God guard me from the thoughts men think
In the mind alone.
He that sings a lasting song
Thinks in a marrow bone.

William Butler Yeats:
"The King of the Great Clock Tower."

THE THINKING BODY

Chapter I

FUNCTION AND FORM IN HUMAN DYNAMICS

BODILY ATTITUDES

WE SIT AND WALK AS WE THINK. WATCH ANY MAN AS HE WALKS DOWN THE AVENUE, AND YOU CAN DETERmine his status in life. With practice, a finer discernment will have him placed socially and economically, and with a fair idea of his outlook on life. We judge our fellow man much more by the arrangement and movement of his skeletal parts than is evident at once.

Living, the whole body carries its meaning and tells its own story, standing, sitting, walking, awake or asleep. It pulls all the life up into the face of the philosopher, and sends it all down into the legs of the dancer. A casual world over-emphasizes the face. Memory likes to recall the whole body. It is not our parents' faces that come back to us, but their bodies, in the accustomed chairs, eating, sewing, smoking, doing all the familiar things. We remember each as a body in action. The individual mental picture gallery knows how Bobby Jones swings, how Nurmi runs, how Helen Wills Moody serves.

Behavior is rarely rational; it is habitually emotional. We may speak wise words as the result of reasoning, but the entire being reacts to feeling. For every thought supported by feeling, there is a muscle change. Primary muscle patterns being the biological heritage of man, man's whole body records his emotional thinking.

The explorer and the pioneer stand up; the prisoner and the slave crouch; the saint leans forward, the overseer and the magnate lean back. The marshal rides, Hamlet walks, Shylock extends the hands, Carmen requires the weight on one foot, hands on hips, eyes over the shoulder. The postures of dramatic tradition crystallize the theory of the actors, and through their body designs, the young study the portrayal of epic qualities in movement. Guilt, craft, vision, meanness, ecstasy, and lure appear in certain arrangements of arms, hands, shoulders, neck, head, and legs. Thus the stuff of the ages goes into man's thinking, is interpreted and comes out in movement and posture again. Personality goes into structure—by denial or affirmation into person again. It is an aspect of life in evolution.

In self-expression are the mental and emotional equipment, temperament, personal experiences and prejudices, influencing and controlling the relation of the bodily parts to the whole. This equipment includes the working unit for motion—the nerve-muscle action on bones. Muscles act automatically. When acting, they move bones. Man's bones play a large part in his sense of control and position in his world. How he centers them, determines his degree of self-possession; they are continually centered and *ex-centered* in his rhythms of movement. Mechanically, physiologically and psychologically, the human body is compelled to struggle for a state of equilibrium.

The physiological approach to the study of body dynamics is based upon the fact that the neuromuscular system is the unit which determines organized movement. Mechanically, separate units of weight (bones) are moving through space in definite time arrangement. The neuromuscular unit is the motive power. Physiologically, various stimuli prepare the muscles for their responses. These stimuli, being both internal and external, must be correlated. This involves psychological factors affecting the response. Response must be adequate to meet the situation.

The value of the receiving-correlating-responding mechanism in adequate action was very well expressed in my presence by Dr. Jesse Feiring Williams, in these terms, "The intelligence of an individual may be determined by the speed with which he orients himself to a new situation."

For every stimulus there is a motor response. The number of

parts involved in this response is conditioned by the person's social reactions and behavior, as well as by his physical status. The individual is a totality and cannot be segregated as to intellect, motor and social factors. They are all interrelated.

The correlation of visceral, psychic and peripheral stimuli, underlying muscular response, involves the whole of a man. It is the very perception of nerves, viscera and organic life. The whole body, enlivened as it is by muscular memory, becomes a sensitive instrument responding with a wisdom far outrunning that of man's reasoning or conscious control. The neuromusculatures of skeleton and viscera interact, always conditioned by what has been received, as well as by what is being received; and this because of emotional and mental evaluations.

We now realize that in the physical economy of the individual the many systems should be working in balance and unison and that thinking is a very part of their activity. We realize that function preceded structure, thinking preceded mind, the verb preceded the noun, doing was experienced before the thing done. Everything moves, and in the pattern of movement, Life is objectified.

Science has increased our knowledge to the better understanding of these values. Finer adjustments have been attained by balancing the endocrines; by study of the chemical constituents of bodily cells, of chemical contents and balance of needed foods; by the effects of temperature and pressure; by the studies of dress, housing, rest and activity, and a more perfect mechanical balance of the human skeleton. All of this has developed a finer appreciation of the interaction of all these systems in rhythm and harmony.

