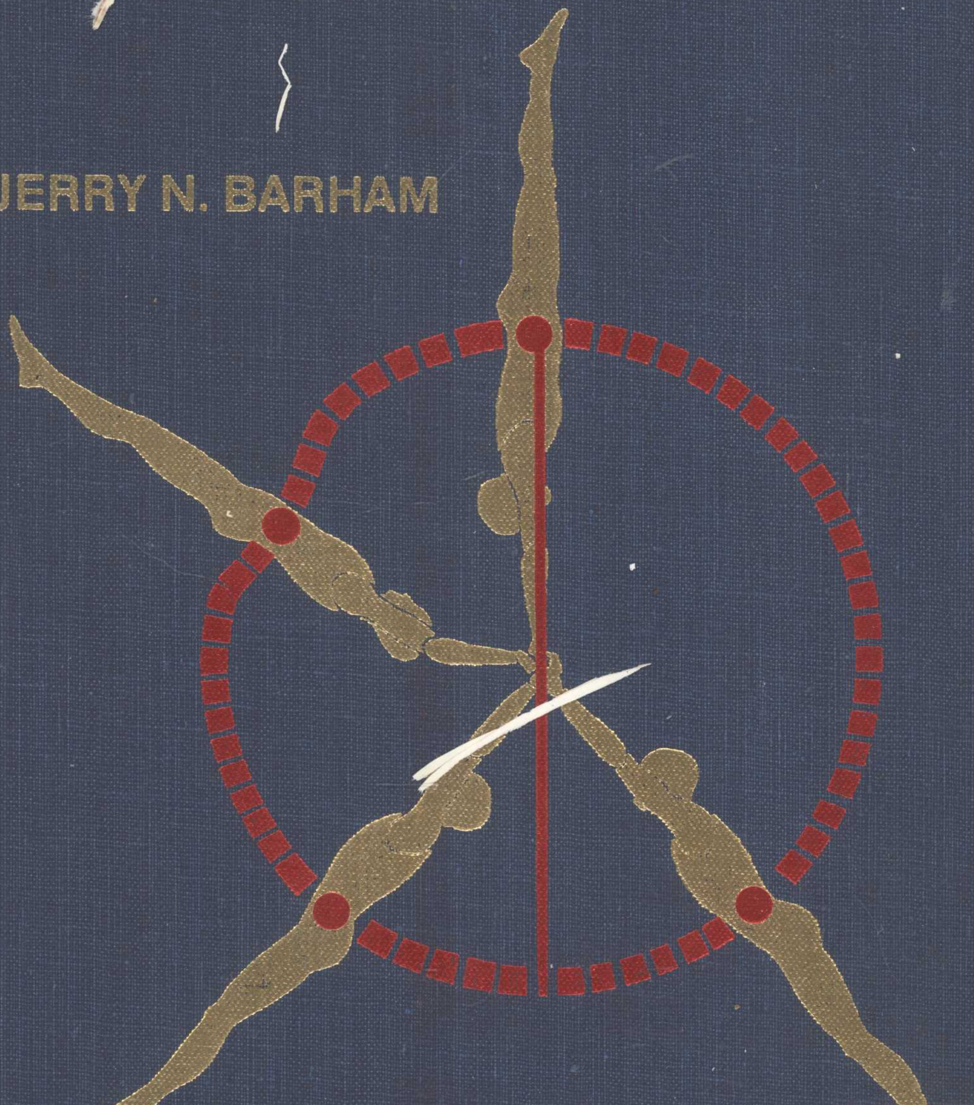
MECHANICAL KINESIOLOGY

JERRY N. BARHAM



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with 507 *illustrations*

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To my wife,

Margrit,

my daughters,

Robin and Lisa,

and my son,

Troy

Preface

Mechanical Kinesiology is an introduction to the mechanical foundations of human movement. However, the text is not intended as a total treatment of these foundations. My experience is that a text which tries to cover all the facets of a subject matter simultaneously is often more confusing to the beginning student than enlightening. For this reason, I have delimited this text largely to the basic principles of human mechanics, with applications being made to movement problems most often found in typical physical education programs. The specific movements studied therefore are not all inclusive but are given only as examples of the kinesiological applications of the mechancial principles involved.

