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1 *Introduction*

> What has been accomplished is only an earnest of what shall be done in the future. Upon our heels a fresh perfection must tread, born of us, fated to excel us. We have but served and have but seen a beginning. Personally, I feel deeply grateful to have been permitted to join in this noble work and to have been united in it with men (and women) of such high and human ideas.
>
> *William Osler* (1849–1919)

The above quotation from the writings of Sir William Osler is fully appropriate. It has been an honor for me to work in the Fels Longitudinal Study. Indeed, all the members of the Fels staff are fully conscious of their debt to those who laid the foundations for the studies that are summarized in this volume. Although much has been achieved, all realize that those who follow will greatly extend our present limited horizons.

This book describes the progress that has been made during the first 60 years of the Fels Longitudinal Study of Growth, Maturation and Body Composition. The remarkable nature of the study justifies this volume. Very few, if any, investigations of human beings are so longlived. Despite its longevity, the Fels Longitudinal Study continually becomes more vigorous and active. Few studies have been responsible for equally important research related to serial changes in physical growth and maturation and body composition in normal individuals.

The Fels Research Institute was founded in 1929 with a single complex research project that came to be called the Fels Longitudinal Study. As the name implies, this was a serial study and it was multidisciplinary. Between 1927 and 1932 several such studies were founded in the US, which in addition to the Fels Longitudinal Study, included the Bolton–Brush Study at Western Reserve University (Cleveland, Ohio), the Berkeley Growth Study, Guidance Study, and Oakland Growth Study at the Institute of Human Development of the University of California (Berkeley), the Child

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Research Council Study at the University of Colorado (Denver), and the Harvard School of Public Health Growth Study (Boston, Massachusetts).

This sudden rush to begin serial multidisciplinary studies of child growth and development between 1927 and 1932 sprang, in part, from desires to shield children from the worst effects of the Great Depression. These same concerns led to the 1933 White House Conference on Child Health and Protection which recommended that such studies be undertaken. It was recognized that further knowledge was required to determine both the effects of the Great Depression and the possible influence of programs intended to mitigate these effects.

Serial data for individuals were recorded in each of these studies but, generally, the data were analyzed cross-sectionally. Each study had its area of concentration and outstanding expertise. The Bolton–Brush Study was responsible for major advances in methods for the study of craniofacial growth (Broadbent, 1931; Broadbent, Broadbent & Golden, 1975), and of maturation (Greulich & Pyle, 1959), and useful information was provided about growth changes in various anthropometric dimensions (Simmons, 1944). This study is scarcely active, although occasional use is made of the records which are intact but not in an electronic format.

The three studies at Berkeley (Berkeley Growth Study, Guidance Study, Oakland Growth Study) were responsible for important research contributions in child growth, psychology and sociology, including advances in methods for the analysis of serial data and the measurement of psychological development. The results of these studies have been summarized by Jones *et al.* (1971). The Berkeley group of studies is now inactive except for occasional sociological studies of participants in adulthood.

The Child Research Council Study contributed valuable information about diet, tissue growth, electrocardiography and basal metabolic rate, although few of the analyses were serial. Data collection in this study ceased in 1968. Many of the recorded data are stored electronically and were reported by McCammon (1970). The Harvard School of Public Health Growth Study was responsible for influential advances in methods for the radiographic measurement of subcutaneous adipose tissue and substantial findings relating to tissue growth and skeletal maturation.

The designs of the Fels Longitudinal Study and the Child Research Council Study were similar in many respects. Each was a study of individuals within families and, in each case, the examinations continued at intervals during adulthood. Physical growth and maturation dominated the Child Research Council program, but there was an approximate balance between research activities in physical areas and in psychological areas in the Fels Longitudinal Study. The balance altered in the Fels Study

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in 1974 when the collection of psychological data ceased and analysis of the existing psychological data slowed considerably.

