Living Anatomy

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I began my professional career as a student assistant to the distinguished American anatomist, Charles Bardeen. In the leisurely and more contemplative days of the early 1920's it was the Dean of the School of Medicine who taught the course in Anatomy especially designed to meet the needs of the student of physical education. It followed as a matter of course at the University of Wisconsin, incredible as it seems today, that all of the medical sciences in the physical education curriculum were taught by senior faculty members of the Medical School, usually the Department Head.

It was inevitable that those of us who had the privilege of ingesting Wisconsin's intellectual feast of the early 1920's subsequently approached physical education with a strong biological bias. I myself never ceased being interested in the physiological aspects of exercise and motor learning. Indeed, at the end of a career in Physiology and Physical Medicine, I have come back full circle, to establish a Motor Learning Research Laboratory that has one leg in the Department of Physical Education at Lathrop Hall, and the other in the Bardeen Laboratories of the School of Medicine.

In the 1920's we were concerned overwhelmingly with the memorization of what individual muscles were purported to do because of their mechanical relationships to the axes of the joint or joints crossed. The attack on the study of movement was wholly mechanistic.

About the Author
Frances A. Hellebrandt, M.D., has published more than 150 papers dealing with exercise physiology, motor learning, posture, rehabilitation, physical education, and administration. Her productive career includes teaching anatomy, physiology, physical medicine and rehabilitation. The University of Wisconsin, where she established a Motor Learning Laboratory supported by the Schools of Medicine and Education, appointed her its first woman Research Professor and Professor in Medicine and Education.

In this article, once again her scholarly and literary pen translates the significance of her special field as a route to enlarged understanding of physical education.
This was true of kinesiology as well as anatomy. The movements comprising gymnastic maneuvers, and to a lesser degree sport skills, were described in anatomical terms and lists were then compiled of the individual muscles which ought to contribute to the production of the joint positions assumed. This was a highly artificial kinesiology, based almost entirely on synthetic reasoning.

Many years elapsed before I realized fully that muscles do not normally act individually; that the concurrent action of two or more muscles affecting a single joint must modify the contribution of each, yielding a new synergy and not one composed of the sum of its parts; that what a muscle ought to do when examined by itself in the cadaver, is not, therefore, necessarily what it does in the living. If we wished to penetrate the secrets of man’s remarkable capacity to execute complex movements with effortless grace, direct observation on the living would have to take the place of inferences arrived at from cadaver dissection.

Those distinguished professors who taught us biological sciences at Wisconsin in the 1920’s were without exception versed in the historical background of their respective fields. Thus, we acquired perspective and humility, qualities necessary to anyone who aspires to contribute to the mainstream of progress in his own field of endeavor. We were taught also how to think, to question, to reason, to seek the truth, and in so doing to go back always to the beginnings of things. And so, at the end of my professional career I propose to take such a backward look at a subject, Living Anatomy, which has grown suddenly exciting because of mid-twentieth century advances in instrumentation subserving biological research. The Living Anatomy of today is, in effect, Electromyographic Kinesiology. Its techniques have developed sufficiently to put them within reach of every student of movement.

The giants in the anatomic study of movement are Winslow, Duchenne, Beevor, and Wright. Each leaned on his predecessors. Each left a written record considered to be a classic. The foundation was laid by the celebrated 18th century anatomist, Winslow. His major work was published in France in 1732. For a century it ranked as the leading text book of Human Anatomy. Winslow included in it only what he himself had verified during “... a very long course of anatomical inquiries ...” (29:xvii). He was 63 when the text was published. It represents 30 years of full time observation, for although Winslow was Professor of Physick, Anatomy and Surgery in the University of Paris, he was not a clinician.

Muscles do not work alone, Winslow concluded. “... where several muscles are fixed to any movable part, they are all in a state of contraction, in every motion of that part; but they are not all in the same degree of action, because the principal movers act more than the moderators. ... This cooperation of muscles is easily perceived by touching them when the part they belong to is moved with a considerable force” (29:
Vol. I, 160). Winslow was aware, therefore, of what we now call the patterning of movement. He introduced the terms principal movers, moderators, and directors in support of this idea. He recognized, also, that gravitational stresses might silence the natural co-contraction of antagonists. Today we possess the instruments needed to verify objectively evidence attained by simple inspection and palpation on living subjects, an art long since forgotten.

