
Introduction to the Handbook of Life Course Health Development

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1 Introduction

Over the past several decades, countless studies have linked early life events and experiences with adult health conditions, delineating the developmental origins of common chronic health conditions and specifying the processes by which both adversity and opportunity are integrated into developing biobehavioral systems (Baltes et al. 2006; Bronfenbrenner 2005; Elder et al. 2015). As a result, there is a greater understanding of how health and disease develop, which is leading to new kinds of individual- and population-level strategies that have the potential to prevent disease

and optimize health by minimizing the impact of adversity, increasing protective factors, and targeting health-promoting interventions to coincide with sensitive periods of health development.

Insights and evidence from life course chronic disease epidemiology have converged with research from the fields of developmental biology, neuroscience, and developmental science, with studies of typical and atypical development and with new findings from research examining the developmental origins of chronic disease. This wide-ranging research, all focused on understanding how health and disease develop, has involved researchers from a wide variety of disciplines. Life-span developmental psychologists,

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life course-focused sociologists, human capital-focused economists, and political scientists studying the structure of social institutions are not only studying the same developmental processes; they are also working alongside epidemiologists, physicians, and basic scientists to better understand how health develops over the life course and how these health development processes promote human flourishing.

In response to this burgeoning knowledge, there is growing momentum among practitioners and policymakers to “connect the dots” between what we know and what we do, that is, between the rapidly expanding evidence base from the emerging field of life course health development (LCHD) and the practices and policies that are implemented within the fields of medicine, public health, nursing, mental health, education, urban planning, community development, social welfare, and others (Halfon et al. 2014; Kuh et al. 2013; Braveman 2014; Gee et al. 2012; Lappé and Landecker 2015). At the same time, there is a strong impetus among researchers to continue to fill the substantial gaps in our knowledge and to ensure that research findings are appropriately synthesized and translated before being applied in clinical, public health, or public policy contexts.

Comprised of 26 chapters that grew out of the 2013 Maternal and Child Health (MCH) Life Course Research Agenda-Setting Meeting that was organized by the MCH Life Course Research Network (LCRN) and funded by Health Resources and Services Administration-Maternal and Child Health Bureau (HRSA-MCHB), this volume represents a groundbreaking effort to explore the history of the LCHD field, to take stock of what we know and do not know about how health and disease develop, to provide practitioners and policymakers with guidance regarding the kinds of interventions and efforts that can be beneficial, and to lay the foundation for a research agenda that identifies high-priority areas for basic, clinical, population, and translational investigations in order to strategically target resources and efforts and advance the life course health sciences.

Each chapter is written by a team of leading experts that often spans several different disciplines and therefore reflects a wide range of perspectives on how innovative research, practice, and policy

can begin to address our most pressing health challenges. Similarly, the volume’s four editors represent different disciplines and perspectives that were brought to bear on the process of selecting topics and authors and on ensuring that each chapter makes a substantial contribution to the field.

In this introductory chapter, we begin by providing a rationale for the publication of this volume, including an historical overview that traces the emergence of the LCHD field and provides evidence of a significant, but as yet incomplete, transformation in how we think about and promote health. We go on to describe the purpose, structure, and content of the volume and to examine some of the challenges for further field building in this area. Finally, we provide readers with information about each section and chapter in this volume, including the impressive backgrounds of the various experts who contributed substantial amounts of both time and original thinking in their roles as authors.

2 Rationale

2.1 The Emergence of a New Field

The science of health has been guided for well over 150 years by a mechanical model that views the body and its component cells as machines and views disease as a breakdown in organ structure and function. Person-environment relationships as causes of disease are either ignored or relegated to secondary concerns. Even though the oversimplified perspective of the body as a machine has been largely abandoned, reducing physiologic and behavioral phenomena to their smallest observable constituent parts remains a mainstay of the biomedical model that dominates contemporary health sciences. This reductionist approach may tell us how parts of a neuron work, but it does not provide an appropriate model for understanding how the nervous system works, how we think, or what produces consciousness (Capra 1982). Even fields like human genomics are moving away from the simplistic notion of single-gene causation, which has failed to yield substantial insights into disease causation, to research on genetic networks and epigenetics

(Huang 2012; Lappé and Landecker 2015). Complex disorders that manifest as a spectrum of phenotypic variability – including cardiovascular disease, obesity, diabetes, and autism – are increasingly understood as manifestations of relations among networks of genes and complex gene-environment coactions that are mediated by equally complex time signatures and temporal coupling. Moreover, the mechanical model of health cannot account for placebo effects, the mind’s effects on the body, or psychosomatic illness. It presupposes a mind-body dualism and reifies the distinction between physical and mental health, a vestige of the Cartesian mind-body split (Overton 2015). A reductionist approach to understanding health is inadequate for addressing how different molecular, physiologic, social, and environmental networks work together to produce dynamic stability and change, which are the cornerstones of health outcome trajectories.