I have divided each lesson into three parts: a part on the text proper; a part entitled study guidelines, which includes behavioral objectives, summaries, and applications of the concepts and principles presented in the text proper; and a self-evaluation test, which students can use to measure their progress toward meeting the lesson objectives.

To me education is a problem-solving process which promotes changes in the behavior of students. Therefore the desired student behavior changes are stated for each section of each lesson in the form of specific behavioral objectives. A behavioral objective is one that is stated in terms of what is expected of students in the way of their personal performances, and not in terms of teacher performances and/or the performances of textbook writers. The self-evaluation section at the end of each lesson allows students to determine their own individual achievement of the stated objectives.

The applications and problem solving section of the study guidelines is included in each lesson to serve the two ends of (1) helping the student develop skill in analytical thought and numerical calculation, both of which are required for the successful study of human movement, and (2) promoting the mastery of the text proper by actually putting its ideas into practice. Perhaps the exhortation of James, i, 22, is appropriate here: "But be ye doers of the word, and not hearers only deceiving your own selves."

No more than the simplest mathematics is used in this text, and no prior knowledge of physics is assumed. A review of the elementary mathematics required for a thorough understanding of the topics covered is presented in Appendix D.

The progression of concepts is from the more basic to the more applied, and from the more general to the more specific. The basic materials are presented with the idea of allowing the student to grasp the total concept before proceeding to the more specific movement applications involved.

The treatment concentrates, as mentioned before, on those mechanical principles primary to an understanding of human movement performances. To make such an emphasis possible, I have omitted peripheral material that might be of value from a general education standpoint since, whatever its merits, including such material would have necessitated delving into ideas of marginal concern to the students of human movement at the possible expense of key kinesiological concepts.

Whenever possible I have tried to present derivations of important results throughout the text, thereby exhibiting rather than merely describing the inductive and deductive methods of science. I have also attempted throughout the text to encourage in the student a feeling of participation that I believe is essential for learning.

However, to completely eliminate the role of students as mere passive receivers of information, I strongly recommend that this text be accompanied by appropriate laboratory work and by supplementary readings.

Special thanks are due to Jerry Krause, for his assistance with the study guideline sections; Stu Horsefall and Jack Tandy, for their art work; Bob Waters, for his photography; Lindy Minihan, Nelson Ng, Dan Caster, Bart Smith, Jeff Broida, Holly Summerlot, Mike Dunafon, Cliff Harris, Dehaven Hill, Patty Sanchez, Jim Goldstone, Rick Marquez, Fred Thompson, Brad Campbell, Larry Martinez, Dave Marrufo, and Keith Anderson, for appearing in photographs; Gertie Fellinger, Marlene Krieger, Joan Lehr, and Debbie Marks, for typing the manuscript; the hundreds of students who worked with and helped to improve the mimeographed editions of the manuscript; Lyle Knudson and Nelson Ng, for helping to proofread the manuscript and to prepare the teacher's guide; and Dr. Nancy Van Anne, for her many helpful suggestions.

Jerry Krause and I have prepared a programmed textbook to facilitate the learning of basic concepts: Kraus, J. V., and Barham, J. N.: *The Mechanical Foundations of Human Motion: a Programmed Text,* St. Louis, 1975, The C. V. Mosby Company.

Jerry N. Barham

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PART I

INTRODUCTORY CONCEPTS

LESSON 1

Concept of mechanical kinesiology

CONCEPT OF KINESIOLOGY

In a world where emerging disciplines are staking claims on words as though they were gold mines (which they are), perhaps the meaning of the word "kinesiology" as used in this text is not evident to every student. Kinesiology is defined as the study of human movement in all its ramifications. Therefore kinesiology is concerned with one of the most complex of all phenomena associated with the most complex of all living organisms—the movement behavior of the human being.

Study of human movement

The movements of humans through their various environments can be studied from three basic points of view. First, we can study human movements from the standpoint of the perceptions and motivations which prompt the movements and the neuronal mechanisms which control them. Second, we can study human movements from the standpoint of the biochemical processes that initiate and sustain them. Third, we can study the movements of people from the standpoint of the time, distance, and force relationships involved. The first approach is identified, for the sake of internal consistency, as being *psychological kinesiology,* the second as *physiological kinesiology,* and the third as *mechanical kinesiology*. Human movement, of course, requires all three of these approaches in order to be comprehended in its entirety (Fig. 1-1).