The sections in Winslow titled, "The General Doctrine of Muscles," and "The Particular Uses of Muscles . . .," are in essence a compendium of kinesiology. They are as fresh and provocative today as when they were written more than two centuries ago.

The second of the classics on muscular movement was written by Duchenne in 1867. It did not appear in English translation until 1959. The translator calls it an untapped reservoir of important anatomical information. Duchenne lived when Winslow's System of Anatomy was still in use. He knew it well, and used it as the starting point for many of his own observations. Duchenne refers often to his Parisian predecessor in the study of movement as "the admirable Winslow."

Duchenne analyzed normal and pathological movement by electrical stimulation. He understood the limitations of this method. In his hands, electrical stimulation was tantamount to dissecting the living body. But Duchenne was interested in more than a revelation of what individual muscles could do because of the nature of their attachments. He was concerned also with the ways in which action was modified by other members of a functional group. Like Winslow, Duchenne concluded that the isolated action of muscles is a theoretical abstraction. He believed that the co-contraction of antagonists provides the living machine with a perfect device for the delicate modulation of movement. "Without this . . . entente of the antagonist muscles, motions inevitably lose their precision and assurance" (11:552), said Duchenne, and in this we concur.

Duchenne pursued the study of motion by electrical stimulation for nearly 40 years with a single-minded constancy. He lived during a brilliant period of French Neurology and was associated in the Neurological Clinics of Paris with some of the greatest physicians of his day. He was a prodigious worker and a most accurate observer. We who study the written record left by this investigator are his grateful beneficiaries.

The third classic consists of Beevor's Croonian Lectures on Muscular Movements (6). Delivered before the Royal Society of Physicians of London in 1903, they were considered important enough to be reprinted in the early 1950's. Although now out of print, they continue to be cited in the current neurological literature. Beevor appears to have studied Duchenne's work exhaustively, and in his Croonian Lectures leans also on the 4th edition of the English translation of Winslow.

Beevor used the same physiological or natural approach to the study of movement adopted by Winslow, that of
inspection and palpation. Like Duchenne, he was a clinical neurologist. He became a Fellow of the Royal College of Physicians in 1888. Delivery of the Croonian Lectures gave him the opportunity of collecting the results of 20 years of research, partly clinical and partly experimental. In his Foreword to the reprint of the Croonian Lectures published by *Brain*, Walshe remarks that neither the clinical neurologist nor the experimental physiologist can afford to overlook the remarkable contributions of this astute observer, and I dare say the kinesiologist might be added. We, ourselves, are engaged currently in the illuminating task of compiling an electromyographic atlas to illustrate the principles enunciated by Beevor out of his contemplation of the writings of Winslow and Duchenne, and his own first hand observations of what muscles actually do when put into action voluntarily.

Wilhelmine Wright's *Muscle Function* was reprinted in 1962. The original, published more than 30 years ago, would never have been written if Wilhelmine Wright had not discovered Beevor's Croonian Lectures at a critical point of her own career. In 1916 she happened to pick up a small volume that had stood disregarded on her bookshelves. It was a copy of Beevor's *Croonian Lectures on Muscular Movements* (6), made meaningful because polio had struck in America for the first time in epidemic proportions, and Wilhelmine Wright had been placed in charge of Lovett’s therapeutic exercise gymnasium. The endless combinations of paralyzed and normal muscles affecting movements seen in Lovett’s clinics provided this perceptive individual with a perfect laboratory in which to study muscle function. She observed, compared, and questioned. Unable to verify on the living what authoritative anatomical sources said about muscle function, she had the audacity to ask who was right, Nature, or Gray's Anatomy. “I watched,” she said, “with the patience of a cat before a mouse-hole; and now and then, perhaps once in a year or once in two years, an explanation of one of my puzzles would show its head cautiously and I would pounce upon it in joyous excitement” (30:xx).