Parallel with the new knowledge of facts is the new knowledge of the unconscious. The unconscious is treasure-house and charnel-house of the creative and one of the keys to physiology. The "backbone" to which we must join new physiological investigations is the study of the unconscious.

We are told that even in the best human machine, only 15 per cent of the total energy is available for conscious purposes; 85 per cent is used in vegetative processes—heart action and so on.

This leaves us only 15 per cent with which to do the work of the world. Any impairment of the vegetative or unconscious processes will require new energy, and the only source to draw upon is the 15 per cent, which should be conserved for the use of the conscious or distinctively human activities—those activities not shared with other animals. In times of stress, however, the 15 per cent may draw upon the reservoir of the 85 per cent unconscious energy, as pointed out by William James in his essay on the reserves of human energy.

HABITS

Habits being biological, racial and individual, the design of the human mechanism has undergone considerable and important changes during its long process of development. While its general features are determined, its many individual variations are capable of still further modifications by habit and training. Faulty arrangement of parts in the design, through artificial habits, may be corrected. What may originally have been good arrangements may be rendered faulty by furthering wrong habits.

The human body, in addition to other requirements of living, meets the same structural problems of interacting forces as the inanimate mechanism. Bones offer not only protection for our organism, but a suitable framework for support of body weights. Through organized leverage, they give direction and purpose to movement.

Our bodies, we know, have a history outrunning by hundreds of millions of years that of the human mind and that fact is now influencing our attitude toward man in many ways. Even if this scientific discovery be denied, one must admit that in his own case, his baby body was well under way before he woke up and began to think, talk and give evidences of human intelligence. But when, in young children, reasoning powers gradually develop, their attention is directed, not so much to their bodies as to the artfully designed clothes with which they find themselves covered.

Many of us still feel a squeamish distaste when bone and

muscle are mentioned. Confidently ignorant as to what goes on under our skin, we go about our daily doings absolutely dependent upon what lies within but with no more interest in it than the dog has in his anatomy.

Our bodies are brought to our attention usually under disagreeable circumstances—when we are sick or injured, and the clothes have to come off to reveal a wound, burn or fracture. We seem messy inside, for when our skin is punctured or torn, out runs a scarlet fluid which makes a horrid stain and is offensive. When it was rumored that a distinguished Harvard physiologist had had his salary raised, a Cambridge lady in excellent standing was reported to have said that she hoped that the doctor could now afford to do something nicer than to fuss with people's disgusting insides.

Unlike dogs, human beings form habits of managing their bodies badly, through false notions about "holding" individual parts. It may never occur to them that mechanically, action and reaction are as persistent in the living mechanism as in that of any inanimate structure.

BONE VERSUS STEEL

Nature has chosen wisely in supplying us with bone. Bone has the qualities of hardness, stiffness and elasticity which made steel the engineer's chosen medium.

The intelligent person realizes the skeleton alive and whole, inside his entire body, with its living engines, the attached muscles, ready to respond.

In this sense, the daring anatomist was modern four hundred years ago. Vesalius, who died in the year Shakespeare was born, showed a skeleton which might be a Hamlet. Standing by a library table, weight on one leg, left elbow on the table, the figure leans forward a little, hand on cheek. The rock, shrubs and leaves at the feet suggest the unfolding of nature's science; the student's pose and the table look toward the invisible universe of philosophy. The skeleton lives, stands. In a moment it will turn, walk, move body and head in the soliloquy. Impossible not to feel that this skeleton is person!

Beating heart and spurting blood mean life. But behind this redness and liquid stream that stand for vitality is bone. Bone makes blood. It is antecedent to blood. The total number of red blood cells in an adult is computed in billions. The length of life of a single cell is about ten days. Renewal and replacement of cells goes on in the marrow of the bones. Bones live. We must *sense* them alive if we are to understand their interdependence with their adjoined soft tissues. We can then appreciate the importance of their function for the whole body. They aid all other tissues by their protection of cavities, support of weight and manufacture of blood cells. In common with all body tissues, bone has the recuperative quality which is the unique property of all living protoplasm.

Bone, while furnishing protection and support, also furnishes points of leverage for the engines of movement, the muscles. Bones move in response to the neuromuscular unit. Man consciously controls bones. He does not consciously control the neuromuscular unit.

When we command movement of arm or leg, we establish all the conditions to effect the movement of several bony levers in organized action. The wisdom lies not in man's "command," but in the various systems cooperating with the neuromuscular mechanism to establish right conditions.