Human movement defined

For the purposes of this text, human movement is defined, without considering the psychological and physiological components involved, as the change in position of the body or body segments in space and time through the application of varying amounts of force.

Since no two objects can occupy the same space at the same time, movement involves a consideration of space-time relationships. It does not matter whether the change in space and time is one of location, volume, or shape. Therefore human movement can take many forms such as running (change in location), expanding the chest (change in volume), or bending an arm (change in shape). However, all these movements resolve themselves into only two fundamental types, *linear* and *angular,* and thus all motion can be described in either linear or angular terms.

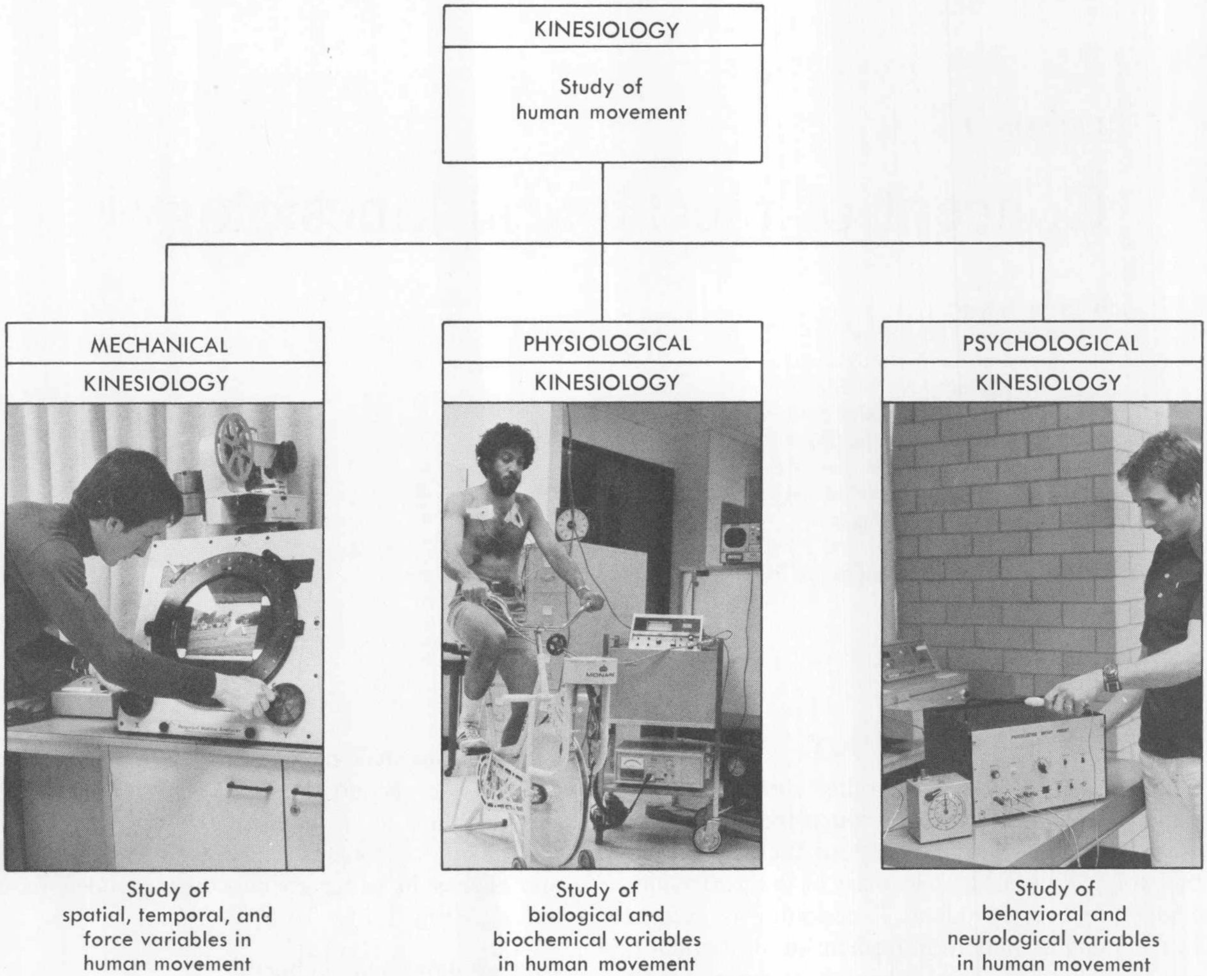

Fig. 1-1. Conceptual model of kinesiology.