The Croonian Lectures struck Wilhelmine Wright as a revelation of common sense. She decided, therefore, to try to do for the lower extremities what Beevor had done for the upper. Twelve years later, in 1928, she published the results of her own observations. Ever since then her book has been a standard text in the training of physical therapists for the difficult and exacting techniques of muscle re-education. Its applicability to the techniques of motor learning in the normal also warrants study.

A single phrase in the Preface of the original monograph, *Muscle Function*, remained with me throughout my own career as an educator. Wilhelmine Wright thanks Lovett because “he had the generosity of mind to encourage original thinking by his subordinates” (30:xxii). In a different milieu, a questing mind might have been silenced. *Muscle Function* belongs, in a sense, as
much to Lovett as it does to Wilhelmine Wright. It leans on Beevor in the same way that Beevor built his concepts on the observations of Duchenne, and Duchenne upon those of Winslow.

As a group, Winslow, Duchenne, Beevor, and Wright forged a strong, direct chain of influence spanning 230 years. Their message rings out “loud and clear.” The action of muscles can only be studied in the living. This is the concept of lasting value they handed down one to the other, and also to us. Few things are more difficult to study than human movement. This calls for a quality of mind related, I think, to the kinesthetic acuity of the observer. It is one thing to perceive what the eye sees, another to feel the movement seen. I like to think that Winslow, Duchenne, Beevor, and Wright were so gifted.

From time to time a new method, electromyography in this instance, forces the investigator to reexamination of the validity of traditional approaches to his subject matter. A kinesiology steeped in inferences based on classical descriptive anatomy can no longer be justified. We shall have to listen to what Winslow, Duchenne, Beevor, and Wright have been trying to tell us, and what the neurophysiologist of the mid-twentieth century knows about the mechanisms responsible for the phenomena observed by them with such discerning brilliance.

I should like next to define muscular movement in more physiological terms, using for this purpose an illustration (Fig. 1) redrawn by Jung and Hassler from an unpublished motion picture made by Hess (22:904). Every volitional movement is composed of two parts, that which is willed or cortically controlled, and that which is evoked spontaneously in association with the purposive act and cannot be introspected. Many years ago Kinnier Wilson had said that a very large part of every “voluntary” movement is both “involuntary” and outside consciousness.

In this model the purposive act consists of one man jumping from the shoulders of another and landing upright on the floor. Three persons represent the action and reaction inherent in the execution of any motor performance. The leaper symbolizes the intentional teleokinetic mechanisms, or the cortical aspect of volitional movement. The leap succeeds only when the right postural set is provided by the carrier in anticipatory readiness for the jump, and when the carrier himself is aided by the supporter who compensates for the rebound. This is illustrated in the row of figures on the left (Fig. 1). The carrier and the supporter symbolize the involuntary aspects of the act. In the figures on the right the carrier is unprepared for the recoil of the leap and falls backward. He is caught by the emergency action of the supporter. The leaper’s jump is short and he falls for want of proper postural support at the take-off, and because the reflex regulation comes too late to compensate for the recoil.

In our electromyographic study of movement we are not interested in the behavior of the jumper alone, that is, in
Fig. 1 — W. R. Hess' (1943) model of the voluntary and involuntary components of willed movement. Figure 1 symbolizes the prime movers activated by cortical mechanisms. Figures 2 and 3 represent reflexes evoked spontaneously to give postural support to the purposive act and compensate for the recoil. The leaper succeeds only if the carrier and his supporter respond appropriately.
the prime movers activated by the will. We are just as interested in the activity evoked reflexly in the antagonists which may be called upon to exert a modulating tension, the synergists, which may neutralize some unwanted action of a muscle which has the capacity to perform more movements than one, and the fixators, which may be needed to stabilize contiguous joints or more remote parts. It is this galaxy of muscular contractions which comprises the so-called patterning of movement. Critchley called this a harmony of which the prime movers constitute the melody. Its components are integrated on various levels in the central nervous system.

