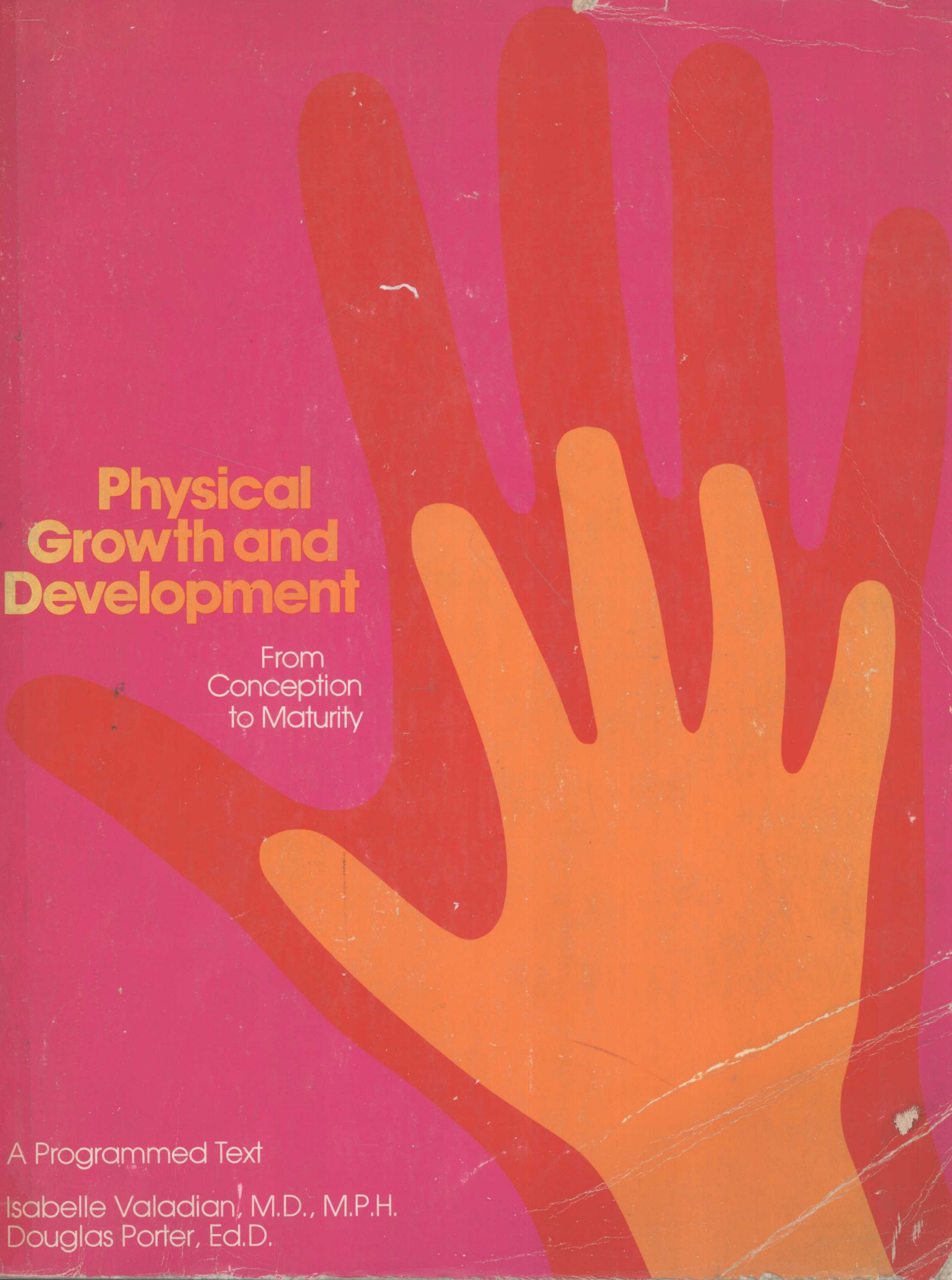
Physical Growth and Development

From Conception to Maturity



A Programmed Text

Isabelle Valadian, M.D., M.P.H.
Douglas Porter, Ed.D.