Linear and curvilinear paths of motion

The two basic pathways that a moving object can follow are (1) a straight-line path and (2) a curved path. The movements which follow these pathways are known as linear and curvilinear, respectively. These two classifications of movement and the subdivisions of primary importance for the curvilinear classification are defined as follows:

1. *Linear movement.* Motion that follows a straight-line path. This type of motion is also called translatory because all parts of the moving body travel exactly the same distance, in the same direction, and at the same time.
2. *Curvilinear movement.* Motion that does not follow a straight-line path.
   a. *Angular or circular movement* (Fig. 1-2). Motion that follows a circular path, i.e., that remains a constant distance from a fixed point. The constant distance from a fixed point is, of course, the radius of a circle. This type of movement can also be called rotatory. The three terms *angular, circular,* and *rotatory* are synonymous from the standpoint of mechanics and can be used interchangeably in the description of movements.
   b. *Parabolic movement* (Fig. 1-3). Motion

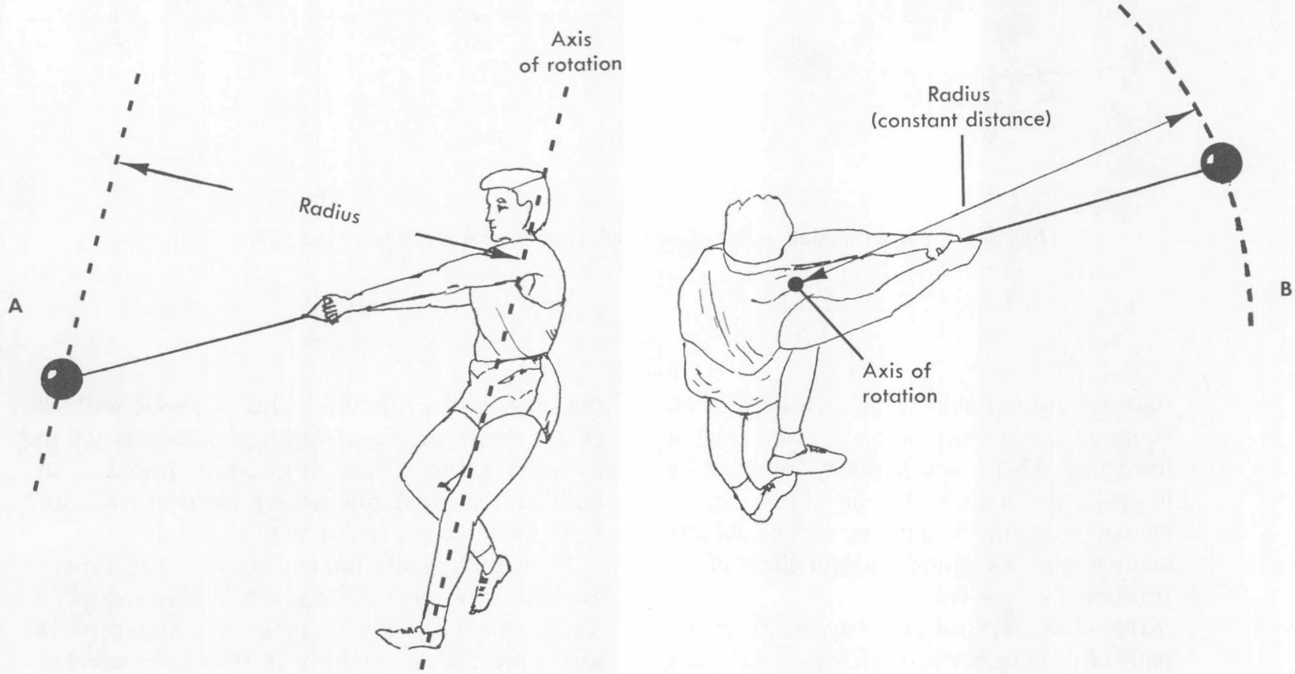

Fig. 1-2. Circular motion. **A,** Side (sagittal) view. **B,** Top (transverse) view.