Reasoning from first principles suggests that pattern elaboration should be similar in all normal human beings. We are all built on the same model, bipedal, withprehensible upper extremities, in the interests of which we assume an orthograde stance. We are all equipped with a finite repertory of natural movements, fired by the activation of built-in patterns of excitation that result from two billion years of successful movement experience, quadrupedal in its ancestry. Thus, stereotype in the behavioral response of man is what the observer of movement should anticipate. In our experience, muscles simply do not contract indiscriminately.

The view presented differs from the one expressed by Basmajian in his new monograph, *Muscles Alive—Their Functions Revealed by Electromyography*. He concludes, for example, that the time-sequence of activity in the muscle groups implicated in a movement of the elbow joint is completely random. There is no set pattern. Any of the muscles destined to show activity fires first or last in a wholly unpredictable fashion.

How can we resolve such divergence in opinion? The views are antithetic. A plausible answer is suggested in Beevor’s method of studying movement. He defined it as follows: A living person is told to perform a definite movement, and it is then observed which muscles take part in the movement (6). The key words are “a definite movement.” I need not tell an audience composed of physical educators that controls must be introduced to insure the proper execution of the purposive act under study. This is expedited when subjects are drawn from a universe composed of individuals capable of movement localization, an ability considerably less simple than it seems at first glance. This is the crux of the whole problem of variability in electromyographic kinesiology. Constancy of electromyographic patterning demands constancy of performance. We must be reasonably certain that the electromyograms we accumulate really reflect variability in the functional organization of the central nervous system, if this is what we conclude, and not differing degrees of precision in physical performance. The point is an important one which warrants emphasis and elaboration. I can do this by narrating an experiment performed by my group in December of 1962.

You will recall that we have been applying the modern techniques of elec-
Figure 2 — Subject J. C. W. attempting to produce the center of gravity shifts stipulated by Beevor. She inclines forward and then backward while standing on a C. of G. platform. The vertical projection of the C. of G. has been introduced into each photograph. The white line is a plumb hanging in front of the backdrop.

Fig. 3 — Change in the EMG response of the soleus and tibialis anticus of the supporting leg as the body inclines backward. No record is being made of action potentials evoked in the muscle groups of the opposite leg.

Fig. 4 — A failure of the Beevor experiment when the maneuver was performed in the manner illustrated in Figure 2.
tromyography to confirm or refute hypotheses proposed by the pioneering advocates of living anatomy, and supported largely by subjective evidence derived from inspection and palpation. One of the last papers published by Beevor appeared in the *Journal of the American Medical Association*. Beevor had been invited to come from England to address the Section on Nervous and Mental Diseases of the A.M.A. at its 59th Annual Session, held in Chicago in 1908. In this paper Beevor describes an experiment designed to demonstrate two principles: *First*, that one part of an anatomical muscle can contribute to a movement without involving the remainder; *Second*, that in every volitional act the prime movers contract in a regular orderly sequence. The muscles successively come into action, adding to their number according to the amount of work that is required to be done. The individual performing the movement has no power to change the order in which the prime movers are mobilized.

The muscles to be studied were the sartorius and the rectus femoris. These are hip flexors. If the thigh is fixed, they flex the trunk on the supporting extremity. "...the person should stand on one leg," said Beevor, "and have the other leg resting on a chair, with the knee and thigh flexed. The person should incline slightly forward, so as to bring the center of gravity in front of the foot on which he is standing on. Then inclining backward, so as to shift the center of gravity behind the foot" (7:90). The latter is impossible, for the subject would fall to the ground, and the former can be achieved only if the "forward inclination" permits flexion of the leg on the foot. Biomechanical terms are often used loosely by the clinician. In Figure 2, the subject (J.C.W.) is trying out Beevor's procedure while standing on a center of gravity platform. A neuromuscularly skilled, well informed and cooperative subject is implementing Beevor's orders as literally as possible, i.e., she is attempting to produce the center of gravity changes stipulated. She had been trained to rid herself of cortical interference when acting as an experimental subject, and to yield without resistance to the natural flow of spontaneous motor reactions. In this way we hoped to reveal how "the wisdom of the body" operates when free of direction by the highest levels of integration.