PHYSICAL GROWTH AND DEVELOPMENT

FROM CONCEPTION TO MATURITY

A Programmed Text

Isabelle Valadian, M.D., M.P.H.

Associate Professor of Maternal and Child Health, Harvard School of Public Health, Boston

Douglas Porter, Ed.D.

Lecturer on Medicine, Harvard Medical School, and Beth Israel Hospital, Boston

With Collaborators

Lucy Carroll, Julia Herskowitz, Judy Ann Lamar, and Elinor T. Neuhauser

Foreword by

Robert J. Haggerty, M.D.

Roger Irving Lee Professor of Public Health (Health Services and Pediatrics), Harvard School of Public Health and Harvard Medical School, Boston

Little, Brown and Company • Boston

Development of the text was supported in part by: Grant No. 5 DO4 AH 01044, Bureau of Health Manpower Education, Public Health Service, Department of Health, Education, and Welfare; Grant No. MC-R-250014, Maternal and Child Health and Crippled Children's Services, Health Services and Mental Health Administration, Department of Health, Education, and Welfare; and a grant from the W. K. Kellogg Foundation.

First Edition

Library of Congress Catalog Card No. 75-41572
ISBN 0-316-89525-3

Printed in the United States of America

1. Child development
2. Child — Growth & development
3. adolescence — Growth & development

FOREWORD

Growth and development has been termed, appropriately, the basic science of child health. The dynamic changes in a child's growth and functioning are major determinants of health and illness and of their manifestations at different stages of childhood; illnesses that have relatively little impact on adults may be devastating to the small child. Deviations from normal growth and development remain among the best early indicators of childhood illness. The profound effect of environmental factors upon a child's growth and development is of special importance to the clinician and to the policymaker.

Until the pioneering longitudinal growth studies were begun in the 1930s, there was little systematic development of knowledge in the field of growth and development. Dr. Harold C. Stuart, then Chairman of the Department of Maternal and Child Health at the Harvard School of Public Health, was one of these pioneers. His original work (*Longitudinal Studies of Child Health and Development*) covered the age span from the prenatal period to the eighteenth year of life; his student and colleague, Dr. Isabelle Valadian, has carried on the tradition through continued study of the original cohort into adulthood. Collaboration with the successors of other major longitudinal growth studies – at The Child Research Council of Denver, Colorado; The Institute of Human Development, Berkeley, California; and The Fels Research Institute, Yellow Springs, Ohio – is beginning to elucidate the important contribution of developmental experience to adult health.

Yet the teaching of growth and development has remained difficult. While child health workers have given lip service to the need for knowledge of child growth and development, few have successfully been able to impart the intellectual excitement of the field to their students. Pediatricians frequently have put aside this field of study only to cram prior to sitting for the American Board of Pediatrics examination. Dr. Valadian and her colleagues, who for many years have taught growth and development at the Harvard School of Public Health and the Harvard Medical School, have recognized the need for a new approach to the teaching of fundamental knowledge in the field. The result is this self-instructional text, which combines the findings from decades of research in growth and development with a modern teaching innovation.

Preliminary versions of the text have been used with gratifying results by students preparing for a variety of health careers. Not only has student knowledge been demonstrably increased, but enthusiasm for the method of instruction suggests that a way has been found to transmit the essential information on growth and development in an intellectually stimulating and emotionally satisfying way. I am pleased that the Harvard School of Public Health, which has been engaged in the scientific study of child growth and development for so many years, has now produced a text that encourages the transmission of this knowledge to the broad range of students who need it to better care for, and plan for the care of, children.

Robert J. Haggerty

PREFACE

An abundance of data on human growth and development has accumulated since careful observers first began recording the changes that occur from conception to maturity. The essence of these findings provides a common core of knowledge for workers in the field of child health and development and for the parents, paraprofessionals, and professionals who may influence the course of an individual's development. Our text presents this common core of knowledge that any person providing health services to children, or planning such services or policies, should have.

We hope that our text will be of benefit to a wide audience – students beginning their study of growth and development, health-related and social service personnel, medical students, and physicians. To this end, technical terms outside the topics of growth and development have been eliminated where possible, often through the extensive use of charts, graphs, tables, diagrams, and photographs that show much with few words. We have been gratified by the response to this teaching strategy from varied student groups.