When a man aims a gun, a whole chain of reflexes is in process of synchronization. These reflexes are preparing as he decides what he is going to shoot, gets his stance, adjusts his shoulder and spine to the weight of the gun, and aims, projecting his eyes. Added to these are internal responses, such as a deep, physical quiet and changed breathing rhythms. He pulls the trigger. Instantly these conditioned reflexes act in accord with principles of mechanics and of organic functioning. He must keep his eye distance correct, his head balanced to insure his stance, and his arm steady. He must absorb the recoil from the gun in his backbone and legs. All these responses are automatic. His duck-shooting skill depends upon the synchronizing of chemical, mechanical and organic conditions. Even the time of the decision to pull the trigger is determined partly by his

kinesthetic sense, which he would call his "feeling that all is ready." His freedom of response is also influenced by his optimism. If his body is well conditioned and unhampered by doubts and fears, the duck drops—to his great satisfaction.

With given conditions established, "it happens," exactly as "it snows, it rains" and for similar reasons; conditions are right. Movement is the result of conditions established according to fundamental principles, governing a dynamic living mechanism. Understanding the underlying principles is fundamental to understanding the movements.

None of these responses would be possible were it not for the varying shape and length of bony levers through which the organism effects direction of movement.

The skeleton is made in a way to do certain things, and it is difficult to separate the doing and the making, growth, development and function being so interlaced.

Bone has four functions: the organic, manufacturing blood cells—bone is alive; the protective, it houses the brain, spinal cord and heart, the lungs and viscera—bone is an enclosing casement; the supporting, it bears the weights of the body and supports the organs of motion, the muscles—bone is form. In evolution the needs of function resolve into form—into structure.

The skeleton is nature's mechanical triumph. Lines of force go through its bones and the feeling of motion is in them. The living machine walks.

BALANCING FORCES

The human being is a composite of balanced forces. To maintain his structural support with the least strain on the several parts is a problem of bodily adjustment to external forces, primarily mechanical.

Through balance man conserves nervous energy and thus directly benefits all his activities, mental as well as physical.

At that stage of the evolutionary process when man assumed the upright posture, he secured freedom of motion and a larger command over his environment than is possessed by any other creature. There are, however, mechanical disadvantages and points of weakness in his structural provision that threaten the stability of his support and the protection of his vital processes. To offset this weakness, it is imperative to recognize and properly utilize the principles of mechanics as applied to the main structural units in the vertical position. How does the pull of gravity act upon the spinal curves and upon the flat body walls, which balance at front and back, upon this curved, supporting upright? How do these function to meet the pull of gravity and to keep the skeletal structure supporting its mass of weight? What are the lines of force operating continuously upon the skeleton? These questions and more we must ask ourselves if we wish to solve the mechanical problem of posture and movement of man in the upright position.

FORM FOLLOWS FUNCTION

The principle that function makes form determines the myriad shapes of life, from the earliest single-celled organism to the latest and most complicated plant or animal. The meaning of any structure is to be found by inquiring what the forces are to which the creature possessing it is reacting so that it can maintain its own existence. Force must be met by force, and the structure evolves as the forces are balancing.

Life in the water and life on land are the two great ways of living from which stem two important patterns of structure in the vertebrates. The fish does not have to contend with gravity; rather it seems to work for him, because of the way in which water presses equally from all sides, and up as well as down. The fish, to be sure, has his own problems of gravity in position and direction of movement, and has met them with various fascinating devices. So long as he displaces more than his own weight of water, he does not sink. The land animal displaces less than his own weight in air, so that he must depend on the surface of the ground to hold him up against gravity, which would otherwise bear him swiftly into the earth. As the animal leaves the water for the land, two adjustments must be made simultaneously: to meet gravity through a hard instead of a liquid medium and to take oxygen from a gas instead of from a fluid. As gravity acts perpendicularly upon the body, vertical appendages must develop if the body-weight is to be moved about speedily and freely; and some means must be devised for carrying air into the body, where oxygen may be taken from it for the use of the cells as they live in their own fluid media. Limbs develop to meet the first need, and lungs to meet the second.

Respiration, that is, the exchange of the gases oxygen and carbon dioxide, has two phases in both man and fish instead of one as in the single-celled organism. In the unicellular forms the exchange takes place directly by diffusion at the surface of the cell; in the multicellular forms, certain cells bring the oxygen to the others and remove their gaseous waste products. The entire process takes place in two stages: (1) external respiration, an interchange of gases between the external medium, whether this be water or air, and the circulating fluid of the body; and (2) internal respiration, an interchange between the tissue cells and the circulating fluid by simple diffusion, as in the single-celled organism. Lavoisier, who discovered oxygen and its rôle in the body, called the external phase primary, and the internal, secondary breathing.