Many fields of science – including physics, biology, and the social sciences (especially developmental science) – have shifted from a Cartesian-Newtonian mechanistic ontology to a more complex system-oriented ontology (Lerner 2012). The mechanistic view divides the world into separate or split categories (e.g., nature versus nurture) and reduces it into discrete elements (genes, behaviors, molecules) that are combined, added, and assembled to form what we perceive as biological phenotypes, patterns of behavior, and personalities. As Overton (2012) and others have described, this revolutionary shift in the epistemological and ontological foundations of science took place during the twentieth century as Newtonian physics gave way to general relativity theory and as contemporary formulations of knowing the world were shown to lack explanatory power and utility (Aldwin 2014). Thus, the need for new models that explain the complex phenomena of human health development became apparent.

The synthesis of human health development as explained by theories associated with relational developmental systems (RDS) metatheory is replacing the now anachronistic mechanical model of health (Lerner and Overton 2008; Lerner 2012; Overton 2012). Overton (2015) explains that compared to earlier formulations of understanding human development, RDS

metatheory focuses on process (systematic changes in the developmental system), becoming (moving from potential to actuality; a developmental process as having a past, present, and future; Whitehead 1929/1978), holism (the meanings of entities and events derive from the context in which they are embedded), relational analysis (assessment of the mutually influential relations within the developmental system), and the use of multiple perspectives and explanatory forms. Within RDS metatheory, the organism is seen as inherently active, self-creating (autopoietic), self-organizing, self-regulating (agentic), nonlinear and complex, and adaptive (Overton 2015).

The RDS metatheory emphasizes the study and integration of different levels of organization ranging from biology and physiology to culture and history as a means to understand life-span human development (Lerner 2006; Overton 2015). Accordingly, the conceptual emphasis in RDS theories is placed on mutually influential relations between individuals and contexts, represented as individual \Leftrightarrow context relations. In a bidirectional relational system, the embeddedness within history (temporality) is of fundamental significance (Elder et al. 2015). The presence of such temporality in the developmental system means that there always exists some potential for systematic change and, thus, for (relative) plasticity in human development. In short, potential plasticity in individual \Leftrightarrow context relations derives from the “arrow of time” (Lerner 1984; Lerner and Callina 2014; Overton 2015) running through the integrated (relational) developmental system. Such plasticity also suggests that there are multiple developmental pathways, across the life-span.

Similar conceptual advances have also been generated by systems biology, which focuses on the complex interactions of biological systems using a holistic framework and integrative relational strategies rather than traditional reductionist approaches (Kitano 2002; Antony et al. 2012; Schadt and Björkegren 2012, Kandel et al. 2014). This transformation has been catalyzed by a greater appreciation of dynamical system theory and, more specifically, complex adaptive system theory and its application to molecular biology (Huang 2012). Moreover, as

our understanding of epigenetics and systems biology has matured, new insights into how complex gene regulatory networks produce multilevel and multidirectional relationships between genotype and phenotype have been elucidated (Foster 2011; Huang 2012; Piro and Di Cunto 2012; Schadt and Björkegren 2012; Greenblum et al. 2012; Davila-Velderrain et al. 2015). This new knowledge would not have been acquired using reductionist statistical models that analyze data by reducing them to their smallest components and estimating marginal effects of linear models.

In summary, the study of human development has evolved from a field dominated by split, reductionist (psychogenic or biogenic) approaches to a multidisciplinary field that integrates observations, evidence, and analysis that spans from biological to cultural and historical levels of organization across the life-span (e.g., Elder et al. 2015; Ford and Lerner 1992; Gottlieb 1998; Lerner and Callina 2014). Reductionist accounts have given way to a more integrated framework associated with RDS metatheory (Overton 2015; Lerner 2006). Across the past several decades, several scholars have provided ideas contributing to the evolution of this metatheory (e.g., Baltes et al. 2006; Bronfenbrenner 2005; Elder et al. 2015; Lerner 2006; and, even earlier, see von Bertalanffy 1933).

For instance, in psychology, the transition away from what some have characterized as the radical empiricism and atomism of the early behaviorist to ideas akin to those associated with RDS-based theories has followed a similar ontological path (Lerner 2006; Lerner and Overton 2008; Overton 2010, 2012). As Arnold Sameroff explains, psychologists were attempting to find and define the laws that explain behavior and how the mind functions (Sameroff 2010). As it became clear that any particular individual- or population-level signal explained very little of the observed variance in behaviors, developmental scientists began to create new techniques for analyzing intraindividual patterns of change that focus on individuals' unique person-environmental interactions and that separate the behavioral signal from the noisy complexity of life, especially for long-term predictive purposes (Molenaar and Newell 2010; Sameroff

2010). Rather than reducing cognitive, emotional, or overall mental function to its mechanistic components, this more holistic approach views psychological functioning as the product of a relational nexus that defines an individual in association with multiple contexts that interact dynamically over time.