A little history

Until 1977, the Fels Longitudinal Study was conducted within the Fels Research Institute and it included concomitant studies of cognitive development, behavior, and family functioning. These studies have been excluded from the present account, which is restricted to physical growth, physical maturation and body composition. In 1977, the Fels Research Institute became part of the School of Medicine at Wright State University and the Fels Longitudinal Study was subsumed as the Division of Human Biology, at first within the Department of Pediatrics and later within the Department of Community Health. Many other investigations by scientists in the Fels Research Institute or in its successor have been omitted from the present account because they were not derived from the Fels Longitudinal Study, even if they relate to the themes of this book.

Many are puzzled by the location of the Fels Longitudinal Study and the Fels Research Institute in Yellow Springs, unaffected by the flow of resources and expertise to large well-known universities such as Harvard and Stanford. The answer concerns two close friends, Arthur E. Morgan and Samuel S. Fels, who were responsible for the foundation of the study and of the institute. In 1929, Arthur Morgan was the President of Antioch College in Yellow Springs. Therefore, it was natural that, from their conception to their maturity, the study and the institute that these men initiated were in Yellow Springs and associated with Antioch College.

Arthur Morgan posed a question that sounds simple: 'What makes people different?' This is one of many questions that sound simple but are extremely difficult to answer. Mr Morgan concluded that a longitudinal study from conception to adulthood was required. He discussed this with many biologists and social scientists but they were skeptical. Mr Morgan was not deterred; he approached Mr Fels, a Philadelphia businessman and philanthropist, about his plans and did not conceal the doubts of the scientists whom he had consulted. Mr Fels was not troubled by the opinion of the 'experts.' Although he realized the results of the study would be delayed, he gave it enthusiastic support and financial backing.

The parents of Samuel Simeon Fels had come from Bavaria to Philadelphia in 1848. They stayed there briefly before moving to Virginia where Samuel Fels was born in 1860. In 1873, his family returned to Philadelphia and achieved financial success in soap manufacturing. For Samuel Fels, financial success was not an end in itself but a means to do

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good. He used his wealth to assist the establishment and the work of many local, national and international causes that were related to education, labor laws, crime prevention, local government, science, and Jewish charities.

The early support by Samuel Fels of the program suggested by Arthur Morgan was given structure in 1932 when a corporation was established in Ohio. The purpose clause stated: 'The principal initial problem to which the organization shall devote its energies is the furtherance of knowledge of the effect of physical, emotional, and nutritional environment during and shortly after the period of gestation upon the physical and mental constitution of the child.' This is remarkable because, at that time, there was widespread scientific belief that a fetus was shielded from environmental effects. Time has shown the wisdom of the stated purpose which matched the attitude expressed by Samuel Fels in his 1933 book 'This Changing World.' He wrote that long-term studies of large groups of children should be made and they 'should begin before the child is born and continue to maturity.' In 1935, the Ohio Corporation was replaced by the Samuel S. Fels Fund which was incorporated in Pennsylvania with much broader charter purposes that matched the wide-ranging interests of Samuel Fels.

The Fels Longitudinal Study began in 1929 with the appointment of Lester W. Sontag as the Director. At that time, Lester Sontag was the Physician at Antioch College in Yellow Springs, having recently received his MD degree from the University of Minnesota. Dr Sontag received further training at various major centers in the US while he planned the Fels Longitudinal Study. The examinations of participants began in 1930 when the institute had a staff of three and an annual budget of $5000. While the institute was small, Lester Sontag was deeply involved in all the research and also managed administrative matters. Until his retirement in 1970, he continued to be active in research concerning skeletal maturation, skeletal variations and developmental changes in intelligence. His major contribution, however, was the foundation and nurturing of the Fels Longitudinal Study which he directed during a long period of growth and increasing effectiveness, and from its initiation under the protective umbrella of Antioch College to the status of a free-standing institution in 1947.