What happened to the muscles sampled electromyographically is illustrated in Figures 3 and 4. As the subject inclined backward, the soleus of the supporting leg suddenly reduced its activity and the tibialis anticus jumped into action (Fig. 3). This is a beautifully coordinated pair of responses. It is a protective reaction, designed to keep the center of weight as close as possible to the middle of the supporting base. Two opposing forces act simultaneously at the ankle joint. When the subject leans back beyond some critical point the soleus is inhibited and the tension exerted by the tibialis anticus is augmented. The living machine resists every tendency of the center of gravity to approach the axis of rotation of the ankle.
joint, let alone "shift behind the foot," which is what Beevor had ordered. But he was not concerned with the behavior of the supporting limb. Beevor was interested only in the non-supporting leg, the one placed on the chair. The flexors of the hip on that side were supposed to contract to prevent the trunk from falling backward, the sartorius first, and if the subject continued to incline backward, then the rectus femoris, but without the vasti. Could we confirm this order of succession electromographically?

Our initial attempts to perform the Beevor experiment were failures. They looked like Figure 4. Every muscle summoned electromographically was evoked. Furthermore, the subject could not remain sufficiently poised in the posture assumed to grade the degree of inclination. She simply fell backward into the arms of observer N.M. Her concept of Beevor’s experimental procedure, derived from a literal interpretation of his instructions, was incapable of demonstrating either temporal sequencing in the response of the hip flexors, or clear-cut fractionation in the activity of the quadriceps.

A systematic effort was made to realign Beevor’s procedure to meet his theoretical objectives. We knew what was necessary to achieve this. The subject performed the strenuous Beevor maneuver, and we recorded it electromyographically and/or photographically, in whole or in part, more than fifty times before the results expected were evoked in pure form. It took the greater part of one day to do this. To make a long story short, it was not until one of the observers, a graduate research assistant (S.R.E.), positioned a mirror to permit the addition of visual clues to proprioception, that the dilemma was resolved.

Learning was instantaneous. In a flash of insight the supporting limb was fixed in a near vertical position, the pelvic girdle was stabilized, and the so-called “forward and backward inclination” of Beevor was restricted to trunk bending. The initial trial was a success, indeed, a perfect experiment (Fig. 5). The sartorius did spring into action appreciably ahead of the rectus femoris. The rectus femoris did contract without evoking significant activity in the vasti. Gravity substituted for the soleus of the supporting leg and the tibialis anticus equilibrated the influence of backward displacement of the trunk on the center of gravity of the body as a whole.

We could now reproduce Beevor’s experiment at will (Fig. 6). The observations were no longer in conflict with his findings arrived at through inspection and palpation. They confirmed his deductions unequivocally. Sequential patterning and fractionation of muscle action did occur when a "definite movement" was executed in a definite way. Had we performed this experiment once on each of 50 untrained normal individuals, selected randomly, our conclusions would hardly have been the same, especially if attention had been focused on the quantification of electromyographic responses rendered unpredictable for want of the requisite skill on the part of the subjects of the inves-
Fig. 5 — A successful experiment performed spontaneously when visual cues were added to proprioception. The serial photographs in Figure 7 were taken while this EMG was being recorded.

Fig. 6 — Confirmation of Beevor's sequential response of the hip flexors and fractionation of quadriceps action evoked by graded gravitational stress.

Fig. 7 — Serial photographs illustrating the correct performance of the Beevor Experiment. The key cue is voluntary fixation of the weight bearing limb.
tigation. The virtue of experimentation of the type illustrated resides in its ability to illuminate for the student of motor behavior, some facet of central nervous system organization operative in the acquisition of a specific skill. With this thought in mind I should like, finally, to present our interpretation of the instructive Beevor experiment.