Fish and man differ in their organs of external respiration. The gills of the fish present a large surface, well supplied with blood, over which water continually passes, while the blood takes the oxygen gas from the water and gives out the carbon dioxide from the tissue cells. Lungs contain numerous air sacs, in which the renewal of air is effected by respiratory movements, while the blood circulates rapidly just beneath the surface of the sacs, through which it takes oxygen from the air and yields the carbon dioxide it has taken up in internal respiration.

The shift from water to land was not made at once, but by gradual stages, represented today by various amphibians which, as their name implies, live both in water and on land. Some live in mud and are able to breathe either water or air as need arises, by means of gills, or by rudimentary lungs, or by special adaptations of their skin. Others, like the toad and the frog, have an early tadpole life in the water, quite like fishes, and upon emerging as adults, lose gills and tails and acquire lungs and legs.

In a real sense the living organism never loses its dependence upon water for its essential vital processes, and however far from the water the animal or plant may get, it carries about within it, its old watery environment in the form of tissue fluids, without which the individual cells cannot live. About 70 per cent of the human body is water, and any departure from this proportion produces serious consequences.

The apparatus for locomotion and for breathing, which appeared simultaneously in the racial pattern as vertebrates came onto the land, continue to be closely associated in the growth of individual organisms and in their functions. They are intimately related through mechanical and nervous tie-ups between appendicular and respiratory structures, also between both these and the cardiovascular system by which blood is conveyed from heart to lungs for aerating and back to the heart with its load of oxygen. And in man, the particular parts of the skeleton and musculature which operate to maintain the spinal curves and to keep the trunk erect are most closely associated with the bony and muscular parts involved in breathing.

The land creatures had not only to learn to breathe air instead of water, but they had to support their weight above ground. This meant adjusting to reduced pressures from above and from the sides, and meeting the downward force of gravity through their own tissues, which had also to withstand the upward push from the ground. This required the development of limbs and a different sort of a skeleton or hard supporting structure. The limbs of land vertebrates developed from special fleshy fins grown by fishes which learned to come up onto the shore and to get about in the mud. These fishes were called "lobe-fins" and were contemporary with the "lung fish" that acquired the earliest type of air-breathing lung, from which the later forms are supposed to have developed.

Out of water, the skeleton had to be both light enough to move about and bulky enough to afford attachments for the

