical Center Research Institute, Scarborough, ME, USA

Seung-Yup Ku Department of Obstetrics and Gynecology, Seoul National University College of Medicine, Seoul National University Hospital, Seoul, South Korea

Takeo Kubota Faculty of Child Studies, Seitoku University, Matsudo, Chiba, Japan

Kyriacos Kyriacou Department of Electron Microscopy/Molecular Pathology, The Cyprus Institute of Neurology and Genetics, The Cyprus School of Molecular Medicine, The Cyprus School of Molecular, Nicosia, Cyprus

Zachary M. Laubach Department of Integrative Biology and Program in Ecology, Evolutionary Biology, and Behavior, Michigan State University, East Lansing, MI, USA

Minh Le Texas A&M Irma Lerma Rangel College of Pharmacy, Kingsville, TX, USA

Daniel Leclerc Departments of Human Genetics and Pediatrics, McGill University, The Research Institute of the McGill University Health Centre, Montreal, QC, Canada

Todd Leff Department of Pathology, Wayne State University School of Medicine, Detroit, MI, USA

Wayne Leifert CSIRO Health and Biosecurity, Personalised Nutrition and Healthy Ageing, Adelaide, SA, Australia

Department of Molecular and Cellular Biology, School of Biological Sciences, University of Adelaide, Adelaide, SA, Australia

Christian Leischner Department of Vegetative and Clinical Physiology, Institute of Physiology, University Hospital Tuebingen, Tuebingen, Germany

Alexey A. Leontovich Division of Biomedical Statistics and Informatics, Mayo Clinic, Rochester, MN, USA

Christine Leroux Herbivore Research Unit -Biomarkers Team, French Institut of Agricultural Research (INRA), St Genès-Champanelle, France

Department of Food Science and Technology, University of California Davis, Davis, CA, USA

Nancy Lévesque Departments of Human Genetics and Pediatrics, McGill University, The Research Institute of the McGill University Health Centre, Montreal, QC, Canada

Chuan Li Department of Immunology, School of Medicine, University of Connecticut Health Center, Farmington, CT, USA

Ting Lian Institute of Animal Genetics and Breeding, Sichuan Agricultural University, Chengdu, Sichuan, China

Ives Y. Lim Singapore Institute for Clinical Sciences (SICS), A*STAR, Brenner Centre for Molecular Medicine, Singapore, Singapore

Chengqi Lin Institute of Life Sciences, The Key Laboratory of Developmental Genes and Human Disease, Southeast University, Nanjing, Jiangsu, China

Xinyi Lin Singapore Institute for Clinical Sciences (SICS), A*STAR, Brenner Centre for Molecular Medicine, Singapore, Singapore

Birgitte Lindeman Department of Toxicology and Risk, Infection Control and Environmental Health, Norwegian Institute of Public Health, Oslo, Norway

Chengyu Liu Tongji School of Pharmacy, Huazhong University of Science and Technology, Wuhan, China

Haoyu Liu Department of Medical Cell Biology, Uppsala University, Uppsala, Sweden

Wenshe R. Liu Department of Chemistry, Texas A&M University, College Station, TX, USA

Ilana Livyatan Department of Genetics, The Hebrew University of Jerusalem, Jerusalem, Israel

Pang-Kuo Lo Greenebaum Cancer Center, Department of Biochemistry and Molecular Biology, University of Maryland School of Medicine, Baltimore, MD, USA

Gaspar Jesus Lopes-Filho Division of Surgical Gastroenterology, Department of Surgery, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil

Hsin-Yi Lu Department of Food Science, Nutrition and Health Promotion, Mississippi State University, Mississippi State, MS, USA

Mark Lucock School of Environmental and Life Sciences, The University of Newcastle, Ourimbah, NSW, Australia

Xiaoping Luo Department of Pediatrics, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

Zhuojuan Luo Institute of Life Sciences, The Key Laboratory of Developmental Genes and Human Disease, Southeast University, Nanjing, Jiangsu, China

Sonia Métayer-Coustard INRA – URA, INRA, Nouzilly, France

Qingyi Ma Center for Perinatal Biology, Division of Pharmacology, Department of Basic Sciences, Loma Linda University, School of Medicine, Loma Linda, CA, USA