The first two units cover basic principles of growth and development and methods of assessing growth, and provide experience with the interpretation of different types of growth standards. The remaining fourteen units extend this basic material to specific body systems, beginning with the skeletal system, which is essential to the overall assessment of growth and development, and concluding with the reproductive system, the last major system to develop and mature. Each of the system-oriented units begins with the basic anatomy and physiology of the system, then describes the developmental changes to be expected, and, finally, offers practice in the interpretation of brief case presentations.

This organization permits fitting of the text to a variety of student needs. Once the first two units have been completed, other units can be selected to meet specific learning objectives. For example, students pursuing the study of adolescent development might choose, in addition to the first two units, from among the following: The Reproductive System, The Endocrine System, Skin and Adipose Tissue, Muscles, and The Skeletal System; pediatric dietitians might choose The Digestive System, The Skeletal System, Dentition, and The Nervous System. In this way, we hope that the text will be helpful to teachers and students in a variety of circumstances: (1) as a basic text in courses on growth and development; (2) as basic material to be mastered before moving on to more advanced topics in second level courses; (3) as the physical growth and development component in courses that also cover the behavioral and social aspects of development; (4) as the basis for informed case discussions of developmental problems; (5) as a basis for independent study by the many individuals who have a need for easily accessible information on growth and development. In whatever way the text is used, it has been our experience that students learn more and enjoy their learning more when the study of a unit is followed by class discussion or other opportunities to practice, extend, and generalize the information they have learned.

We believe that programmed self-instruction is the most reasonable way of presenting factual material because superfluous verbiage is eliminated and the teaching questions help students keep track of their understanding. We have provided a test for each unit that can be used before study to diagnose learning needs or after study to assess learning outcomes. Each unit is preceded by a list of topics covered. A thorough index should facilitate use of the text as a reference work.

During its development, this text has undergone repeated testing and revision, based on student responses, test results, and comments, by individuals and groups representing the interests of

potential users. Pretest-posttest data obtained during field trials show an average improvement of 84 per cent for the 16 units. More extensive performance data are available from the authors.

Finally, a word on what the text does not cover. We have not treated social, behavioral, and psychological development. These matters of great concern, and sometimes controversy, are covered at length elsewhere. It should be recognized, however, that the objective description of physical development can often illuminate the origins of acquired behaviors: for example, the contribution of endocrine changes at adolescence to teenage behavior problems, or the contribution of changes in the digestive system to feeding or toilet training problems. We have preferred to offer a physical perspective to the study of human behavior by addressing the objective facts of growth and development.

Many people have contributed to this text as writers, artists, consultants, editors, critics, and friends.

We have been especially fortunate in our collaborators: Lucy Carroll, Ed.M., Director, Title I Project "Career Education," Vanguard School, Haverford, Pennsylvania; Judy Ann Lamar, M.D., Instructor in Pediatrics, Harvard Medical School, and Assistant in Pediatrics, Children's Hospital Medical Center, Boston; Elinor T. Neuhauser, M.D., M.P.H., Teaching Fellow in Maternal and Child Health, Harvard School of Public Health; and Julia Herskowitz, M.A., Research Director, Taunton Area Service Integration Project, Taunton, Massachusetts. Ms. Carroll, as Instructional Development Specialist at the Harvard School of Public Health, participated in the planning and drafting of major portions of the text and carried out field trials of early editions. Dr. Lamar also joined in the planning and drafting of many units. Dr. Neuhauser, as Teaching Fellow in the Department of Maternal and Child Health, and Ms. Herskowitz, while a student in the Department of Maternal and Child Health, worked on drafting the remaining units and revising the text on the basis of field test data. The original illustrations, as well as some adaptations of drawings from other sources, were prepared by Martin G. Langer, with occasional contributions from Thérèse Langer. The text has benefited much from the close, scholarly collaboration of these fine artists.