The Fels Research Institute was owned and operated by the Fels Fund of Philadelphia, with considerable assistance from the US Government through grants and contracts. This arrangement continued until 1977 when, as a result of increasing financial strains, the Fels Fund donated the institute to the School of Medicine at Wright State University, with an

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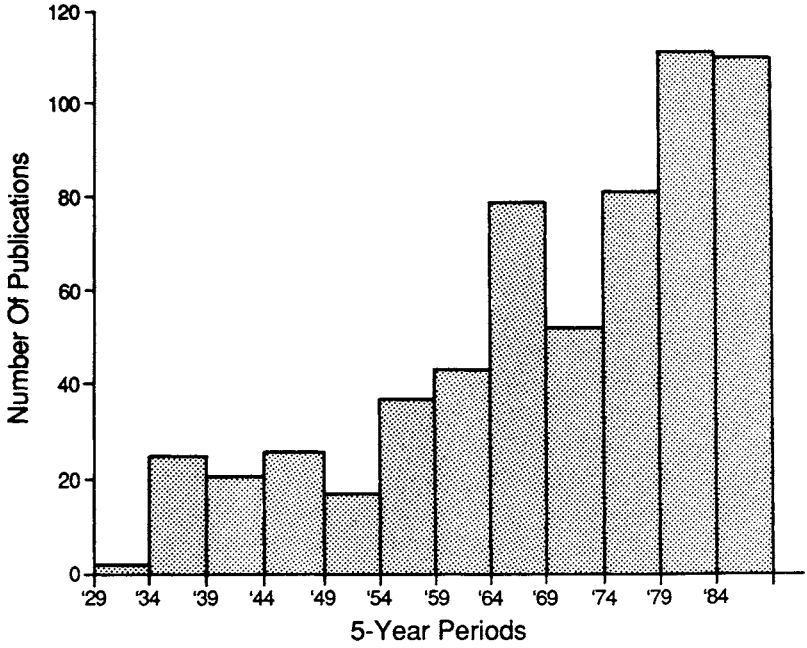

Fig. 1.1 The number of publications (articles, chapters, books, and monographs) dealing with physical growth and maturation from the Fels Longitudinal Study within 5-year periods. The numbers on the horizontal axis refer to calendar years at the beginning of these periods (e.g., '29 = 1929–1933).

agreement to fund the institute for a further 5 years. Wright State University is situated in Dayton, about 8 miles (13 km) from the institute. It was expected that the institute would be beneficial to the school of medicine that had just been established at the university by providing an immediate research base. This expectation was realized to some extent, but the institute was fragmented when part was moved to the main campus and it rapidly became weaker and smaller as scientists who resigned or retired were not replaced. Now, the institute is reduced to the Division of Developmental Psychology in the Department of Psychiatry and the Division of Human Biology in the Department of Community Health. Both these divisions are located in Yellow Springs near the building that housed the institute from 1947 through 1984.

On balance, the decision to locate the Fels Longitudinal Study and the Fels Research Institute in Yellow Springs was a good one. The local population is more stable in place of residence than is usual in the US; this stability is very important for a long-term serial study. Since the institute was not on a university campus, the professional staff were not burdened

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by teaching responsibilities and committee work. Nevertheless, some disadvantages accompanied the relative isolation of the Fels Research Institute. Each department in the institute lacked a critical mass of scientists and it was difficult to obtain the effective help of specialists in other disciplines, e.g., biostatistics.

The Fels Research Institute grew from its commencement in 1929 until about 1968, whether growth is judged by the number of staff or the size of the building. The achievements of the staff in research related to growth, maturation, and body composition are difficult to measure. One inadequate guide is the number of articles, chapters, books and monographs that have been published. The totals for 5-year periods remained fairly stable until about 1954, after which they increased markedly (Fig. 1.1).

From the beginning of the longitudinal study, some serious attempts were made to address directly the question posed by Arthur Morgan concerning what was responsible for differences between individuals. Analyses were made to determine the influence of environmental factors operating near the time of birth on the development of children. Such investigations are difficult, particularly in human beings, because random assignment to experimental and control groups is likely to be unethical and unacceptable. These topics were studied at Fels in what are sometimes called 'natural experiments' without controlling the conditions. With this approach, the data must be adjusted statistically for the influences of intervening variables. Consequently, large samples are required and data must be collected for many variables that could influence the results. Even then, the findings from such studies commonly remain inferential. Any observed effects may be due to another variable or set of variables for which data were not collected.