Paolo Emidio Macchia Department of Clinical Medicine and Surgery, University of Naples "Federico II", Naples, Italy

Licínio Manco Department of Life Sciences, Research Centre for Anthropology and Health (CIAS), University of Coimbra, Coimbra, Portugal

Krishna Prahlad Maremanda Facility for Risk Assessment and Intervention Studies, Department of Pharmacology and Toxicology, National Institute of Pharmaceutical Education and Research (NIPER), Mohali, Punjab, India

J. Alfredo Martinez Department of Nutrition, Food Science and Physiology, and Centre for Nutrition Research, University of Navarra, Pamplona, Spain

Department of Nutrition and Dietetics, King's College London, London, UK

Madrid Institute of Advanced Studies (IMDEA Food), Madrid, Spain

David J. Martino Gastro and Food Allergy, Murdoch Children's Research Institute, The University of Melbourne Department of Paediatrics, The Royal Children's Hospital, Melbourne, VIC, Australia

Nina Nayara Ferreira Martins Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belem, Brazil

Diego M. Marzese Department of Translational Molecular Medicine, John Wayne Cancer Institute at Providence Saint John's Health Center, Santa Monica, CA, USA

Annalisa Masi Institute of Organic Synthesis and Photoreactivity (ISOF), CNR, Bologna, Italy

Petra Matoušková Department of Biochemical Sciences, Charles University, Faculty of Pharmacy, Hradec Králové, Czech Republic

Elise Maximin Micalis Institute, INRA, AgroParisTech, Université Paris-Saclay, Jouy-en-Josas, France

Andre Souza Mecawi Department of Physiological Sciences, Institute of Medical and Biological Sciences, Federal Rural University of Rio de Janeiro, Seropedica, RJ, Brazil

Claudia Meconi Research Organization CRF (Cooperativa Ricerca Finalizzata Sc), Tor Vergata University Science Park, Rome, Italy

Bodo C. Melnik Department of Dermatology, Environmental Medicine and Health Theory, University of Osnabrück, Osnabrück, Germany

Isabel Mendizabal School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA, USA

Department of Genetics, Physical Anthropology and Animal Physiology, University of the Basque Country UPV/EHU, Leioa, Spain

Eran Meshorer Department of Genetics and the Edmond and Lily Safra Center for Brain Sciences (ELSC), The Hebrew University of Jerusalem, Jerusalem, Israel

Alessandra Mezzelani National Research Council, Institute of Biomedical Technologies (CNR-ITB), Segrate (MI), Italy

Mirjana Mihailović Department of Molecular Biology, Institute for Biological Research Siniša Stanković, University of Belgrade, Belgrade, Serbia

Fermin I. Milagro Department of Nutrition, Food Science and Physiology, and Centre for Nutrition Research, University of Navarra, Pamplona, Spain

Dragan Milenkovic School of Medicine, Division of Cardiovascular Medicine, University of California Davis, Davis, CA, USA

Department of Human Nutrition, French Institut of Agricultural Research (INRA), St Genès-Champanelle, France

Francis Minvielle UMR INRA/AgroParisTech – GABI, Jouy-en-Josas, France

Brett M. Mitchell Texas A&M, Department of Medical Physiology, College Station, TX, USA

Dragana Mitić-Ćulafić Microbiology, Center for Genotoxicology and Ecogenotoxicology, Faculty of Biology, University of Belgrade, Belgrade, Serbia

Naoko Miyauchi Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Lenha Mobuchon Herbivore Research Unit -Biomarkers Team, French Institut of Agricultural Research (INRA), St Genès-Champanelle, France

Kazuki Mochizuki Department of Local Produce and Food Sciences, Faculty of Life and Environmental Sciences, University of Yamanashi, Kofu, Yamanashi, Japan

Myth Tsz-Shun Mok School of Biomedical Sciences, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong

Simon G. Møller Department of Biological Sciences, St. John's University, New York, NY, USA

Norwegian Center for Movement Disorders, Stavanger University Hospital, Stavanger, Norway

Raquel Moral Multidisciplinary Group for the Study of Breast Cancer, Department of Cell Biology, Physiology and Immunology, Physiology Unit, Faculty of Medicine, Universitat Autònoma de Barcelona, Barcelona, Spain