The following individuals also have given generously of their skills: Carol MacMurray Christian revised many units and unit tests; Jean B. Fuller typed the final manuscript with a consistency and skill that saved the authors from many blunders; Deborah M. Garbose compiled test results and, with good cheer, carried out the thankless task of obtaining permissions; Susan P. Alexander provided a detailed analysis of learning outcomes; Judith C. Caldwell produced the index; Mary Jane Pinkos and Marjorie D. Morse, Jr., typed and compiled test results of preliminary editions; and Olivia Brum coordinated people, money, and other resources throughout. Constance E. West was helpful in providing resources from the Office for Instructional Development, Harvard School of Public Health. We thank you all for your generous help and the pleasure of working with you.

Many people have given freely of their time by reading or teaching from preliminary editions and offering helpful suggestions. The following colleagues served as consultants on particular units: Alan Leviton, M.D., Assistant Professor of Neurology, Children's Hospital Medical Center, Boston, on The Nervous System; Coenraad F. A. Moorrees, D.D.S., Professor of Orthodontics, Forsyth Dental Center, Boston, on Dentition; S. Idell Pyle, Ph.D., Bolton-Brush Growth Study Center, Cleveland, on The Skeletal System; Peter A. Vardy, M.D., Head, Department of Pediatrics, Bargilar Medical Centre, Ashkelon, Israel, on The Endocrine System and The Immune System; and John B. Watkins, M.D., Assistant Professor of Pediatrics, Harvard Medical School, Children's Hospital Medical Center, Boston, on The Digestive System. Thank you all for your wise counsel.

Students and others from many institutions and programs have participated in developmental trials of the text, through the good offices of colleagues. You have offered suggestions fearlessly and have suffered our blunders with tolerance. Future users of the text will thank you many times over. Thank you for helping us: students enrolled in Maternal and Child Health courses, Harvard School of Public Health (Isabelle Valadian, M.D., Associate Professor) and School of Public Health, University of North Carolina (Earl Siegel, M.D., Professor); dietetic interns, Beth Israel Hospital (Adele Dronsick, R.D., Educational Director, Dietary Department), Massachusetts General Hospital (Annie Galbraith, R.D., Associate Director, Dietary Department and Dietetic Internship Program), Peter Bent Brigham Hospital (Mary Ellen Collins, R.D., M.Ed., Director, Dietetics and Nutrition); nutritionists in public health, Boston Council of MIC and C&Y Projects (Janet Packard, Nutrition Coordinator); School Health Nurses, Division of Family Health Services, Massachusetts Department of Public Health (Rita Pope, Assistant Director for Nursing); nursing students, Boston College School of Nursing (Professor Anne R. Wallace); pediatric nurse practitioner students, College of Nursing, Northeastern University (Priscilla M. Andrews, R.N., M.S., Program Director, Nurse Practitioner Program); policy-making personnel in health, education, and welfare, Bureau of Maternal and Child Health, New Hampshire Department of Health and Welfare (Selma R. Deitch, M.D., Director of the Bureau, and Ruth M. Butler, Consultant to the Bureau, and Research Associate, Harvard School of Public Health); students, Rhode Island College (Leo Miller, Ph.D., Department of Social Sciences); medical students enrolled in Pediatrics course, Harvard Medical School (Judy Ann Lamar, M.D., Instructor in Pediatrics, and Assistant in Pediatrics, Children's Hospital Medical Center, Boston); and professional and auxiliary staff, Children and Youth Project, San Juan, Puerto Rico (Antonio S. Medina, M.D., Professor and Head, Department of Human Development, School of Public Health, University of Puerto Rico).

We wish to express appreciation to the Maternal and Child Health Service, Charles P. Gershenson, M.D., Vince L. Hutchins, M.D., and Gloria Wackernah; and to the Bureau of Health Manpower Education, W. S. Brooks, and Juanita Allen; all of the U.S. Public Health Service, Department of Health, Education, and Welfare, for their support throughout the development of this text.

Finally, we offer special thanks to Sarah Boardman for the editorial guidance that has made working with our publisher such a pleasure and to Diane Faissler for her skill in coordinating the production of our complicated manuscript.