Instead of beginning with the recognition and measurement of effects, the institute staff, quite properly, began by describing the status and patterns of change with age in variables related to growth, maturity and body composition. In this they followed the wise advice of William Harvey: 'I am of the opinion that our first duty is to inquire whether a thing be or not, before asking wherefore it is.' Throughout its history, the Fels Longitudinal Study has resulted in many hypotheses that have been tested by the analysis of facts.

Until about 1945, almost all the research activities of the Fels Research Institute concerned the longitudinal study. In those days, the longitudinal study *was* the institute. In subsequent years, many other projects were located in the institute; some of these did not have direct relationships to the hypotheses that could be tested using data from the longitudinal study.

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Biographical sketches

Brief biographical sketches follow, ordered alphabetically, of some of the scientists who worked at the Fels Research Institute and were leaders in the analysis of data relating to growth, maturation, and body composition. The list does not include the many scientists who worked at the Fels Research Institute in areas such as biochemistry, endocrinology, psychology and physiology. Others who came to Fels for short periods to work in the areas of growth, maturation and body composition so that they could share their special skills or acquire new ones are not listed. Many of these visitors and fellows reported analyses of Fels data, as is clear from the author index which contains the names of many distinguished scientitsts. The years in parentheses after each name in the following sketches give the period during which the scientist worked at the institute.

Richard N. Baumgartner (1985–1990). Rick Baumgartner received a PhD in Public Health from the University of Texas at Houston in 1982. He has contributed greatly to the longitudinal study by supervising the measurement procedures and by analyzing serial changes in patterns of adipose tissue distribution (fat patterns) and their relationships to risk factors for cardiovascular disease and to diabetes. In addition, he investigated new methods for the measurement of body composition including electrical impedance, computed tomography, and magnetic resonance imaging.

Pamela Byard (1981–1982). Pam Byard obtained a PhD degree in Biological Anthropology from the University of Kansas in 1981. While at the Fels Research Institute, she worked partly in Roger Siervogel's study of blood pressures within large family groups. She has also analyzed data from the Fels Longitudinal Study both while at Fels and after she left. These analyses concerned familial associations for growth, body composition and craniofacial variables and secular changes in body composition variables.

Wm Cameron Chumlea (1978–). Cameron Chumlea obtained a PhD in Physical Anthropology from the University of Texas at Austin in 1978. He was responsible for all measurement procedures in the Fels Longitudinal Study until 1985 and plays an important part in the general design of the study. One of his major research interests is the assessment of nutritional status from body measurements, especially in the elderly. He is prominent in research related to adipocytes (fat cells), body composition,

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bioelectric impedance, the measurement of total body water, and the assessment of skeletal maturity.

Christine E. Cronk (1980–1982). Chris Cronk was awarded a DSc degree by the Harvard School of Public Health in 1980. While she worked in the Division of Human Biology, her research addressed the application of recently developed statistical methods to analyses of serial body composition data. She also developed national reference data and reported studies of growth and body composition in children with Down syndrome.

Frank Falkner (1971–1979). Frank Falkner received his medical training in England where he graduated in 1945, becoming a Fellow of the Royal College of Physicians in 1972. He succeeded Lester Sontag as the Director and steered the institute through a period of financial and administrative difficulties. In addition, he established the Fels Division of Pediatric Research at the University of Cincinnati and began a multinational study of infant mortality. While at Fels, Dr Falkner's personal research related to the assessment of nutritional status, infant mortality, and the joint editorship, with James M. Tanner, of a three-volume treatise on human growth.

Stanley M. Garn (1952–1968). Stanley Garn obtained a PhD in Physical Anthropology from Harvard University in 1948. During a stay of exactly 16 years as Chairman of the Department of Growth and Genetics, he gave the institute national and international prominence by his many publications and his answers to novel questions. Dr Garn's major research contributions related to skeletal and dental maturation, age changes in subcutaneous adipose tissue, the gain and loss of bone substance, and the sizes and shapes of teeth.

Shumei Guo (1985–). Shumei Guo received her PhD in Biostatistics from the University of Pittsburgh in 1983. She is in charge of all statistical matters in the Division of Human Biology, including the management of our large and complex data bases. In addition to acting as a statistical consultant to other staff members, Dr Guo is particularly active in the development of new methods for the analysis of serial data, in the use of new procedures to construct equations that predict body composition variables from values that are relatively easy to obtain, and in the analysis of risk factors for cardiovascular disease.