Angélica Morales-Miranda Department of Reproductive Biology, Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán", Mexico City, Mexico

Fabiano Cordeiro Moreira Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belém, Pará, Brazil

Fernando Salvador Moreno Laboratory of Diet, Nutrition and Cancer, Department of Food and Experimental Nutrition, Faculty of Pharmaceutical Sciences, University of São Paulo, São Paulo, SP, Brazil

Sumiko Morimoto Department of Reproductive Biology, Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán", Mexico City, Mexico

Mireille Morisson GenPhySE, Université de Toulouse, INRA, INPT, ENVT, Castanet Tolosan, France

Elizangela Rodrigues da Silva Mota Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belém, Pará, Brazil

Philippe Moulin Claude Bernard University, Lyon, France

Department of Endocrinology, Diabetology, Metabolic Diseases and Nutrition, Cardiovascular Hospital Louis Pradel, Bron Cedex, France

Meltem Muftuoglu Department of Molecular Biology and Genetics, Acibadem University, Istanbul, Turkey

Begoña Muguerza Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Eiji Munetsuna Department of Biochemistry, Fujita Health University School of Medicine, Toyoake, Aichi, Japan

Daniele Musiani Department of Experimental Oncology, European Institute of Oncology, Milan, Italy

Vivek Nagaraja Division of Rheumatology, Department of Internal Medicine, University of Toledo Medical Center, Toledo, OH, USA

Varun Sasidharan Nair Department of Pathology, Hallym University, College of Medicine, Chuncheon, Gangwon-Do, Republic of Korea

Kazuhiko Nakabayashi Division of Developmental Genomics, Department of Maternal-Fetal Biology, National Research Institute for Child Health and Development, Tokyo, Japan

Chau Nguyen Texas A&M Irma Lerma Rangel College of Pharmacy, Kingsville, TX, USA

Luciano Nicosia Department of Experimental Oncology, European Institute of Oncology, Milan, Italy

Biljana Nikolić Microbiology, Center for Genotoxicology and Ecogenotoxicology, Faculty of Biology, University of Belgrade, Belgrade, Serbia

Roberta Noberini Center for Genomic Science of IIT@SEMM, Istituto Italiano di Tecnologia, Milan, Italy

Clévio Nóbrega Department of Biomedical Sciences and Medicine, Center for Biomedical Research (CBMR), University of Algarve, Faro, Portugal

Center for Neuroscience and Cell Biology, University of Coimbra, Coimbra, Portugal

Rita Nocerino Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Eva Nüsken Department of Pediatrics, Pediatric Nephrology, University of Cologne, Cologne, Germany

Kai-Dietrich Nüsken Department of Pediatrics, Pediatric Nephrology, University of Cologne, Cologne, Germany

Kwon Ik Oh Department of Pathology, Hallym University, College of Medicine, Chuncheon, Gangwon-Do, Republic of Korea

Koji Ohashi Department of Clinical Biochemistry, Fujita Health University School of Health Sciences, Toyoake, Aichi, Japan

Hiroaki Okae Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Daniela Oliveira Centre for the Research and Technology of Agro-Environmental and Biological Sciences (CITAB), Department of Biology, University of Minho, Braga, Portugal

Rui Oliveira Centre for the Research and Technology of Agro-Environmental and Biological Sciences (CITAB), Department of Biology, University of Minho, Braga, Portugal

Centre of Biological Engineering (CEB), Department of Biology, University of Minho, Braga, Portugal

Kelly Cristina da Silva Oliveira Núcleo de Pesquisas em Oncologia, Universidade Federal do Pará, Belem, Pará, Brazil

Javier I. J. Orozco Department of Translational Molecular Medicine, John Wayne Cancer Institute at Providence Saint John's Health Center, Santa Monica, CA, USA

Ana Laura Ortega-Márquez Department of Reproductive Biology, Instituto Nacional de Ciencias Médicas y Nutrición "Salvador Zubirán", Mexico City, Mexico

Richa Pant Chromatin and Disease Biology Lab (# 08), National Centre for Cell Science, NCCS Complex, Savitribai Phule Pune University Campus, Pune, Maharashtra, India