I. V.
D. P.

CONTENTS

1 Assessing Physical Growth

Isabelle Valadian
Douglas Porter

With the collaboration of
Lucy Carroll

CONTENTS

INTRODUCTION

The measurement of physical growth and development provides data of value to researchers, health care workers, and growing individuals. Growth standards developed out of systematic, long-term measurements reveal the basic patterns of human growth and can facilitate the assessment of an individual's development. The methods described here for obtaining, organizing, and displaying growth data are basic tools in the study of growth and development.

PHYSICAL GROWTH AND DEVELOPMENT

Growth and development are not the same processes, nor are they independent of one another. They are interrelated processes occurring in the human body, which is continuously reacting and adjusting to genetic and environmental factors. Growth and development of an individual begin at conception and continue throughout life.

1. Mark the following statements T (true) or F (false).

_____ Growth and development are interrelated.

_____ Growth and development are *not* related to environmental and genetic factors.

_____ Growth and development begin at conception.

_____ Growth and development begin at birth.

While the processes of growth and development cannot always be totally differentiated, *growth* generally refers to "those increases in the size of the body as a whole, or any of its dimensions, parts, or tissues which occur as part of the child's progress toward maturity" (Stuart and Prugh, 1960, p. 7).

Development generally refers to the remaining changes occurring during the process of attaining the mature state, such as the differentiation of organs and tissues during the embryonic period, the postnatal establishment of efficient digestive function, skeletal maturation throughout childhood, and the life-long production of antibodies to produce immunities.

Physical growth and development are also accompanied by the acquisition of motor skills and intellectual and emotional development.

2. Label each process below, G for each process that is primarily *growth*, and D for each process that is primarily *development.*

_____ Production of polio antibodies following vaccination

_____ Differentiation of neural, muscular, connective, and epithelial tissues in the embryo

_____ Enlargement of the circumferential dimensions of the skull

_____ Increased secretion of sex hormones during adolescence

_____ Perfection of small muscle coordination during school years

_____ Change in height from 24 to 39 inches

---

1. T, F, T, F
2. D, D, G, D, D, G

MATURATION AND ADAPTATION

Maturation and adaptation both contribute to the process of development.

Maturation refers to physical changes that occur between conception and maturity in all healthy, growing children, usually in similar order, as a result of internal body processes. Examples of maturation are organ differentiation in the developing embryo, myelination of nerve fibers, replacement of skeletal cartilage by calcified bone in the growing child, and appearance of secondary sex characteristics during adolescence.

Adaptation is the result of the body's accommodation or adjustment to its immediate environment. Examples of adaptation are the development of antibodies to combat specific bacterial infections, the increase in size of the heart and other muscles of an athlete who participates in strenuous training, the increase in subcutaneous fat in Eskimos living in extreme cold, the enlargement of the pupil of the eye in dim light, and learning to recite the multiplication tables or to ride a bicycle.

3. Label each process below. Put an M beside each example of *maturation,* an A beside each example of *adaptation,* and a G beside each example of *growth.*

_____ Arrival of menarche in an adolescent girl

_____ Enlargement of the muscles most used by an adult for a specific act, such as the arm muscles a weight-lifter might develop

_____ Increase in the length of the eyeball between birth and age 6 years

_____ Increase in the number of red blood cells at high altitudes

_____ Changes in the wrist as cartilage becomes ossified (replaced by bone)

_____ Enlargement of a remaining kidney after removal of the other

_____ Increase in the length of the bone shafts in the lower legs

_____ Eruption of the permanent teeth

DEFINITION OF PHYSICAL HEALTH

Health, as defined here, is "a state of physical well-being appropriate to an individual, taking into account his age, his progress toward maturity, and, in the case of the handicapped, his permanent limitations. It implies relative freedom from *illness*, but the healthy child is subject to the usual self-limited diseases . . . " (Stuart and Prugh, 1960, p. 8) without complications and can be expected to recover from such illnesses relatively quickly.

---

3. M, A, G, A, M, A, G, M

4. Answer the following questions *yes* or *no*.

   a. Would a child chronically ill with kidney infections be considered healthy?
   _____ yes _____ no

   b. According to the above definition, would a child with an uncomplicated case of the mumps be considered healthy if he recovers relatively quickly? _____ yes _____ no

   c. Would a child who is free of infection but shows retarded development because of nutritional deprivation be considered healthy? _____ yes _____ no

   d. Would an 8-year-old child who was born with deformed arms be considered healthy provided his overall progress and well-being were satisfactory? _____ yes _____ no

GROWTH STANDARDS

Periodic assessment of a child's general pattern of growth and development is important in promoting his health and progress toward maturity.