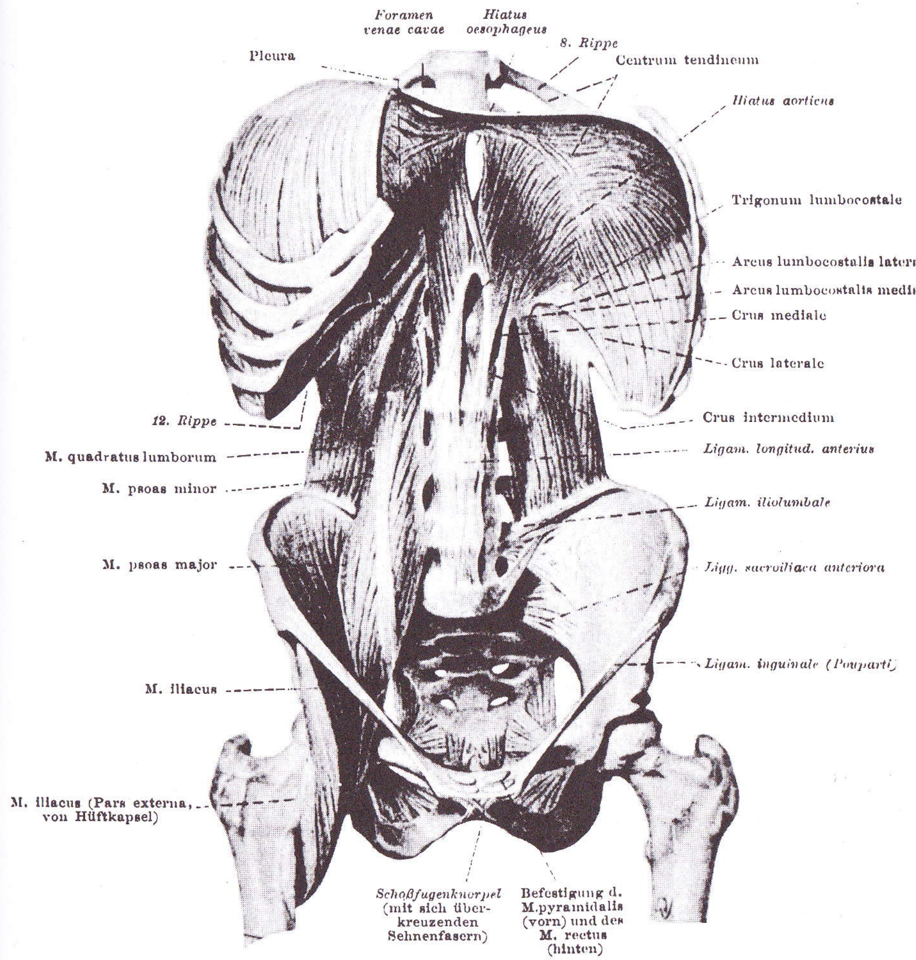

FIG. 2. The diaphragm. Back abdominal wall and diaphragm. Natural position of bones and natural shapes of muscles. At right, a part of diaphragm is cut away above lumbocostalis, to show upper origins of psoas and quadratus lumborum. (From Braus.)

strong muscles that were needed to move it. Thus it appears that the type of spine and the shape and manner of attachment of the limbs differ in the various types of veretebrates according to the kind of locomotion adopted. The snake gets on without arms or legs because its spine is so very flexible that tiny movements from side to side, communicated through the ribs, serve to pull the body along. The actual motion in the snake depends upon friction between the ground and the transverse oblong scales which cover the under-body wall. In all the reptiles the skin tends to be either very tough or quite hard, as in the turtle, and since the legs do not raise the body much, an exoskeleton is needed for protection against ground shocks.

Bird and mammal both derived from the reptile but followed divergent patterns in their supporting and moving mechanisms. The bird, in taking to the air, exchanged a flexible spine for a rigid one, selected light, hard, and relatively hollow bones, and specialized in powerful forearms, with a highly developed clavicle and a large sternum, giving an attachment and a fulcrum for the strong wing muscles, while ignoring the legs except as accessories.

The mammal lifted himself up from the ground on all fours, and at first used both arms and legs fairly equally in locomotion. When the ancestor of the primates (monkeys, apes and men) got off the ground and began to live in the trees, a change in the type of locomotion became necessary, with a differentiated use of arms and legs. In the trees the arms and hands were used to pull the body up from one level to another, and as progression had to be vertical a great part of the time, the lower limbs bore the bulk of the weight both in climbing and in resting.

The four-legged animal on the ground had to do many things with his head that the tree animal learned to do with his forepaws. Grasping and climbing developed the hand and its power of manipulation. This ultimately freed the head and enabled it to serve increasingly the needs of the special senses of seeing, hearing, smelling and tasting without having to undertake such acquisitive movements as seizing and holding. The animal could rest and pick up food or some other object and bring it to his mouth, or hold it to smell it or to look at it, without having to move the head toward it. Consequently, more kinds of impressions could be obtained simultaneously, and the need for the correlation and coordination of a multiplicity of impressions coming at once through sensory channels brought increased need for relay and storage centers in the neuromuscular system. This gradually resulted in higher and rounded brain shapes, and since the bones accommodated themselves to the brain growth, skulls became higher and rounder, culminating at length in the relatively huge, dome-shaped head characteristic of the human being. The growth of the skull to match the brain is characteristic of the way in which, in the body, hard tissues are altered by soft tissues.

While the primate lived in the trees, the arm and hand were developed for long-range action as compared with their simpler use in quadrupedal locomotion. This developed the characteristic shoulder girdle of the primate, especially the clavicle, or collarbone. The scapula, or shoulder blade, had already been developed as a supporting structure for the forelimb and a protective roof for the shoulder-joint, distributing the muscles and attachments of the arm in such a way as to shield the upper thorax from their action. The extension of the clavicle laterally in a plane nearly at right angles to the breastbone, or sternum, strengthened the protective function of the shoulder girdle as the increasing variety and vigor of the arm movements brought greater hazard to the heart and to the respiratory mechanisms of the chest.

Returning to the ground, however, the ape did not develop upright posture in the human sense. For a long time locomotion continued to be largely on all-fours, and when the animal rested it was in a sitting, or rather squatting, position; only in emergencies and for brief periods did it stand on its hind-legs. Walking on two legs became a regular procedure only with the development of the frontal brain and consciousness of self in man. Dr. Gregory, in his "Bridge-that-Walks,"* gives a fas-

* The Bridge-that-Walks, an essay by William K. Gregory.