In the same way that biology and psychology have faced the limits of reductionist mechanical models, medicine and health sciences are also experiencing the constraints of the biomedical approach that focuses more on the components of the organism than on the totality of human health. While the biomedical model has been remarkably successful in defining the components of human anatomy, physiology, biochemistry, and metabolism, and has provided useful frameworks for understanding simple mechanics of more linear disease processes (such as infectious diseases), it is increasingly challenged by the complexity of health development and by complex disease pathways that emerge out of multi-level and multiphasic processes that include genetic, biological, behavioral, and whole-organism processes (Halfon et al. 2014).

Similarly, at the clinical and population health levels, simple mechanistic biomedical models, or even more multifaceted biopsychosocial models of health, have difficulty explaining a wide variety of health phenomena, such as how integration of body systems and subsystems results in emergent properties of health at the level of the individual; how evolution constrains the timing and plasticity of human health development; how epigenetic processes result in multiple intermediary endophenotypes that may progress to pathological phenotypes, hover in subclinical states, or resolve; how the adaptive capacities of individuals and populations interact with rapidly changing physical, natural, chemical, social, and nutritional environments to reprogram developing physiology and other regulatory processes through epigenetic modulations of previously selected biological and behavioral scripts; and how integration occurs between biological, behavioral, and environmental systems, organized and driven by adaptive routines structured around different developmentally entrained time

horizons. These conundrums have challenged health researchers to develop new frameworks to explain how each of these complex processes contributes to the development of health over time (i.e., contribute to health development).

2.2 The Maturation of the LCHD Field

A vast amount of empirical literature investigating the developmental, genomic, and epigenetic origins of health and disease – as well as on the epidemiology of chronic disease across the life course – has been generated in the past two decades (Halfon and Hochstein 2002; Kuh and Ben-Shlomo 2004; Gluckman and Hanson 2004; Gluckman et al. 2008; Kuh et al. 2013; Berkman et al. 2014; Halfon et al. 2014; the evolution of life course health science is reviewed in Halfon and Forrest 2017). New academic research journals and international research organizations have been spawned that focus on the developmental origins of health and disease. Established professional organizations now include life course and epigenetic and developmental origins of health and disease (DOHaD) tracts at their research meetings, and many major scientific journals have published special issues packaging articles that focus on biological embedding, epigenetics, or other disease-causing mechanisms that are framed from a life course perspective. The US National Academy of Sciences and National Academy of Medicine have both issued several reports on the health, social, and behavioral determinants of health, health measurement, health disparities, and health-care improvement that have incorporated a life course perspective, and the recent framework for the US Healthy People 2020 goals was upgraded to include life course as an organizing principle of the overall framework (Committee on Future Directions for Behavioral and Social Sciences Research 2001; Committee on Evaluation of Children's Health 2004; Committee on the Recommended Social and Behavioral Domains and Measures for Electronic Health Records 2015).

Perhaps the biggest stimulus for thinking differently about origins and development of chronic disease came from a series of provocative studies that were conducted by David Barker and his team. Beginning in the 1980s, Barker's studies began to describe how the prevalence of heart disease in specific areas of England was related to the distribution of birth weights in those same regions. Barker and others went on to use longitudinal datasets to solidify these observations that birth weight, and the nutritional environment and exposures of the fetus and infant, had a direct influence on the development of heart disease that was often only clinically recognized many decades later (Barker et al. 1989, 1993; Barker 1995). These startling findings challenged conventional models of direct or cumulative risk that posited that heart disease was the result of either contemporaneous or lifelong risks including poor nutrition, lack of exercise, smoking, or other behaviors and suggested that there were important latent effects of early nutrition that were somehow conditioning later pathological response patterns. Barker's studies brought attention to other research with similar findings that were less dramatic but entirely consistent with the latent lifelong effects that the Barker studies were revealing. As a result, developmental time frames started to become an important consideration, and the timing of exposures and the recognition of sensitive periods of development all took on new salience.

As this new perspective on the developmental origins of chronic disease began to unfold, there was also another emerging set of new constructs coming into play in what is now termed the field of population health. Following on in the tradition of the 1974 Lalonde Report (produced under the aegis of Canadian Minister of National Health and Welfare) that challenged the dominance of the biomedical model and proposed that the health field needed to consider biology, environment, lifestyle, and health-care organization, a broad multidisciplinary team of Canadian researchers led by the economist Robert Evans began to ask: *why are some people healthy and others not?* (Hancock 1986; Evans et al. 1994). This question led not only to a consideration of the crucial influence of upstream social and

behavioral determinants on individual and population health but also to a concern about how early social environments can mold lifelong health trajectories.