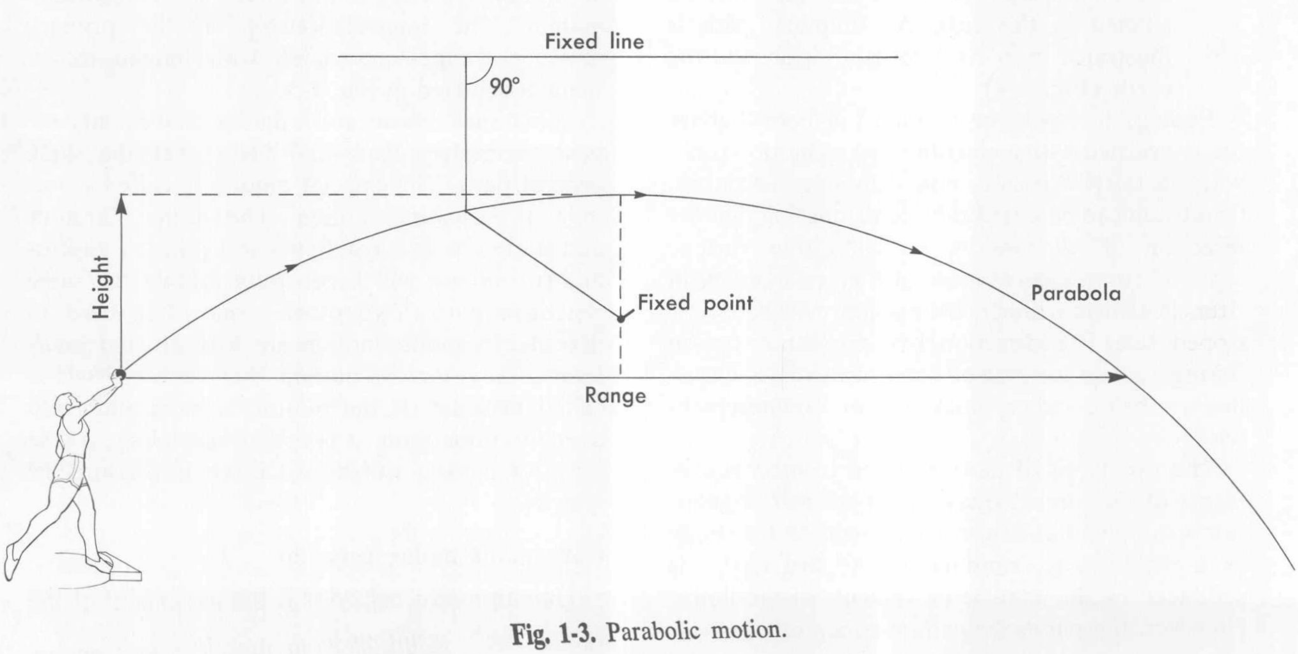

Fig. 1-3. Parabolic motion.

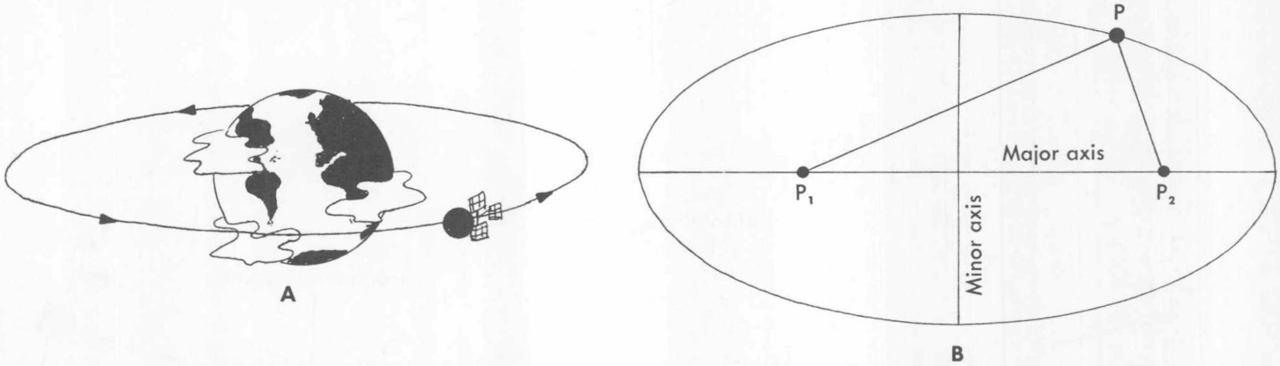

Fig. 1-4. Elliptical motion. **A,** Orbiting satellite. **B,** P_1 and P_2 are two fixed points.

that follows a path which is always an equal distance from a fixed point and a fixed line. This is the pathway followed by a projectile in flight in the earth's atmosphere when it is moving at an oblique angle to the horizontal and the effect of air resistance is ignored.