Growth is measured in dimensions such as height, weight, volume, and thickness of tissues, but measurement alone, without any standard of comparison, limits interpretation of the data. A number of standards have been developed that make it possible (1) to compare the measurements of any one child to other children of the same age and sex, and ideally race, and (2) to compare that child's present measurements with his former rate of growth and pattern of progress. These standards, often available as growth charts, are among the tools that have been used to assess the child's overall development. It should be noted that a majority of these standards and most of the other data referred to throughout this text are derived from studies of Caucasian children from middle-income families.

The consistency of a child's measurements over time and among different measurements at the same point in time is a better indicator of maturation for him than is comparison with the population average. It must be kept in mind that the standards are always based on the average measurements of samples from a population and that individual cases can be expected to deviate.

5. In order to evaluate the growth of a 6-year-old Caucasian boy, his measurements should be compared to which of the following? (*check all that apply*)

   _____ other 6-year-old Caucasian boys
   _____ other 6-year-old Caucasian girls
   _____ his growth record from birth to age 6 years
   _____ other 6-year-old Negro boys

6. Growth standards are based on: (*check all that apply*)

   _____ the average measurements of population samples
   _____ the measurements of an individual who is typical of a particular population
   _____ the measurements of individuals who do not deviate very much from the population average

---

4. a. no b. yes c. no d. yes
5. other 6-year-old Caucasian boys; his growth record from birth to age 6 years
6. the average measurements of population samples

THE NORMAL DISTRIBUTION

Many types of biological measurements, including height, weight, and other attributes that change with development, occur in nature in such a way that most of the observations cluster around a central value called the *mean*, or average. The further a measurement deviates from the mean, the less frequently it will be observed. When many observations are made, the measurements distribute themselves to approximate the *normal distribution* (see Figure 1-1), which has certain properties that are useful in formulating growth standards.

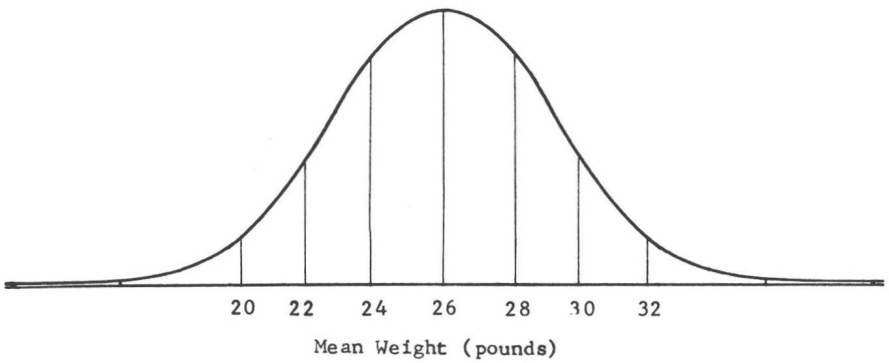


Figure 1-1 Distribution of weights of 21-month-old girls.

Study Figure 1-1 and answer the following questions.

7. If you were asked to guess the most likely weight of a 21-month-old girl, which would you pick?

   _____ 20 pounds _____ 24 pounds _____ 26 pounds _____ 30 pounds

8. What would be an appropriate response to someone who told you that their 21-month-old daughter weighed over 32 pounds? (*check one or more*)

   _____ Most girls of that age weigh about the same.

   _____ Some girls that age weigh more.

   _____ She is certainly overweight.

   _____ Most girls that age weigh less.

---

7. 26 pounds
8. Some girls that age weigh more. Most girls that age weigh less.

THE STANDARD DEVIATION

The *standard deviation* (SD or σ) is a statistical measure of *variability*, or the extent to which measurements are dispersed about the mean. It is expressed as a distance in either direction from the mean along the baseline of a normal distribution (see Figure 1-2). About 68 percent of the measurements of children can be expected to fall between +1 and −1 standard deviations from the mean; 95 percent fall between +2 and −2 SD, and 99 percent between +3 and −3 SD.