Leading this exploration of the developmental role that upstream social factors on health and development for the Evans-led team was Clyde Hertzman. Hertzman went on to solidify his analysis about the importance of what at the time he termed “biological embedding” through a series of studies, analyses of other studies, and reinterpretations of existing literature through this new life course health development lens. In addition to publishing several important articles of conceptual synthesis, Hertzman and Daniel Keating edited the volume *Developmental Health and the Wealth of Nations* in which they unpacked the impact of social gradients on health development and began to specify how different time-specific and pathway effects were at play early in development (Hertzman 1999; Keating and Hertzman 1999; Hertzman and Boyce 2010). They synthesized a wealth of evidence on how early experience affects a child’s brain development, social and emotional functioning, and overall health capacities (Hertzman 1994; Keating and Hertzman 1999). The Evans and Hertzman work in Canada emerged about the same time that the *Independent Inquiry into Inequalities in Health Report* (1998) led by Sir Donald Acheson was released in the UK (Acheson 1998). This review – whose panel of experts included David Barker, Michael Marmot, and Hilary Graham, among others – very clearly identified how many health inequalities have their roots in the conditions and experience of mothers and children, with impacts that feedforward across the life-span.

Diana Kuh and Yoav Ben-Shlomo edited a volume entitled *A Life Course Approach to Chronic Disease Epidemiology*, first published in 1997, which coined the term “life course epidemiology” and presented for the first time a series of articles that integrated the empirical research on several specific types of disease from a life course perspective (Kuh and Ben-Shlomo 1997). This work was followed by a second edition in 2004 that updated each of the chapters on the life course approach to obesity or the life course

approach to cardiovascular disease, and that began to provide an overarching framework including chapters on life course pathways to adult health (Kuh and Ben-Shlomo 2004). In that volume, there were chapters on “Life course approaches to differentials in health” (Davey Smith and Lynch 2004), “A life course approach to obesity” (Gillman 2004), “Socioeconomic pathways between childhood and adult health” (Kuh et al. 2004), and “Should we intervene to improve childhood circumstances” (Boyce and Keating 2004). Kuh and Ben-Shlomo have gone on to edit a series of books on life course chronic disease epidemiology that continue to analyze and synthesize the literature on health development from a life course perspective (Lawlor and Mishra 2009; Kuh et al. 2013).

In 2000 (Halfon et al. 2000) and 2002 (Halfon and Hochstein 2002), Halfon and colleagues reviewed and synthesized several different life course-focused research streams and suggested that beyond its increasingly well-documented importance for understanding the mechanisms involved with the origins and development of health and disease, this new life course approach was of profound importance for a consideration of how health care should be organized, financed, and delivered. They also suggested that some general principles were emerging and beginning to outline a new model or framework that they termed “*life course health development*.” At the same time, many other scientists provided their own synthesis of this emerging literature and what they considered to be its implications for health, health-care delivery, and health policy (Ben-Shlomo and Kuh 2002; Halfon and Hochstein 2002; Lu and Halfon 2003; Forrest and Riley 2004; Worthman and Kuzara 2005). These various attempts at synthesizing the evidence from this new field constituted a tipping point, and over the next decade, the number of empirical studies accelerated at a much faster pace as the early objections to the “Barker hypothesis” melted away in the wake of many confirmatory studies, and the explanatory power of this new conceptualization began to take hold.

This early LCHD synthesis highlighted the linked importance of biological conditioning; the

role of multiple, ecologically nested risk, protective, and promoting factors in influencing health trajectories; the developmental significance of different time frames; and the evolution of different health development pathways in relationship to particular socially, culturally, and biologically specified transitions and turning points in an individual's life (Halfon and Hochstein 2002). Over the intervening decade, research has continued to accelerate, advancing in the use of more sophisticated methodologies; employing new and rapidly advancing epigenetic, genomic, and other techniques from systems biology; and, at the same time, supporting and providing more concrete evidence on behalf of these early summative concepts. These threads of scientific inquiry have coalesced to form a network of research that has produced a much more robust and integrated conceptual framework.

3 The Purpose, Structure, and Content of This Volume

The absence of an integrative conceptual framework through which scientists could organize and extend the manifold insights about the individual and contextual processes involved in the development of health across the life course was a fundamental challenge constraining the acceptance and understanding of a LCHD perspective (Halfon et al. 2014; Hanson and Gluckman 2014). However, as noted above, empirical and conceptual advances over the last 30 years have crystallized in the generation, and growing acceptance, of just such an integrative perspective. As a result, the life course health sciences are rapidly maturing and progressing, and the life course health development framework is coming into clearer focus. Nevertheless, there remain a number of challenges and growing pains that are evident as scientists, clinicians, and public health professionals from different fields attempt to incorporate LCHD notions into already established areas of scholarship, practice, and policy development.