1. It is a curious and interesting fact that there was little trial and error variance in the arduous succession of attempts which preceded the proper execution of the “definite movement” ordered by Beevor. A cooperative subject, trained in the art of functional decortication, simply gave in to the automatic running of archaic movement patterns. There are variable degrees of voluntariness, and this subject was intent on keeping cortical activity down to the minimum. The resultant kinetic melody was composed almost wholly of the innate component of motility. It was as “involuntary” as “voluntary” movement could be and still carry out a specific order.

2. Every time the body inclined forward or backward, the effect on the center of gravity was compensated for by automatic reverse movements on the part of other segments of the multi-jointed whole. Such readjustments are obligatory in the mindless subject. They are stereotypes embedded in the heritage of a bipedal species which stands normally in an unstable equilibrium with a high center of gravity poised precariously over a relatively small supporting base. The subject’s responses were subcortically driven. She had no real awareness of what she was doing. No admonitions offered, and these were persuasive, could remodel behavior as long as the subject remained functionally decorticated. “Correcting the movements carried out by our proprioceptive reflexes is something like trying to reset a machine, whose works are intangible, and the net output all we know of the running” (24:89).

Involuntary movement experiences of the type being described, in which an order is issued and the machine then runs automatically, are cloaked in a vagueness which gives them a dreamlike quality. Herrigel, in his engaging discussion of Zen in the Art of Archery, defines this as an exquisite state of unconcerned immersion in oneself (21).

3. The driving force that triggered the “definite movement” which had caught Beevor’s interest a half century ago was the input from a special sense organ whose receptor is the retina. Suddenly, the subject perceived, as a visual image, an automatic response which she had been unable to introspect. Instantaneously this changed the mental design of the motor act to be executed. It led unerringly, without further ado or trial and error, to that fixation of the weight bearing limbs which was the key cue to the correct performance of Beevor’s experiment. Sherrington had observed that “the mirror can tell us often more than can the most painstaking attempt to ‘introspect’ ” (24:89). And it was Bartlett who said it is more important to know WHAT to do than HOW to do it. The how will take care of itself. It is not practice which makes
perfect but practice the results of which are known which makes perfect (3).

4. What was missing in our too co-operative subject, caught in some primordial miasma, was mentation. The neocortex had to be aroused in order to break up, by power of the will, a series of primitive protective reactions evoked for no purpose other than preservation of the constancy of the center of gravity of the body as a whole. This is an example of physiological homeostasis. Once the intellective antecedent of movement was allowed to function, a specific stimulus responsible for a specific result made itself felt. It was an act of inhibition, i.e., cortical suppression of a spontaneous postural adjustment, that placed at the disposal of the subject a delicate means of grading gravitational stresses affecting the hip joint flexors. When the center of gravity was allowed to shift posteriorly, a critical point was reached at which equilibration was obligatory but satisfied by contraction of the sartorius alone. Augmenting the stress mobilized the equilibrating power of a second flexor, the rectus femoris. The subject could grade the stress which fired the effectors, but no power of the will could arouse their sequential contraction per se, or reverse the order in which they responded.

5. Serial photographs taken during a successful experiment demonstrate how imperfect localization of movement really is. To put this in another way, they demonstrate how tenaciously primitive responses resist cortical disruption in the interests of some unnatural or learnt movement.

The first view in Figure 7 is the starting position. In the second the trunk has reached its maximum forward position. The tendency of the buttocks and knee-cap to move backward is obvious. The involuntary compensatory movement is reversed in the last view, where the trunk has reached its maximum position backward.

The postural alignment at which the sartorius was excited is that illustrated in the third view; in the fourth the rectus femoris came into action; in the fifth, there was augmented activity of the tibialis anticus in association with reciprocal inhibition of the soleus. The weight line now falls close to the geometric center of the supporting base. Many years ago I had said, in a long series of posture papers, that few physiological constants are guarded more jealously than the positioning of the center of gravity in relation to the diameters of static security (15, 16, 17, 18, 19, 20).