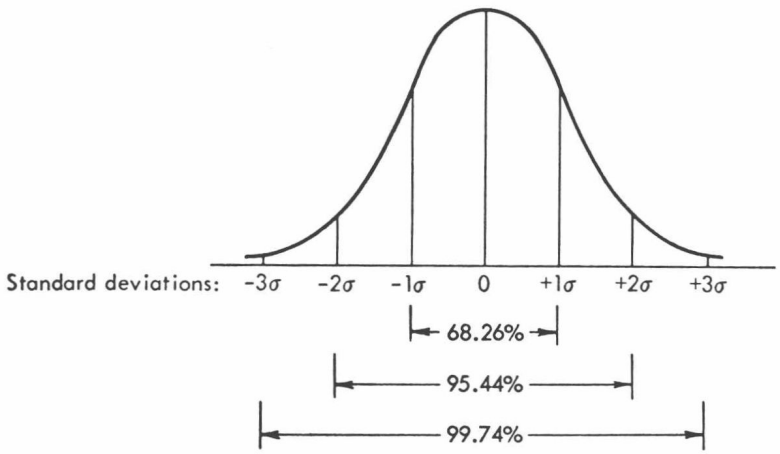


Figure 1-2 The normal distribution showing percentages of cases falling between +1 and −1 SD, +2 and −2 SD, and +3 and −3 SD from the mean (0).

The standard deviation provides a convenient way of expressing how much a particular measurement deviates from the mean, or norm, of all the measurements in a sample.