For example, the definitions of terms are not always clear, some terms are being redefined to

be integrated into this new approach, and other concepts and constructs are adopted before their meaning and significance are fully vetted and analyzed. Good examples of these challenges include terms like “sensitive and critical periods,” “developmental programming,” “biological embedding,” “trajectories,” and “pathways.” Terms like “programming” have been criticized as being too deterministic given the implication that a certain experience or set of risk factors can program a disease pathway; such a term eschews the nature of developmental plasticity and the phenotypic range that can emerge as the organism or individual encounters other experiences. Hanson and Gluckman have suggested that a term like priming, induction, or conditioning be used to describe the process by which an exposure or experience induces a phenotypic alteration that prepares the organism for a similar environmental challenge later in the life course (Hanson and Gluckman 2014). Throughout this volume, we have sought and encouraged the authors to avoid terms like programming and biological embedding in favor of conditioning or priming. Similarly, notions of critical periods have been part of embryology for over a century, and many biologists will refer to critical periods in biological development as a specific time that usually starts and ends abruptly and during which a given event or its absence has a specific impact on development. The experiments by Hubel and Wiesel to examine the development of the visual cortex seemed to indicate that there were critical periods for specific complex neurons to develop (Hubel and Wiesel 1977). However, most developmental science suggests that because of the inherent plasticity in human development and in many specific regulatory systems, the term “sensitive period” is less deterministic and therefore much more appropriate.

In addition to the confusion around terminology, Hanson and Gluckman suggest several other reasons for why the related concept of developmental origins of health and disease has faced challenges, including confusion between factors correlated with disease and those involved in causation, the assumption that the only pathway connecting early exposures and later disease was

low birth weight, a lack of plausible biological mechanisms, a failure to recognize developmental origins under normal rather than under extreme conditions, and the lack of evidence of its relative importance in relationship to other risk factors (Hanson and Gluckman 2014). Whereas all of these challenges are important and have begun to be addressed, the relative risk issues have been some of the most daunting since these questions require longitudinal data over very long time horizons to tease out.

This volume is designed to address these challenges and bridge the resultant gaps, including the delay in broad acceptance and understanding of how health develops across the life-span (Hanson and Gluckman 2014), as well as in the translation of that perspective to health practice and policy.

Each of the six sections comprising this volume was conceptualized during the process of planning the LCRN's 2013 MCH Life Course Research Agenda-Setting Meeting, with the ultimate goal of informing the development of an MCH Life Course Research Agenda (LCRA) that would provide MCHB, the National Institutes of Health (NIH), and other funding institutions and organizations with guidance regarding priority research questions and topics worthy of investment. With input from the LCRN advisory committee, project staff determined that the LCRA (Sect. 6), which is in many ways the culmination of the LCRN's 6 years of work to date, would have to address theoretical concerns (Sect. I), specific periods of the life course (Sect. II), specific health conditions (Sect. III) – some common and some rare but nevertheless important because of their severity or their representativeness of a set of conditions sharing similar life course origins and/or implications – cross-cutting topics in LCHD (Sect. IV), and methodological issues (Sect. V) to support researchers in carrying out the kinds of studies the research agenda would call for.

Similarly, the majority of the chapter topics contained in this volume were selected early on in the development of the agenda-setting process. However, as noted in the Preface, several chapters were commissioned following the 2013 agenda-setting meeting in response to identified gaps, and others were selected based

on author interest in submitting a chapter for inclusion in the agenda-setting process and/or published volume. The editors acknowledge that several important topics have not been included in this edition of the volume. In some cases, this omission was due to the difficulty of identifying a qualified author/author team willing to develop a chapter on a given topic; in other instances, chapters were commissioned but not completed in time for inclusion in this edition. It is the editors' hope that future editions of this volume will address these worthy topics through new chapters on topics ranging from asthma and ADHD to family experiences, mental health conditions, and LCHD measures and biomarkers, among others. For now, however, it is our hope that readers will appreciate the range of topics included in this edition and the potential for these 26 chapters – all of which synthesize existing LCHD research, identify knowledge gaps, and/or recommend priorities related to future research and efforts to ensure the appropriate and timely translation of that research into practice and policy – to have a significant impact on how LCHD stakeholders think about, study, and work to promote health.

Chapters “Middle Childhood: An Evolutionary-Developmental Synthesis” and “Pregnancy Characteristics and Women's Cardiovascular Health” contain modified versions of previously published reviews and analyses of existing research. Given the relatively recent emergence of the field of LCHD and our goal to further coalesce that field through the publication of this volume, we thought it important to include the content in the handbook so that the important research both chapters contain could be situated firmly within the growing body of LCHD research and have a meaningful influence on the content of the LCRA.