John H. Himes (1976–1979). John Himes obtained a PhD in Physical

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Anthropology from the University of Texas at Austin in 1975. While working in the Division of Human Biology, he supervised data collection for studies of body composition and hearing ability. His main research interests concerned bone lengths, the estimation of stature from bone lengths, the correct interpretation of observed statures, the hearing ability of children in relation to noise exposure, the assessment of nutritional status, body composition, and the provision of reference data for growth rates.

Harry Israel III (1964–1975). Harry Israel obtained his DDS degree from the University of Michigan in 1956 and a PhD degree from the University of Alabama in Birmingham in 1971. During the long period that he worked part-time at the Fels Research Institute, his research interests were related to growth and aging in the craniofacial part of the skeleton, variations in the bones of the fingers, aging of vertebrae, and the radiographic density of bones and teeth.

Arthur B. Lewis (1939–). Arthur Lewis obtained his DDS degree from Ohio State University in 1933 and was awarded an MS in Orthodontics by the University of Illinois in 1935. He has a remarkable half-century record of part-time voluntary work at the Fels Research Institute. His research publications describe the sizes and shapes of teeth, dental development including its genetic control, the occasional failure of teeth to develop, and craniofacial growth.

Debabrata Mukherjee (1980–1984). Debu Mukherjee received a PhD in Biostatistics from the University of Alabama in Birmingham in 1980. At the Fels Research Institute, he was responsible for statistical analyses and the management of data bases. His main publications concerned serial analyses related to body composition, hearing ability, craniofacial growth, the development of equations to predict body composition variables, infant growth patterns, and the measurement of skeletal mass.

Earle L. Reynolds (1943–1951). Soon after he obtained a PhD degree from the University of Wisconsin, Earle Reynolds came to the Fels Research Institute as Chairman of the Department of Growth and Genetics. While at Fels, he published landmark papers dealing with age changes in adipose and other tissues, the growth of the pelvis, and methods for grading the development of secondary sex characters.

Meinhard Robinow (1939–1943). Meinhard Robinow obtained his MD

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degree from the University of Hamburg in 1934. While at the Fels Research Institute, he made very thorough physical examinations of the participants and recorded his findings in a script that was very easy to read. His research publications related to the maturation of bones and teeth, methods for grading the posture of children, and the provision of reference data for growth rates.

Alex F. Roche (1968–). The present author graduated in medicine from the University of Melbourne (MB, BS) in 1946 and subsequently received PhD, DSc and MD degrees from the same university before becoming a Fellow of the Royal Australasian College of Physicians. He came to the institute as Chairman of the Department of Growth and Genetics and was later Head of the Division of Human Biology and Director of the Fels Longitudinal Study. He is in charge of research relating to physical growth, maturation, and genetics. His research interests include growth of the whole body and of the craniofacial region, skeletal maturation, the prediction of adult stature, body composition, risk factors for cardiovascular disease, hearing ability in relation to noise exposure, and methods for the analysis of serial data.

Roger M. Siervogel (1974–). Roger Siervogel obtained a PhD in Human Genetics from the University of Oregon in 1971. He has led the Fels Division of Human Biology into the computer age and is active in research related to body composition, risk factors for cardiovascular disease especially blood pressure, dermatoglyphic patterns, hearing ability in children in relation to noise exposure, and genetic and familial factors that affect these traits.

Lester W. Sontag (1929–1970). Soon after graduating in medicine from the University of Minnesota in 1926, Lester Sontag became the resident physician at Antioch College, and in 1929 he was appointed as the Founding Director of the Fels Research Institute. His research work, in relation to the topics covered in this book, concerned prenatal growth, nutrition, genetics, the growth and maturation of bones, and basal metabolic rate. After 1945, Dr Sontag's interests became more behavioral and his administrative activities occupied more of his time.

The major US longitudinal studies

Sontag (1971)[281], in an illuminating review of the major longitudinal studies in the US, drew attention to the changes that had occurred in these studies since they began in the late 1920s and early 1930s. All of them

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