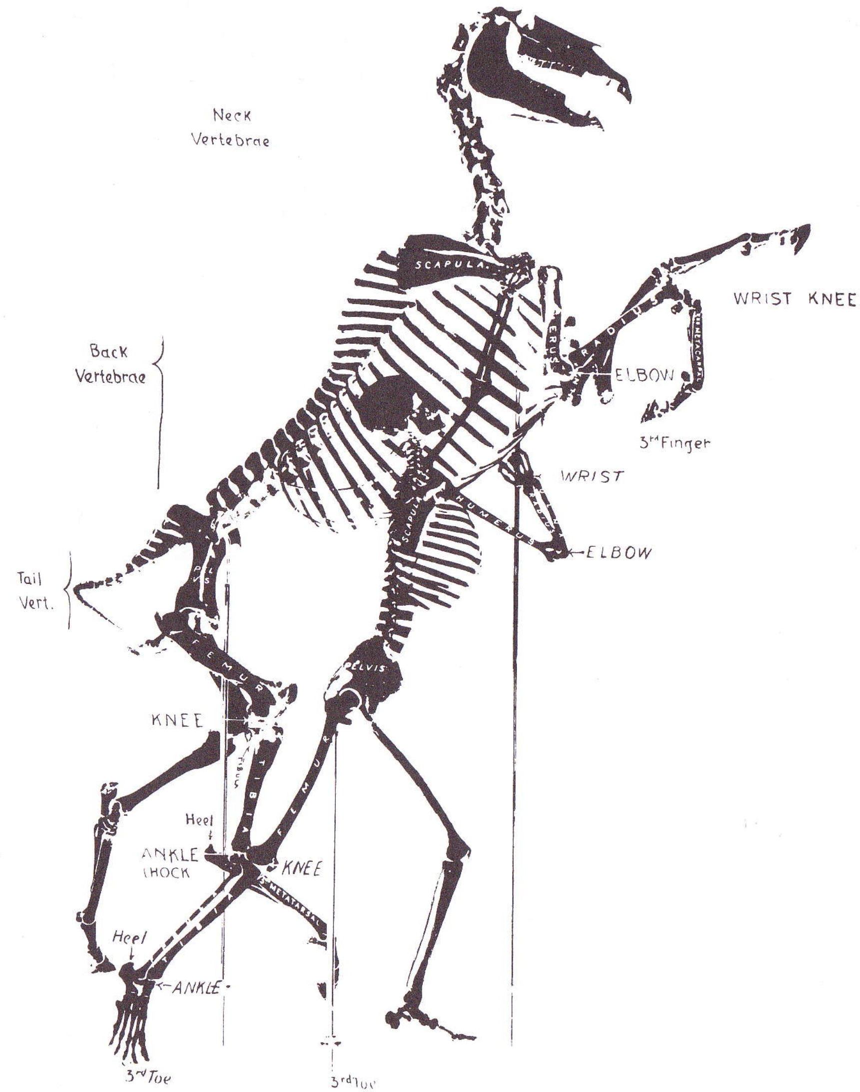

FIG. 3. Comparison of bones and joints of horse and man. (From Gregory)

cinating picture of the gradual development of the human locomotor mechanism.

The course of development involved in the erect carriage is reflected in the history of the individual. In the embryo both the arms and legs develop rather late, with the lower limbs relatively inconspicuous, even for some time after birth, while the arms and hands are comparatively strong in the newborn. The legs and pelvis do not begin to get their later proportions until they are needed for walking. They are prepared for this use in the creeping stage of the baby's activities.

The spine remains the fundamental basis of support and movement for all of the various vertebrate structures. The strength of arms and legs depends upon their closeness of association with the strongest parts of the spine. Thus the great muscles binding the pelvis and legs to the spine extend deep into the trunk, and some reach high up into the thorax, where they are attached at a level opposite the lower end of the sternum.

These are the important muscles for support and movement in walking, so that we walk with the help of our lower chest structures as well as by the more obvious muscles of thigh, calf and foot. Shoulders and rib-cage are likewise connected with the lower spine and with the pelvis through the strong muscles of the back and sides. Strength of movement of the arms, in throwing or grasping, or in lifting outside weights, is dependent upon the underlying support and strength of loins and thighs. The essential structures for the support of body-weight and for the control of movement are thus to be looked for in the lower spine, where the oldest and best-established patterns of neuromuscular activity are found, as well as in the legs.

Activity, when following the primary patterns of the animal, reveals the intimate association of the vital processes of the body, as well as the structural interrelationships and coordination. As soon as the body must function actively as a unit, as in walking or running, or dealing in any direct way with the environment, the structural lines of connection are drawn tighter and the bony and muscular parts are moved toward center, so that there may be as much economy of effort as possible. Witness the crouch of the animal or the preparation for a race or a pole vault.