Everything we know about the mechanisms of voluntary movement suggests that all normal men will respond to Beevor's experiment in exactly the same way if the key cue is used with conscious effort. This unlocks a limb synergy operated by preformed, built-in synaptic arrangements. The magnitude of the stress necessary to generate a feedback capable of altering the configurational stimulus sufficiently to evoke mobilization of the hip flexors may vary from individual to individual, as well as other parameters of the response. Assessment of variables of this kind must also be made the subject of investiga-
tion, but this is a different kind of research, a second step as it were, designed to prove or disprove hypotheses arising out of attempts to explain phenomena observed.

It was inevitable that the availability of electromyography would re-focus attention on the muscles engaged in the production of movement. This experience has not been unique to us. As recently as 1954 LeGros Clark remarked that electromyography is teaching the anatomist how much he still has to learn about the anatomy of muscles. "...we have learnt, unexpectedly," he said, "that certain muscles may be quite inactive in movements or postures in which they have always been supposed to play rather an important part" (9:11). He then suggests that the anatomist get down as quickly as possible to the systematic study of patterns of muscular activity; the kinesiologist also needs to do this.

Physical educators have all but forgotten the anatomical basis of the activities comprising their programs. For decades biomechanics has usurped the stage. The end-results of the motor acts will have been translated into mechanical units and then tested and measured by application of increasingly sophisticated methods. Preoccupied with the intricacies of these elaborate procedures, the biomechanical kinesiologist has become a superb archivist of valid and reliable facts. But he has forgotten to ask why the behaviors occur, and how they are implemented. He has lost interest in the machinery responsible for that beautifully integrated sequencing of the responses of privileged combinations of muscles which characterize precisely executed motor skills (23). It is the neurophysiologic approach to kinesiology which has been more or less by-passed at a time when what we know about the functioning of the nervous system has been leaping forward with one brilliant stride after another (1, 2, 5, 8, 12, 13, 14, 27).

Recent contributions to the anatomical literature like those of Smith suggest that the electromyographic study of muscle function is much enhanced when combined with biomechanics (25, 26). Since the biomechanics of movement is a subject in which the physical educator is often more experienced than the biological scientist, a conjoint attack might be more productive than the efforts of either alone. The whole literature in this field is disappointing often because of failure to use the interdisciplinary approach.

I have thought often of that Sunday in December when the minds of five individuals focussed on the preliminary task of confirming generalizations made by a predecessor whose observations had excited our interest and imagination. It was a Sunday because electrical interference from the neighboring hospital is less critical on that day. We work in an open laboratory and not in a shielded room. It requires several hours to get ready for an experiment of the type described, that is, to locate motor points by electrical stimulation, prepare and apply electrodes, test the accuracy of their placement, calibrate the recording equipment, load and test
the cameras. The experiments themselves cannot be hurried. They may require five or six hours of uninterrupted observation, a time span difficult to arrange in the midst of the exigencies of everyday responsibilities. The atmosphere of the laboratory must be relaxed. Our team was composed of one subject and four observers, each trained for a particular operation. These are the limitations of electromyographic kinesiology. But they are no more stringent than those imposed upon the experimental scientists occupying countless laboratories in the Medical Center. Sometimes the lights burn throughout the night. There is no short cut to real knowledge. Students know this and respond to it instinctively. We never want for subjects, no matter how rigorous or time consuming our experimental procedures are. To stand shoulder to shoulder with the experimental scientist on the frontiers of human knowledge is an invaluable educational experience, and one many students are eager to share.

Is electromyographic kinesiology a practical tool for the physical educator? Yes, we think so. Dr. Waterland is testing its feasibility on the undergraduate level, working, however, through a cross-departmental laboratory whose base of operation for this aspect of our program is the Department of Anatomy of the Medical School. I would like to say in closing that the physical educator has a contribution to make in the unfolding of the story inherent in living anatomy. I believe it is a contribution of inestimable value. No one else is trained to make it. But the physical educator must qualify himself first, in the old fashioned "solid subjects," i.e., the basic sciences. Only this will give him entry to laboratories equipped to do modern biological research. And if he passes through the door thus opened, he not only serves his own profession, but may experience also the deep satisfactions which come from an opportunity to add to human knowledge.

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