3.1 Section I: Emerging Frameworks

This section contains a single chapter by pediatricians and public health experts Neal Halfon, MD, MPH, and Christopher B. Forrest, MD, PhD, entitled *The Emerging Theoretical Framework of*

Life Course Health Development (Halfon and Forrest 2017). The authors – who also served as two of the editors of the volume – propose a set of principles that together form a more unified theoretical framework for the emerging LCHD field. These principles have the potential to guide future theory building, research, and policy pertaining to optimizing health development in the USA and abroad. Each subsequent chapter refers to the principles when appropriate to demonstrate how they can help to explain empirical findings or set the stage for future inquiry.

3.2 Section II: Life Stages

Section II is comprised of six chapters exploring health development from the preconceptional/prenatal period to early adulthood. Each describes the kinds of experiences and exposures that result in more (or less) optimal outcomes during a given developmental period *and* the importance of that period for outcomes over the remainder of the life course. As such, this section of the volume grounds the literature reviewed about each life stage firmly within the LCHD framework.

Preconception and Prenatal Factors and Metabolic Risk – by pediatrician, MCH researcher, and molecular epidemiologist Xiaobin Wang, MD, MPH, ScD, and colleagues Guoying Wang, MD, PhD, and Tami R. Bartell – examines health during the earliest part of the life course, reviewing what is known about the mechanisms underlying both its sensitivity to alterations in the intrauterine environment. The authors explain the importance of this life period for lifelong and transgenerational health, including links to obesity, diabetes, cardiovascular disease, behavioral and psychiatric disorders, and more (Wang et al. 2017).

Early Childhood Health and the Life Course: The State of the Science and Proposed Research Priorities was authored by social epidemiologist and developmental-behavioral pediatrician W. Thomas Boyce, MD, and the late Clyde Hertzman, MD, MSc, who, as noted in this introduction, played a central role in delineating early childhood development as a determinant of lifelong health. The chapter

reviews the literature regarding the susceptibility of young children to social environmental conditions, explains how variation among individuals in terms of both their susceptibility and their exposures helps to explain variation in health development outcomes, and examines the process by which early adversity becomes biologically embedded (Boyce and Hertzman 2017).

Marco Del Giudice's chapter on *Middle Childhood: An Evolutionary-Developmental Synthesis* demonstrates the unique significance of middle childhood by examining – from an evolutionary perspective – the cognitive, behavioral, and hormonal processes that characterize this life stage, as well as its function as a switch point in the adaptive development of life history strategies and the implications for life course health development (DelGiudice 2017).

Adolescent Health Development: A Relational Developmental Systems Perspective is the result of collaboration among experts in developmental psychology, human development, public health, and pediatrics. The authors are Richard M. Lerner, PhD; Claire C. Brindis, DrPH; Milena Batanova, PhD; and Robert Wm. Blum, MD, MPH, PhD. This chapter relates the seven proposed principles of LCHD to the Relational Developmental Systems (RDS) metatheoretical perspective, illustrating their interrelationships and differences. The authors discuss the implications of both conceptual frameworks for studying the life course origins and impact of adolescent health and for promoting thriving during adolescence (Lerner et al. 2017).

Early Adulthood as a Critical Stage in the Life Course was produced by a group of authors with expertise in pediatrics, occupational therapy, psychology, and public health. In this chapter, David Wood, MD, MPH; Tara Crapnell, ORD, OTR/L; Lynette Lau, PhD; Ashley Bennett, MD; Debra Lotstein, MD, MPH; Maria Ferris, MD, PhD, MPH; and Alice Kuo, MD, PhD, employ an ecological approach to examine the period of life from 20 to 30 years of age. The authors also discuss the impact of chronic disease and other factors that affect the transition to adulthood in the educational, employment, and social arenas (Wood et al. 2017).

Epidemiologists Abigail Fraser, MPH, PhD, MRC; Janet Catov, PhD; Debbie Lawlor, MRC; and Janet Rich-Edwards', ScD, MPH, chapter on *Pregnancy Characteristics and Women's Cardiovascular Health* is a unique contribution exploring the link between women's reproductive outcomes and their risk for cardiovascular disease. The chapter presents the implications for research and policy including the potential to identify high-risk women earlier in the life course (Fraser et al. 2017).

3.3 Section III: The Life Course Origins and Consequences of Specific Diseases and Health Conditions

Section III of this volume examines the life course origins and consequences of some of the most common diseases and health conditions facing the US population today, as well as some less common but nevertheless important ones. Each of the eight chapters reviews and synthesizes prior basic and intervention research, points out the gaps in our knowledge, and speaks to the importance of additional research and its application to the policy and practice arenas. Together, these chapters demonstrate the value of the LCHD perspective in understanding and improving outcomes across a variety of populations and challenges.