Lorella Paparo Department of Translational Medical Science, University of Naples "Federico II", Naples, Italy

Sonal Patel Chromatin and Disease Biology Lab (# 08), National Centre for Cell Science, NCCS Complex, Savitribai Phule Pune University Campus, Pune, Maharashtra, India

Vinood B. Patel School of Life Sciences, University of Westminster, London, UK

Rakesh Pathak Institute of Molecular Genetics (IGMM), Centre National de Recherche Scientifique (CNRS), UMR-5535, University of Montpellier, Montpellier, France

Ketan S. Patil Department of Biological Sciences, St. John's University, New York, NY, USA

Wei Perng Department of Nutritional Sciences, Department of Epidemiology, University of Michigan School of Public Health, Ann Arbor, MI, USA

Meirav Pevsner-Fischer Department of Immunology, Weizmann Institute of Science, Rehovot, Israel

Luciano Pirola INSERM U1060, Oullins, France

Frédérique Pitel GenPhySE, Université de Toulouse, INRA, INPT, ENVT, Castanet Tolosan, France

Igor P. Pogribny Division of Biochemical Toxicology, National Center for Toxicological Research, Food and Drug Administration, Jefferson, AR, USA

Goran Poznanović Department of Molecular Biology, Institute for Biological Research Siniša Stanković, University of Belgrade, Belgrade, Serbia

Victor R. Preedy Diabetes and Nutritional Sciences Research Division, Faculty of Life Science and Medicine, King's College London, London, UK

Fabienne Le Provost Génétique Animale et Biologie Intégrative, French Institut of Agricultural Research (INRA), Jouy-en-Josas, France

Rajkumar Rajendram Department of Medicine, King Abdulaziz Medical City, Ministry of National Guard Health Affairs, Riyadh, Saudi Arabia

Diabetes and Nutritional Sciences Research Division, Faculty of Life Science and Medicine, King's College London, London, UK

Omar Ramos-Lopez Department of Nutrition, Food Science and Physiology, and Centre for Nutrition Research, University of Navarra, Pamplona, Spain

Department of Molecular Biology in Medicine, Civil Hospital of Guadalajara "Fray Antonio Alcalde", Guadalajara, Jalisco, Mexico

Richa Rathod Department of Nutritional Medicine, Interactive Research School for Health Affairs, Bharati Vidyapeeth Deemed University, Pune, India

Mirunalini Ravichandran Institute of Biochemistry, University of Stuttgart, Stuttgart, Germany

E. Albert Reece Department of Obstetrics, Gynecology and Reproductive Sciences, University of Maryland School of Medicine, Baltimore, MD, USA

Caroline Relton MRC Integrative Epidemiology Unit, School of Social and Community Medicine, University of Bristol, Bristol, UK

Institute of Genetic Medicine, Newcastle University, Newcastle upon Tyne, UK

Jose Ignacio Riezu-Boj Department of Nutrition, Food Science and Physiology, and Centre for Nutrition Research, University of Navarra, Pamplona, Spain

Alberto PG Romagnolo University of Arizona Cancer Center, College of Medicine, University of Arizona, Tucson, AZ, USA

Donato F. Romagnolo Department of Nutritional Sciences, University of Arizona, Tucson, AZ, USA

University of Arizona Cancer Center, College of Medicine, University of Arizona, Tucson, AZ, USA

Jaume Roquer Head of the Department of Neurology, Hospital del Mar; Neurovascular Research Group, IMIM (Institut Hospital del Mar d'Investigacions Mèdiques), Barcelona, Spain

Department of Medicine, Universitat Autònoma de Barcelona, Barcelona, Spain

Cheryl S. Rosenfeld Department of Biomedical Sciences, Bond Life Sciences Center Investigator, Thompson Center for Autism and Neurobehavioral Disorders, University of Missouri, Columbia, MO, USA

Rima Rozen Departments of Human Genetics and Pediatrics, McGill University, The Research Institute of the McGill University Health Centre, Montreal, QC, Canada

Lewis P. Rubin Departments of Pediatrics and Biomedical Sciences, Paul L. Foster School of Medicine, Texas Tech University Health Sciences Center El Paso, El Paso, TX, USA

Hitaji Sanford Texas A&M Irma Lerma Rangel College of Pharmacy, Kingsville, TX, USA