NOTE: The *elliptical pathway,* which is the path of a point the sum of whose distances from two fixed points is constant, is not listed here because it is not a normal pathway followed by moving objects within the earth's atmosphere. It will not therefore be studied in this text. An elliptical path is illustrated by a satellite in orbit around the earth (Fig. 1-4).

Perhaps it should be pointed out here that we are concerned with a classification of motion pathways in this discussion, not of motion directions. Confusion can be avoided by remembering that the direction of *all* motion, including the various types of curvilinear motion, at a given *moment* in time, is always linear. This concept will be developed later. The direction of curvilinear motion during a given *interval* of time, however, is classified as being either clockwise or counterclockwise.

The two types of motion found in *most movements* of the human body are linear and angular. For example, the linear movement of the body as a whole (e.g., running a 100-yard dash) is produced by the angular movements of the limbs. However, the parabolic path is commonly seen in the motion of projectiles. The parabolic pathway of an object projected through the air is unique to aerial activities. The trajectory followed by the body in the air during a long jump in track and field, for instance, is a parabola.

Even though the human body at one time or another performs all three types of movement—linear, angular, and parabolic—angular movements are the most typical of the musculoskeletal system; that is, the angular movement of a body lever rotating at a joint because of the force imparted to it by a muscle contraction is the type of motion typically found in the musculoskeletal system. The interrelationship of the primary movement types associated with human movement is depicted in Fig. 1-5.

Sometimes linear and angular movements repeat themselves back and forth over the same general path. This special motion is called *vibratory* or *harmonic* motion. The terms vibratory and harmonic are synonyms and refer to any to-and-fro motion which generally follows the same repetitive path. Two other terms often used to describe harmonic motion are *periodic* and *oscillatory*. Any sort of motion that repeats itself is called periodic. If the motion is back and forth over the same path, it is called oscillatory. These types of motion will be discussed in Lessons 19 and 24.

Concept of motor behavior

Human motor behavior is the movement of the human body resulting from muscle forces acting