Social epidemiologist Summer Sherburne Hawkins, PhD, MS, collaborated with pediatrician and prenatal nutrition expert Emily Oken, MD, MPH and pediatrician and preventive cardiology expert Matthew W. Gillman, MD, SM, to produce *Early in the Life Course: Time for Obesity Prevention*. This chapter adopts a multilevel approach in identifying the periods and factors that are the greatest contributors to obesity and explores how innovative research methodologies can be used to demonstrate causality (Hawkins et al. 2017).

Pediatric Type 2 Diabetes: Prevention and Treatment Through a Life Course Health Development Framework was written by Pamela Salsberry, PhD, RN, FAAN; Rika Tanda, PhD,

RN; Sarah E. Anderson, PhD; and Manmohan K. Kamboj, MD, an author team representing a range of fields and disciplines including nursing, pediatrics, public health, endocrinology, and epidemiology. Their chapter uses an LCHD perspective to promote a better understanding of the development of pediatric T2DM, as well as a more effective approach to prevention and treatment (Salsberry et al. 2017).

Clinical psychologist Irene E. Drmic, PhD, CPsych, collaborated with psychiatric and genetic epidemiologist Peter Szatmari, MD, MSc, and *Journal of Autism and Developmental Disabilities* editor-in-chief Fred Volkmar, MD, MA, to produce *Life Course Health Development in Autism Spectrum Disorders*. This chapter applies the LCHD framework to autism spectrum disorders (ASD) in order to inform future research and ultimately improve health development for individuals with ASD, as well as their families and communities (Drmic et al. 2017).

Self-Regulation was written by a large and diverse group of experts spanning developmental, quantitative, and educational psychology. Together, Megan McClelland, PhD; John Geldof, PhD; Frederick J. Morrison; Steinunn Gestsdóttir, PhD; Claire Cameron, PhD; Ed Bowers, MEd, PhD; Angela Duckworth, PhD; Todd Little, PhD; and Jennie Grammer, PhD, examine the development and importance of self-regulation through an LCHD lens and from the standpoint of the relational developmental systems (RDS) metatheoretical framework (McClelland et al. 2017).

A Life Course Health Development Perspective on Oral Health was written by James J. Crall, DDS, ScD, and Christopher Forrest, MD, PhD. By applying the LCHD framework and their expertise in pediatric oral health and public health, the authors advance a more contemporary conceptualization and definition of oral health as a more integral and integrated component of overall health and well-being (Crall and Forrest 2017).

Life Course Health Development Outcomes After Prematurity: Developing a Community, Clinical, and Translational Research Agenda to Optimize Health, Behavior and Functioning is

the result of a collaboration among pediatrician Michael E. Msall, MD, and a group of colleagues representing nursing, pediatrics, sociology, and demography, including Sarah A. Sobotka, MD, MS; Amelia Dmowska; Dennis Hoga, PhD; and Mary Sullivan, PhD, RN. Together the authors examine the underlying causes of observed disparities in LCHD outcomes among children born prematurely, the value of life course-focused population-level interventions for closing the gap, and the need to improve the availability and systematic provision of such services (Msall et al. 2017).

A *Life Course Approach to Hearing Health* was written by Shirley A. Russ, MB, ChB, MRCP, FRACP, MCH; Kelly Tremblay, PhD, CCC-A; Neal Halfon, MD, MPH; and Adrian Davis, BSc, MSc, PhD, FFPH, FSS, OBE – an author team representing both pediatrics and speech and hearing. The chapter explores the origins of the full spectrum of hearing loss, including genetic, congenital, and environmental causes, and the mechanisms by which they interact and act upon an individual's hearing health development over the life-span (Russ et al. 2017).

Nephrologists Patrick Brophy, MD; Jennifer R. Charlton, MD, MSc; J. Bryan Carmody, MD; Kimberly J. Reidy, MD; David Askenazi, MD; and Susan P. Bagby, MD, teamed up with pediatrician Lindsay Harshman, MD; neonatologist Jeffrey Segar, MD; and public health expert David Shoham, PhD, MSPH, to produce *Chronic Kidney Disease: A Life Course Health Development Perspective*. In this chapter, the authors find that the LCHD framework is of great value in both elucidating the sequelae of CKD risk and identifying the kinds of early life interventions that have the potential to mitigate it (Brophy et al. 2017).

3.4 Section IV: Cross-Cutting Topics in Life Course Health Development

This section of the volume addresses four key issues – growth, nutrition, adversity, and disparities – that are relevant to understanding and

addressing a wide range of diseases and health conditions.

Growth and Life Course Health Development was written by a team of authors spanning medicine, public health, and anthropology. In their chapter, Amanda Mummert, MA, Meriah Schoen, and Michelle Lampl, MD, PhD, employ a systems biology approach to examine the pathways affecting growth and explore auxology's role in a variety of health trends (Mummert et al. 2017).