Michael P. Sarras Jr. Department of Cell Biology and Anatomy, Chicago Medical School, Rosalind Franklin University of Medicine and Science, North Chicago, IL, USA

E. R. Sauter Hartford HealthCare Cancer Institute, Hartford, CT, USA

Luís Fernando Schütz Department of Pharmaceutical Sciences, Irma Lerma Rangel College of Pharmacy, Texas A&M Health Science Center, College Station, TX, USA

Tanya L. Schwab Department of Biochemistry and Molecular Biology, Mayo Clinic, Rochester, MN, USA

Ornella I. Selmin Department of Nutritional Sciences, University of Arizona, Tucson, AZ, USA

University of Arizona Cancer Center, College of Medicine, University of Arizona, Tucson, AZ, USA

Parames C. Sil Division of Molecular Medicine, Bose Institute, Kolkata, India

Minati Singh Department of Pediatrics, The University of Iowa, Iowa City, IA, USA

Marilia Arruda Cardoso Smith Division of Genetics, Department of Morphology and Genetics, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil

Monica Soldi Department of Experimental Oncology, European Institute of Oncology, Milan, Italy

Berna Somuncu Department of Molecular Biology and Genetics, Acibadem University, Istanbul, Turkey

Carolina Soriano-Tárraga Neurovascular Research Group, IMIM (Institut Hospital del Mar d'Investigacions Mèdiques), Barcelona, Spain

Valeria Spadotto Department of Experimental Oncology, European Institute of Oncology, Milan, Italy

Barbara Stefanska Land and Food Systems, Food, Nutrition and Health, University of British Columbia, Vancouver, BC, Canada

Silvia Stringhini Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital, Lausanne, Switzerland

Elena Sturchio Department of Technological Innovation and Safety of Plants, Product and Anthropic Settlements (DIT), Italian Workers' Compensation Authority (INAIL), Rome, Italy

Manuel Suárez Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili (URV), Tarragona, Spain

Souta Takahashi Department of Informative Genetics, Tohoku University Graduate School of Medicine, Aoba-ku, Sendai, Japan

Junji Takaya Department of Pediatrics, Kawachi General Hospital, Higashi-Osaka, Osaka, Japan

Department of Pediatrics, Kansai Medical University, Moriguchi, Osaka, Japan

Qihua Tan Epidemiology and Biostatistics, Department of Public Health, Unit of Human Genetics, Department of Clinical Research, Faculty of Health Sciences, University of Southern Denmark, Odense, Denmark

Paniz Tavakoli CSIRO Health and Biosecurity, Personalised Nutrition and Healthy Ageing, Adelaide, SA, Australia

Department of Molecular and Cellular Biology, School of Biological Sciences, University of Adelaide, Adelaide, SA, Australia

Tincy Thomas Department of Pharmaceutical Sciences, Irma Lerma Rangel College of Pharmacy, Texas A&M Health Science Center, College Station, TX, USA

Anja Tolić Institute for Biological Research, University of Belgrade, Belgrade, Serbia

Eckardt Treuter Department of Biosciences and Nutrition, Karolinska Institutet, Huddinge, Sweden

Paola Ungaro Institute for Experimental Endocrinology and Oncology, "G. Salvatore"(IEOS), National Research Council (CNR), Naples, Italy

Aleksandra Uskoković Department of Molecular Biology, Institute for Biological Research Siniša Stanković, University of Belgrade, Belgrade, Serbia

Karin van Veldhoven Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, UK

Ernesto Vargas-Mendez Laboratory of Diet, Nutrition and Cancer, Department of Food and Experimental Nutrition, Faculty of Pharmaceutical Sciences, University of São Paulo, São Paulo, SP, Brazil

Anthony T. Vella Department of Immunology, School of Medicine, University of Connecticut Health Center, Farmington, CT, USA

Nicolas Venteclef Sorbonne Universités, Université Pierre et Marie-Curie, Institut National de la Santé et de la Recherche Médicale (INSERM), UMR_S 1138 Cordeliers Research, Paris, France

Sascha Venturelli Department of Vegetative and Clinical Physiology, Institute of Physiology, University Hospital Tuebingen, Tuebingen, Germany