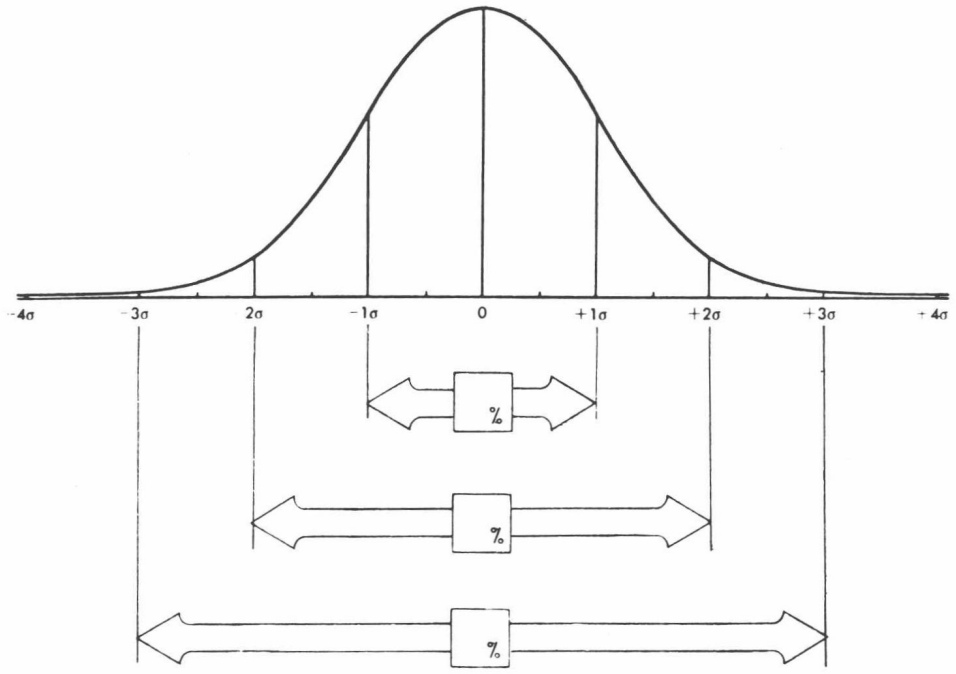


Figure 1-3

9. In Figure 1-3 fill in the percentage of cases that fall between +1 and −1 SD, +2 and −2 SD, and +3 and −3 SD.

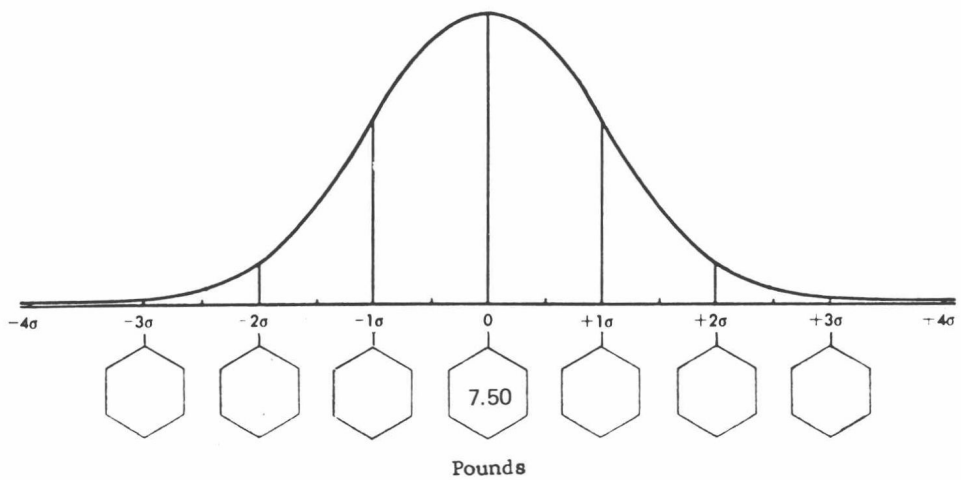


Figure 1-4

10. The mean birth weight for Caucasian American boys is 7.50 pounds, with an SD of 0.85. On Figure 1-4, fill in the weights that correspond to +3, −2, −1, +1, +2, +3 SD from the mean.

---

9. 68%, 95%, 99%
10. 4.95, 5.80, 6.65, 8.35, 9.20, 10.05

THE PERCENTILE CHART

Another, more commonly used type of growth standard is based on *percentiles*, sometimes called percentile rank.

In a growth standard based on percentiles, all the measurements of a large sample of children are ranked in size from the smallest to the largest and are assigned percentiles that correspond to their positions in the rank order. For example, the middle measurement, or *median*, is called the 50th percentile; a percentile of 90 indicates a measurement that is as great or greater than that of 90 percent of the children in the sample. Half the children in a normal distribution can be expected to fall between the 25th and 75th percentiles, which are equidistant from the median; 80 percent of the children can be expected to fall between the 10th and 90th percentiles.

Study Figure 1-5 and answer the following questions.

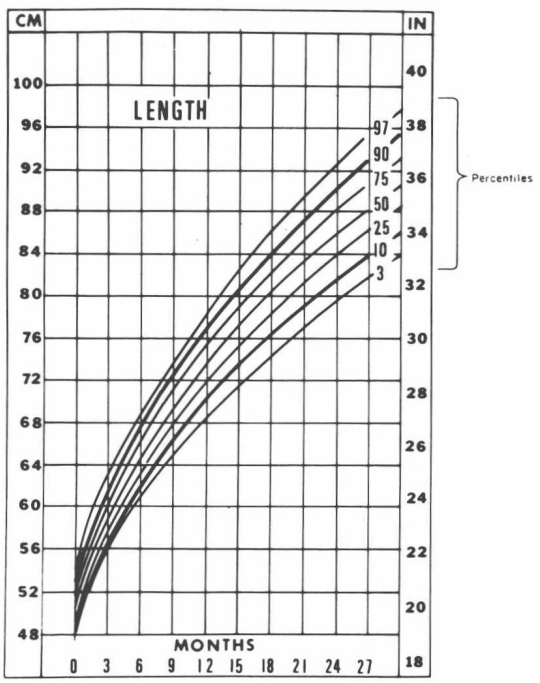


Figure 1-5 Percentile chart for length of infant girls.

11. At 27 months, the 90th percentile length for a girl is _____ inches.
12. An 18-month-old girl whose measurement is at the 50th percentile is _____ centimeters in length.
13. A 24-month-old girl measuring 84 centimeters is at the _____ percentile.
14. A 12-month-old girl measuring 27 inches would be placed at the _____ percentile.

---

11. about 37
12. about 80
13. 25th
14. 3rd