In the neuromuscular mechanism the oldest and therefore the strongest associations between one part and another, center along the vertical axis of the spine. Here lie the central tubular structures of the circulatory, respiratory and digestive systems, constituting the "service supply" for the whole. Along this axis also, safely protected by the spine, lies the "service of communication," the nervous system. The spine is the power center, the protective center and the coordinating center for both structural and organic rhythms.

When the animal is resting quietly, as after eating, and the rhythm of organic function may be perceived, there appears only a passive relationship between the various parts of the body; there is the look of an all-pervasive comfort and well-being and of little effort in the living processes—the cow comfortably chewing her cud. All the organic activity is along the central axis, in the central tube-like structures of the circulatory, respiratory and digestive mechanisms. The service of supply is preparing for future expenditures.

As the animal begins to move about or to react in some positive way to his environment, the functional interrelation of bodily parts becomes evident. Breathing is deepened and speeded up, as required by the increased need of the active muscles for oxygen. This means deepened action of the diaphragm. Its great sheet and stem alternately contract and relax, to make the chest cavity larger and smaller, until not only diaphragm and intercostal muscles are moving but additional groups of muscles in abdomen and pelvis are engaged, actively and obviously, in working the pump. Finally the muscles extending between the chest-wall and shoulder girdle become engaged; in fact, all skeletal muscles may be called upon to take part under the stress of extreme exertion.

The heart muscle, too, responds to hasten the blood on its way to the lungs, and then to carry oxygen to the clamoring

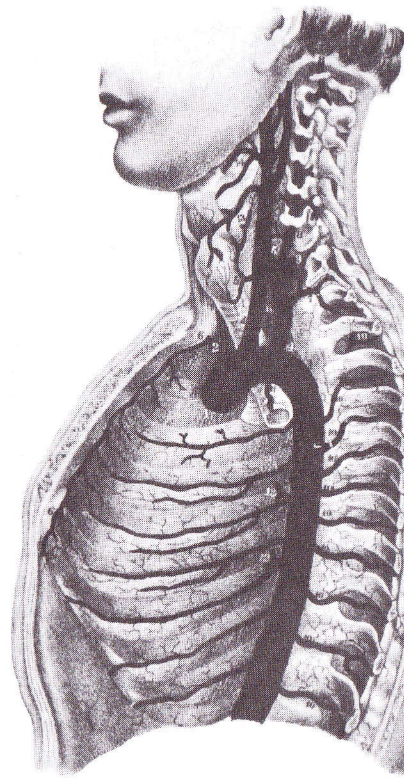

FIG. 4. Inside of upper chest, showing depth of spine and relation of main arterial trunk to spine. (From Goddard.)

muscle cells. The digestive apparatus is affected, not so much in its immediate chemical activities, which are abated by violent exercise, as in the gross movements of its muscular walls. These movements propel the columns of food onward and speed the absorption of the prepared food by the lymphatic vessels, which then hasten to pour it into the blood stream, so that the blood sugar used in muscular activity may be restored.

Maintaining a balanced relationship of spinal parts to the long axis is an important aid to the primary rhythms of breathing. The vertical action of the diaphragm to its greatest depth along this axis is necessary if full dimension of the oxygen tank is to be established. A short spinal axis reverses this picture. It widens the curves and interferes with ligamentous and muscular functioning at the segments.

As the diaphragm deepens its action through the lumbar region of the spine, the muscles of the lower spine which extend from deep within the pelvis take a stronger hold and a basic lower trunk support is established. As the breathing deepens, the whole body comes alive, ready for action. Or, as is the case in sleep, the potential energy which hangs in the balance, ready for use, drops nearer and nearer to the perfect balance leading toward rest. Thus in sleep as in waking hours the centers for locomotion and for breathing are coordinating and the body acts as a unit in making the two adaptations necessitated by its land environment, that is, supporting its upright weight on a narrow base, and breathing air.

To understand these processes and the bodily adaptations, we must begin with an outline of the structural provisions for bodily reactions and know something about the mechanism of nervous and muscular coordination by which its reactions are effected.

POSTURAL PATTERNS

In applying the principles of mechanics to the human body, considering it both as an entity in the midst of universal forces and as a unit made up of a large number of parts, each definitely related to every other, the words "postural patterns" offer a convenient terminology. Should the term seem to convey a fixed outline or shape, recall that the body, like all other known objects on earth, is continuously subject to the pull of gravity and to inertia and must incessantly meet them. As it is being drawn toward the earth's center, it maintains itself by virtue of constant movement of the various parts; and it must as persistently withstand a tendency to continue moving in the same direction, or to remain at rest. The shape, or pattern, of the body is therefore a moving one, dynamic, not static.