Martin Veysey School of Medicine and Public Health, The University of Newcastle, Gosford Hospital, Gosford, NSW, Australia

Mark H. Vickers Liggins Institute, University of Auckland, Auckland, New Zealand

Melita Vidaković Department of Molecular Biology, Institute for Biological Research Siniša Stanković, University of Belgrade, Belgrade, Serbia

Paolo Vineis Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, UK

Branka Vuković-Gačić Microbiology, Center for Genotoxicology and Ecogenotoxicology, Faculty of Biology, University of Belgrade, Belgrade, Serbia

Danyang Wan College of Life Sciences, Wuhan University, Wuhan, China

Zhipeng A. Wang Department of Chemistry, Texas A&M University, College Station, TX, USA

Gaofeng Wang Dr. John T. Macdonald Foundation Department of Human Genetics, John P. Hussman Institute for Human Genomics, University of Miami Miller School of Medicine, Miami, FL, USA

Department of Human Genetics, Dr. Nasser Ibrahim Al-Rashid Orbital Vision Research Center, Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Miami, FL, USA

Jian Wang Department of Pathology, Wayne State University School of Medicine, Detroit, MI, USA

Cardiovascular Research Institute, Wayne State University School of Medicine, Detroit, MI, USA

Inga Wessels Institute of Immunology, RWTH Aachen University Hospital, Aachen, Germany

Oliwia Witczak Faculty of Health Sciences, Oslo and Akershus University College of Applied Sciences, Oslo, Norway

Thomas E. Witzig Division of Hematology, Mayo Clinic, College of Medicine, Rochester, MN, USA

Benjamin Wolfson Greenebaum Cancer Center, Department of Biochemistry and Molecular Biology, University of Maryland School of Medicine, Baltimore, MD, USA

Vincent Wai-Sun Wong Department of Medicine and Therapeutics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong

Xiaosheng Wu Division of Hematology, Mayo Clinic, College of Medicine, Rochester, MN, USA

Xinhua Xiao Department of Endocrinology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China

Xuemei Xie Department of Pediatrics, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

Department of Endocrinology, The First Affiliated Hospital of Guangxi Medical University, Nanning, China

Hiroya Yamada Department of Hygiene, Fujita health University School of Medicine, Toyoake, Aichi, Japan

Mingyao Yang Institute of Animal Genetics and Breeding, Sichuan Agricultural University, Chengdu, Sichuan, China

Peixin Yang Department of Obstetrics, Gynecology and Reproductive Sciences, University of Maryland School of Medicine, Baltimore, MD, USA

Department of Biochemistry and Molecular Biology, University of Maryland School of Medicine, Baltimore, MD, USA

Zoe Yates School of Biomedical Sciences and Pharmacy, The University of Newcastle, Ourimbah, NSW, Australia

Soojin V. Yi School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA, USA

Wei Ying Department of Medicine, Division of Endocrinology and Metabolism, University of California, San Diego, La Jolla, CA, USA

Yangmian Yuan College of Life Sciences, Wuhan University, Wuhan, China

Miriam Zanellato Department of Technological Innovation and Safety of Plants, Product and Anthropic Settlements (DIT), Italian Workers' Compensation Authority (INAIL), Rome, Italy

Diana Zapata Department of Pharmaceutical Sciences, Irma Lerma Rangel College of Pharmacy, Texas A&M Health Science Center, College Station, TX, USA

Helmut Zarbl Department of Environmental and Occupational Health, School of Public Health Environmental and Occupational Health Sciences Institute, Rutgers, The State University of New Jersey, Piscataway, NJ, USA

Tatiana Zerjal UMR INRA/AgroParisTech – GABI, Jouy-en-Josas, France

Lubo Zhang Center for Perinatal Biology, Division of Pharmacology, Department of Basic Sciences, Loma Linda University, School of Medicine, Loma Linda, CA, USA

Xiaofei Zhang Fudan University Shanghai Cancer Center, Shanghai, China

Ruqian Zhao Key Laboratory of Animal Physiology and Biochemistry, Ministry of Agriculture, College of Veterinary Medicine, Nanjing Agricultural University, Nanjing, China

Jia Zheng Department of Endocrinology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China