From Epidemiology to Epigenetics: Evidence for the Importance of Nutrition to Optimal Health Development Across the Life Course was written by nutrition experts Marion Taylor-Baer, PhD, MSNS, RD, and Dena Herman, MSNS, MPH, RD. Their chapter uses the LCHD framework to examine the crucial role that nutrition plays in the development of health potential over the life-span, including the role of evolutionarily driven adaptive responses during the prenatal and early childhood periods (Taylor-Baer and Herman 2017).

In *How Socioeconomic Disadvantages Get Under the Skin and into the Brain to Influence Health Development Across the Lifespan*, developmental psychologists Pilyoung Kim, PhD; Gary Evans, PhD; Edith Chen, PhD; and Gregory Miller, PhD, collaborated with epidemiologist Teresa Seeman, PhD, to explain the neurobiological mechanisms and processes by which SES-related adversity, including chronic stress, affect health trajectories from early life to old age (Kim et al. 2017).

Health sciences researcher Kandyce Larson, PhD, together with pediatricians Shirley A. Russ, MD, MPH; Robert S. Kahn, MD, MPH; Glenn Flores, MD, FAAP; Elizabeth Goodman, MD; Tina L. Cheng, MD, MPH; and Neal Halfon, MD, MPH, produced *Health Disparities: A Life Course Health Development Perspective and Future Research Directions*. This chapter explores the factors and processes that contribute to health disparities across lifetimes and generations from the perspective of life course health development in order to illuminate potential practice and policy solutions to this persistent problem (Larson et al. 2017).

3.5 Section V: Methodological Approaches

Section V is comprised of five chapters that will be of practical use to researchers who are engaged or who would like to engage in future research aimed at enhancing our understanding of how health develops over the life course and/or understanding how practice and policy can optimize health development outcomes. The first two chapters in this section review current research methods and study designs that are of particular value for LCHD research. The remaining three chapters describe existing longitudinal datasets that have the potential to be used to answer the kinds of research questions that are described in the Life Course Research Agenda, Version 1.0 (Halfon et al. 2017).

In *Core Principles of Life Course Health Development Methodology and Analytics*, developmental and educational psychologist and statistician-methodologist Todd Little, PhD, acknowledges the inherent complexity of LCHD studies. He suggests that underutilized techniques, such as structural equation modeling, multilevel modeling, and mixture distribution modeling, as well as new and collaborative team-based research practices, have the potential to rapidly advance the field (Little 2017).

In *Epidemiological Study Designs: Traditional and Novel Approaches to Advance Life Course Health Development Research*, epidemiologists Stephen L. Buka, PhD; Samantha R. Rosenthal, PhD; and Mary E. Lacy explore the benefits and limitations of the various approaches that can be used to study the development of health and disease over the life course (Buka et al. 2017).

Using the National Longitudinal Surveys of Youth (NLSY) to Conduct Life Course Analyses by sociologist Elizabeth Cooksey, PhD, demonstrates how this long-running three-cohort longitudinal study – which provides a wealth of data on health, education, employment, household information, family background, marital history, child care, income and assets, attitudes, substance use, and criminal activity – can be used to explore various LCHD-related research questions (Cooksey 2017).

Sociologist and demographer Narayan Sastry, PhD, worked with research scientists Paula Fomby, PhD, and Katherine McGonagle, PhD, to develop the chapter on *Using the Panel Study of Income Dynamics (PSID) to Conduct Life Course Health Development Analysis*. This chapter explains how this nationally representative longitudinal study – which is the longest-running household panel study in the world, covering 47 years of data on a wide range of economic, demographic, social, and health topics – can be used to examine health development over the life course (Sastry et al. 2017).

In *Using the Fragile Families and Child Wellbeing Study (FFCWS) in Life Course Health Development Research*, sociologist Amanda Geller, PhD, collaborates with FFCWS staff members Kate Jaeger and Garrett Pace to describe this nationally representative birth cohort study that contains both biological and social indicators. The authors provide examples of its use for exploring questions about health development in households with unmarried parents (Geller et al. 2017).

3.6 Section VI: Conclusions

Section VI of this volume contains a single chapter entitled *Life Course Research Agenda (LCRA), Version 1.0* in which editors Neal Halfon, MD, MPH; Christopher B. Forrest, MD, PhD; Richard M. Lerner, PhD; and Elaine Faustman, PhD, together with LCRN staff members Ericka Tullis, MPP, and John Son, MPH, synthesize the recommendations for future research contained in many of the previous chapters and propose a set of priority research types, topics, and questions, as well as a set of activities aimed at improving our ability to carry out this critical research and ensure its timely translation to practice and policy. The authors also recommend strategies that can support the ongoing refinement of the LCHD theoretical framework (Halfon et al. 2017). As this volume goes to press, the LCRN is initiating an inclusive process to review and refine this initial version of the LCRA so that it is sure to guide both researchers and potential funders toward the

studies that will be of greatest benefit in terms of enhancing our rapidly growing but as yet incomplete understanding of life course health development.

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