The laws of gravitation and of motion were derived through the observation of falling bodies. Without a working knowledge of these laws the high steel skyscrapers and great bridges of today would be impossible. Through experience man has learned that unless he combines his materials, whether wood, brick or steel, in certain ways his structures will fail to meet the stresses thrown upon them by the interacting forces exerted by weights which push or pull upon them, by air pressure, or by jars and shocks in the ground. Through much testing of materials in divers types of construction and terrain, he has learned how forces act upon materials and how these must be arranged to meet the constant impact from such forces. The pattern will vary with the substance, and with the use for which it is destined.

In the human body it is the same: the postural pattern is that of many small parts moving definite distances in space, in a scheme perfectly timed, and with the exact amount of effort necessary to support the individual weights and to cover the time-space-movement. These delicate, accurate and intricate regulations are made in the substrata, below the "threshold of consciousness." Through such adjustment, man preserves his unity and copes with his world.

If we keep to the concept of ceaseless motion from a great play and flux of forces, and the resulting action and reaction between all objects, we can better understand the mutual resistance in balance that gives the physical universe its solid, secure look. So with the human body. Even the individual cells of the body are organized by balancing forces. The great authority on the cell, Edmund B. Wilson, tells us that cell*

* The Cell in Development and Heredity, by Edmund B. Wilson.

bodies do not necessarily have confining walls, but that in some cases forces acting within them hold them to their individual shapes, while they remain "masses of naked protoplasm." Again, within the cell there is a configuration of particles varying with the cell's activities, and in constant motion. This may be seen in the micro-movies of living cells and growing tissues of plants and animals.

To attain conscious control of the structural balance of the human body, we must know its component parts, their relationships, and the forces acting upon and within them. We must understand its materials and their functions and behavior. Understanding the mechanical principles of weight support which apply alike to animate and inanimate structures must be a part of this knowledge.

The bones are the weight-bearing parts, and gravity the primary force to which they are subjected. The balance of bones at their contacting surfaces, the joints, as well as their movement by the muscles, must be considered if economical adjustment of materials of the body is to be attained.

This adjustment involves psychophysical reactions as well as the purely physical reactions to the forces of gravity and inertia which operate alike on organic and inorganic mechanisms.

THE PSYCHOPHYSICAL BASIS OF POSTURE

In the building of artificial structures, the engineer's prime concern is with the character of the materials available for his use. He must know their inherent qualities and their behavior under stress of external forces before he makes a choice: for certain structures, stone or wood; for others, steel. So too, the intelligent use of our bodily mechanism depends upon our understanding of the nature of its materials and their behavior.

Without attempting to enumerate the components of the human body, we note that the important characteristic common to all is a capacity for responsive action. This capacity is inherent in the protoplasm, which constitutes the living material of all organisms, plant or animal. As more is learned of the complexity and variability of protoplasm, the more difficult it is to define. Thomas Huxley called it *the physical basis of life*; this is as near to a satisfactory definition as we are likely to come. For there appears to be no single substance which can be called protoplasm; there are rather an indefinite number of protoplasms, varying not only from cell to cell in chemical make-up, but even within a single cell.

This primordial moulding matter is neither solid nor fluid; it is both. It is just sufficiently solid to keep a form it assumes, and just sufficiently fluid to change to some other form at need. Any protoplasm is a mixture of extremely complex chemical compounds arranged in a minute cell structure, which is usually differentiated into a nucleus and surrounding substance called cytoplasm. The structure is found in its greatest complexity in man. All the myriad cells of the body have characteristics in common, but each lives a somewhat independent life of its own in a fluid medium. Each breathes, assimilates and displays irritability, and in varying degrees all can repair and reproduce themselves. In addition to these common cell functions, which are shared by all organisms from the single cell to the most elaborate multicellular plant or animal, each individual cell has a special rôle to play in the functioning of the whole structure.

The cells for the various functions combine into groups known as systems, such as muscular, bony, nervous, epithelial, vascular or glandular, which severally react to a variety of external and internal stimuli. Glands react primarily in emotional changes and muscles execute movements, both responding to stimuli transmitted through the nervous system. The reactions of all parts are so coordinated and integrated by several different factors, chemical, physical and nervous, that we perceive the individual as a whole rather than as a collection of parts.