Ling Zheng College of Life Sciences, Wuhan University, Wuhan, China

Beiyan Zhou Department of Immunology, School of Medicine, University of Connecticut Health Center, Farmington, CT, USA

Qun Zhou Greenebaum Cancer Center, Department of Biochemistry and Molecular Biology, University of Maryland School of Medicine, Baltimore, MD, USA

Jianhong Zhu Department of Preventive Medicine, Department of Geriatrics and Neurology at the Second Affiliated Hospital, and Key Laboratory of Watershed Science and Health of Zhejiang Province, Wenzhou Medical University, Wenzhou, Zhejiang, China

Niv Zmora Department of Immunology, Weizmann Institute of Science, Rehovot, Israel

Part I

Introductory Material and Foundations

Environmental Effects on Genomic Imprinting in Development and Disease

1

Rakesh Pathak and Robert Feil

Contents

Abstract

Genomic imprinting mediates the parent-of-origin-specific, mono-allelic expression of many protein-coding genes and noncoding RNAs. This paradigm for epigenetic gene regulation plays diverse roles in mammalian development, growth and behavior. Mechanistically, it involves parentally inherited DNA methylation marks that control clusters of imprinted genes. Perturbation of these epigenetic imprints affects embryonic and postnatal development and leads to complex diseases in humans, including different types of diabetes. This chapter discusses imprinted genes, with emphasis on those that control metabolism and cellular proliferation, several of which encode proteins of the insulin-like growth factor/insulin signaling pathway. Nutrition, chemical pollutants, and other environmental cues can readily perturb DNA methylation imprints, not only during development, but sometimes even in adults. Such epigenetic alterations

R. Pathak · R. Feil (✉)
Institute of Molecular Genetics (IGMM), Centre National de Recherche Scientifique (CNRS), UMR-5535, University of Montpellier, Montpellier, France
e-mail: pathak.rakesh@igmm.cnrs.fr; robert.feil@igmm.cnrs.fr

V. B. Patel, V. R. Preedy (eds.), *Handbook of Nutrition, Diet, and Epigenetics*,
https://doi.org/10.1007/978-3-319-55530-0_92

("epimutations") may affect imprinted gene expression and, hence, can have deleterious effects on phenotype. In the future, clinical and environmental imprinting studies will gain from taking a broader approach that considers not only the imprinted gene loci themselves, but also similarly controlled loci located elsewhere in the genome.

Keywords
Epigenetics · Environment · Genomic imprinting · DNA methylation · Growth · Metabolism · IGF/Insulin pathway · Endocrine disruptor

List of Abbreviations

ART	Assisted Reproductive Technology
BPA	Bisphenol A
BWS	Beckwith-Wiedemann Syndrome
ICR	Imprinting control region
IGF	Insulin-like growth factor
INS	Insulin
IUGR	Intra-uterine growth restriction
ncRNA	Noncoding RNA
SRS	Silver Russell Syndrome
TNDM	Transient neonatal diabetes mellitus

Introduction

Epigenetic mechanisms contribute to the establishment and maintenance of stable patterns of gene expression during development and throughout postnatal life. DNA methylation at cytosine residues is the best studied epigenetic modifications in mammals. It plays essential roles in cells and tissues. These include stable repression of endogenous retroviruses and the tissue-specific silencing of developmental genes, particularly germ line genes, which become silenced in the embryo. DNA methylation also contributes to X-chromosome inactivation. This is a gene dosage mechanism in female embryos that leads to the repression of most genes on one of the two X chromosomes.

The current chapter focuses on another gene dosage mechanism for which cytosine methylation is essential, namely genomic imprinting (Bartolomei and Ferguson-Smith 2011). It introduces the roles of imprinted gene expression in mammalian development and its perturbation in disease and makes the link with the insulin/IGF signaling pathway, metabolism and growth control. The chapter also discusses how diet and environmental cues may perturb the epigenetic regulation of imprinted genes and that this can have long-lasting phenotypic consequences (Feil and Fraga 2012).

Mammalian genomic imprinting evolved coincident with the emergence of viviparity and the growing importance of placentation and the evolution of defense mechanisms against transposable elements. The oldest imprinted genes arose about 170 million years ago, during the Jurassic period. Today, more than 100 protein-