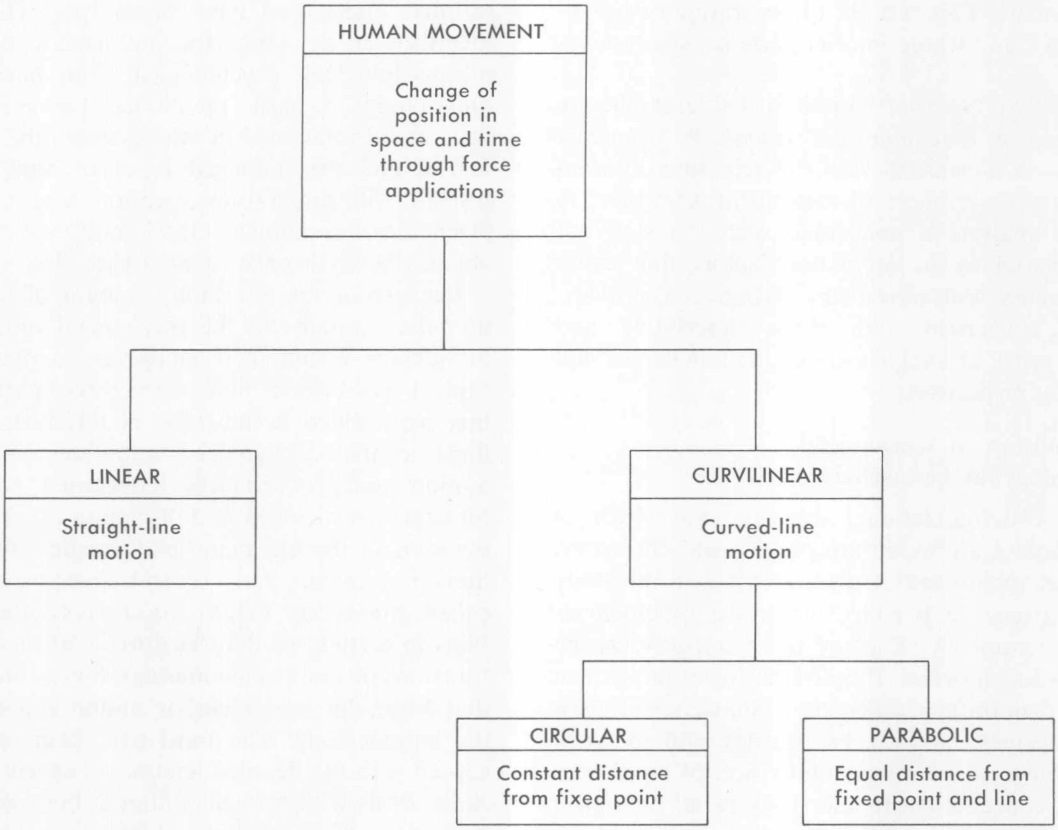

Fig. 1-5. Classification system for the primary pathways traced in human movement.

through the muscles, tendons, bones, and joints of the body. The function of muscles in producing human motion can be likened to the function of an electric motor, water turbine, or gasoline engine in other machine systems; that is, muscles, through the conversion of chemical energy into mechanical energy, serve as the movers of the body. Therefore muscles may be conceptualized as being the motors of the human body.

In identifying muscles as motors, the word *motor* is used as a noun but it also can be used as an adjective. As an adjective the word means "causing or imparting motion." Following are some of the ways the word motor is used as an adjective:

motor activity or behavior Movements of the body produced and controlled through the contraction of skeletal muscles; example, the act of running

motor task A specific type of goal-oriented motor activity; example, the act of running a 100-yard dash in track and field

motor performance The actual execution of a motor task by an individual

CONCEPT OF MECHANICAL KINESIOLOGY

Since kinesiology is defined as the study of human movement, mechanical kinesiology is defined as that branch of kinesiology concerned with studying the mechanical factors affecting human movement, i.e., with applying the physical laws of mechanics, a branch of physics, to the study of human motion. Mechanical kinesiology can also be defined as that branch of kinesiology concerned with the "mechanical analysis" of human motor behavior.

The mechanical analysis of human motor behavior requires that we separate or break down movement performances into their mechanical components. This process of separating or breaking down any whole into its parts is called *analysis*.

The two types of kinesiological analysis are identified as *kinematic* and *kinetic*. A kinematic analysis is concerned with the scientific observation and description of movement variables. A kinetic analysis is concerned with the study of these variables as interacting factors that cause movements and movement changes. The disciplines concerned with these descriptive and causal types of analysis are called kinematics and kinetics, respectively.

Relationship of mechanical kinesiology to biomechanics

The two foundational sciences upon which all life sciences are based are physics and chemistry, and the application of these sciences in the study of life processes is called biophysics or biochemistry, respectively. Each of these sciences can be further subclassified. Biophysics, for example, can be further broken down into biomechanics, biothermogenics, bioptics, bioelectrics, and so forth. Thus biomechanics is a subdivision of biophysics and is concerned with the study of *all* biological movements. Such diverse movements as those performed by lower animals, plants, and the visceral organs of mammals are all within the academic domain of biomechanics.

Since movement is a characteristic of all biological functions, biomechanics is just as much a concern of the physiological kinesiologist as of the mechanical kinesiologist. The heart and blood vessels, for example, must be studied from a biomechanical standpoint if their physiological functions are to be fully understood. Mechanical kinesiology, however, is concerned only with the study of such gross human motor behaviors as are involved in specific sport, dance, and work performances. Thus mechanical kinesiology can be conceptualized as being a subdivision of both biomechanics and kinesiology, for both these disciplines are considerably broader in scope.

Delimitations of this text

Since movement behavior is generally studied from the three basic approaches previously identified as physiological, psychological, and mechanical, there are three basic approaches to the descriptive and causal types of analysis. These are identified as the kinematic and kinetic divisions of physiological, psychological, and mechanical kinesiology. As also mentioned previously, we will not be concerned in this text with the physiological and psychological types of analysis but instead will direct our attention solely toward mechanics, mechanical kinesiology, and the mechanical analysis of movement variables.

Because of the enormous amount of information that pertains to the mechanical functioning of humans within their many environments, the subject is divided here into three parts. The first part, which is the focus of this text, is confined to the mechanical foundations of human motion and is primarily concerned with the fundamental methods and principles of mechanics involved in the kinematic and kinetic analysis of human motion. The second part, sometimes called *anatomical* or *structural kinesiology,* pertains to a study of the structures and mechanical functions of the specific muscles, bones, and joints that form the movement or motor apparatus of the human body. The third part, primarily concerned with the detailed analysis of specific motor skills, deals with how the different body segments and joint actions are linked together in the proper sequence for the most effective and efficient production of total body movements.

Perhaps it should be emphasized that we are dealing here with the arbitrary division of a total subject matter into three parts. Even though the mechanical foundations of human motion are the primary concern of this text, numerous examples of the mechanical analysis of motor apparatus structures and functions and of motor skills will be given throughout the various lessons.

Perhaps it should also be pointed out here that we will not be concerned in this text with the total discipline of biomechanics, which, as already discussed, applies the principles of mechanics to the study of life processes. In other words, we are not concerned in mechanical kinesiology with the study of all conceivable forms of movement associated with human beings and with other forms of life. For instance, the biomechanical functions of the heart, lungs, and other visceral organs are relegated to physiological kinesiology and will not be studied here. Likewise, the movement of impulses through the nervous system is relegated to psychological kinesiology. The movements of plants and lower animals are omitted entirely.

ACADEMIC DIMENSIONS OF MECHANICAL KINESIOLOGY

The mechanical kinesiologist, like all scientists, is concerned not only with the solution of practical problems but also with the advancement of man's knowledge of human movement as a natural phenomenon. He has, in other words, an academic as well as a practical interest in his subject.

Academically a mechanical kinesiologist is primarily interested in identifying and understanding the mechanical events involved in the successful performance of motor tasks. This interest normally leads to original research—which can be observational, theoretical, or experimental in nature.

The *observational* researcher in mechanical kinesiology simply observes the movements of different performers and identifies those which consistently produce the best results. The researcher might observe, for instance, that all successful major league baseball batters have certain movement patterns in common. Thus he or she might infer that these patterns are necessary for successful batting performances. This, of course, may or may not be true but it does lead to the next logical step, which is to develop a theoretical explanation for the observations.

The *theoretical* study of movement patterns involves special application of the mechanical laws and principles of classical physics. The assumption here is that if a movement pattern is essential for successful performance then a reason for this fact can be hypothesized from a knowledge of classical mechanics. Not all theoretical hypotheses, of course, are generated to explain current practices. They may, in fact, be outgrowths of creative attempts to develop better and previously untried techniques.

The formation of a theoretical hypothesis, however, usually leads to some type of *experimental* research through which the tenability of the hypothesis is tested.

Through the procedures of observational, theoretical, and experimental research, we are able to develop movement models for the various types of performance. Thus we can speak of the "proper" or "model" techniques of performing such skills as throwing a baseball, shooting a basketball, or clearing a high hurdle in track and field. The words "technique" and "mechanics" will be used as synonyms in this text when they refer to the process of movement. Therefore, when we speak of the mechanics of a performance, we mean the specific movements used by a performer in the execution of a motor task.

In summary, it should now be evident that the study of movement techniques and the development of movement models are what comprise the academic subject matter of mechanical kinesiology.

PROFESSIONAL APPLICATIONS OF MECHANICAL KINESIOLOGY

The professional applications of mechanical kinesiology are chiefly focused in the area of physical education instruction. It is assumed here that the physical educator is primarily a teacher of motor skills and that the improvement of motor performance is one of his or her main professional responsibilities.

It is also assumed that the teaching competence of a physical educator is largely determined by his or her ability to analyze a student's movement performances in terms of cause-and-effect relationships; that is, a competent teacher of motor skills should be able to analyze a performance and answer such questions as (1) what is right about the performance (using a performance model), (2) what is wrong, (3) why it is wrong, and (4) what must be done for improvement. This skill in analysis should, of course, be combined with certain communication skills and with certain leadership skills. Communication skills are necessary for communicating the results of the analysis to the student in a positive manner. Leadership skills are also necessary for motivating the student to use the results of the analysis in his or her practice sessions.

The background for a movement analysis can come from two basic approaches. The first approach is that of the lay participant, whether as a performer or a spectator. Golf can be studied, for example, by the weekend golfer (performer), and football can be studied by a housewife (spectator). Each of these approaches leads to a certain amount of insight into movement problems;