Manifestations of Mechanical Force in Biological Subjects*

J. Howard Furby, D.D.S.

Pasadena, California.

In order to lay a foundation for discussion of mechanical forces as manifested in biological subjects, it will be necessary to first present some of the general views of biologists and philosophers on natural science. These will be offered as a justification for ensuing claims that mechanical forces predominate throughout all living tissue and hence our immediate field of orthodontia is deeply concerned with such forces. Consequently it does not suffice to turn back failure or relapse in orthodontic treatment on the Almighty with the too usual remark, "it is a biological problem!" How often we have heard that excuse; how frequently it has appeared in journals as a dogmatic, all inclusive statement that implies the impossibility of discussion or denial. Some orthodontists seem to have the idea—or at least they so express themselves—that although orthodontic treatment is of a mechanical nature, yet it is an operation performed on living tissue and, therefore, the whole subject becomes a vital one and the mechanical or physical side of the operation is of minor importance.

We shall endeavor to prove, by biology itself, that such a concept is not scientific; that biology embraces mechanics; that mechanics not only overlap biology but they are necessary to all natural science.

Let us state at this point, that we have no controversy with biology, neither do we intend to discount or belittle the vital forces of life. We concede, at once, that there is something dominant behind all life other than the phenomena that are manifested. Life ceases as soon as this unknown quality, this vital force, is lost. However, we maintain that so long as nothing is known of this force, except that it exists, and, so long as we have no control over this phenomenon, it is not to the best interests of our profession to attribute all or most of our failures to the something which we are to prone to call "a biological problem."

It seems more logical, more scientific and to the better interests of orthodontia to study the forces of natural science from the standpoint of known qualities; to learn about the structure and function of tissues, factors which so clearly manifest themselves. Then, by becoming more scientific,

*Read before the Ninth Annual Meeting of the Edward H. Angle Society of Orthodontia, October 21st, 1933.

more proficient and more skillful in our mechanical technic we can adapt the extraneous forces to work harmoniously with the living or vital forces.

This is the theme of my essay. I shall attempt to prove that such knowledge is the basis for a correct architectural understanding of our immediate field—the human denture; for the skillful application and adjustment of orthodontic appliances; and for the visualization of the correct orientation of teeth in the arches. These are our problems and if these mechanical operations are performed properly and in such manner that the vital forces respond to them as they would under nature's plan and effort, we shall be able to accomplish the desired end quickly and successfully.

It is my firm belief that all treatable cases of malocclusion can be so corrected by the orthodontist in conformity with natural laws, that, given the proper cooperation by the patient, the result should be perfect occlusion of the teeth, maintained by the natural function of all parts of the denture as originally intended.

The Divisions of Natural Science

Custom has divided natural science into three main divisions or categories:—the earth sciences, which include geology, geography, paleontology, and aspects of astronomy; the physical sciences, including chemistry and physics; and the biological sciences, including botany and zoology with their branches—morphology, physiology, genetics, etc.

Former definitions excluded biology from the science of physics, and it may account for some of the apparent unwillingness to grant mechanics a place in biology. As a matter of fact the science of biology is profoundly indebted to the physical sciences, chemistry and physics, and could make little progress without their fundamental principles. Biology and the earth sciences, geology, geography, etc., are interdependent, for organisms have changed earth's history, while organic matter has been modified in accordance with changes on the earth's surface.

There are two main theories of biological philosophy, each with its advocates. These are Mechanics or Monism and Vitalism or Dualism. The first believes that life is an expression of the transformations of energy and matter in a large group of materials—protoplasm—that Huxley termed "the physical basis of life." Dualism embraces the protoplasmic theory, the transformations of matter and energy, but adds "some all controlling, unknown and unknowable, mystical, hyper-mechanical force."

We do not intend to discuss these subjects but merely to point out that there is a school of biological philosophy which goes so far as to regard mechanics or physical science as a universal mechanism accounting for everything in the universe, and even the vitalistic school believes in a "hyper-mechanical force." All science agrees, however, that transformations of matter and energy constitute the mechanical forces of all nature.

The difference between one group of sciences and another is largely one of levels. The uppermost level, and one over which organisms have no control, is that including astronomy and geology. The lowest level is occupied by the inorganic world and includes chemistry and physics. This leaves organic matter in the middle level, which is its natural place, for it undergoes changes far below either the cosmic or geological level and far above the world of atoms and electrons.

In attempting to limit the scope of mechanics and its synonymous terms, the material corporeal and physical, we find all of them embracing the action of forces on material bodies—a material body being "that of which anything is composed or may be constructed." In fact, all things, from atoms or electrons of inanimate matter to the nucleus of the animate cell, either have a mechanical structure or are mechanical in their actions. Think of what you will—there will be connected with that object some mechanical phenomena upon which its very existence depends. So we find that biology, the physical sciences and the earth sciences all overlap and depend upon one another.

Mechanics

Mechanics is divided into two divisions, kinematics and dynamics. As kinematics has no reference to forces, it will be eliminated from this discussion. Dynamics has two divisions, kinetics and statics. Kinetics deals with variable motion. It is motor, active, and depends upon motion. Statics deals with uniform motion and rest. Both of these mechanical forces are manifest in organisms and will be considered in the discussion.

Man's existence on earth depends entirely upon the combination of two separate organisms. He is composed throughout of minute cells and intercellular substance. His whole structure is made up of the mechanical continuity of these tiny structures, each interdependent and the whole dependent upon each part.

Protoplasm, "the Physical Basis of Life"

Considering the subject of protoplasm, "the physical basis of life," do we find any manifestations of physical force in the structure or function of this substance either within itself or in its relation to adjoining cells? Upon the answer to this question hinges the entire theory or demonstration of physical forces in biological subjects. As all organisms are composed of cells containing protoplasm, it becomes obvious that unless we demonstrate either physical action within cells or physical action by cells, all mechanistic theories of biology will fall. The composition of a cell is such that physical properties may be easily demonstrated. For instance, protoplasm appears under the microscope to be made up of granules, fibers, and droplets of liquid, embedded in a matrix. It looks like a mechanical mixture held within the confines of a limiting membrane. From this physical standpoint we find protoplasm to be a colloidal mixture. A colloid is a substance of glue-like consistency, lacking crystaline structure and incapable of going into ordinary solution in certain solvents. To illustrate:—In the attempt to dissolve colloids in water, the molecules do not break up into ions, but remain in mechanical suspense in the medium, some of them large enough to be seen with the naked eye. It seems that nature's plan is to mechanically suspend these ingredients within the cell and mechanically hold them by means of an outer membrane. The fact that almost all cells have the ability to change their shapes to conform to attending mechanical pressure, demonstrates mechanical adaptability of such cells. This ability is present either in addition to or in conjunction with the vital forces behind cell reproduction.

Probably the most easily demonstrated mechanical force in living tissue is that manifested in the multiplication of cells, which constitutes what we term growth. The entire structure of every organism is built by growth of cells, two for one, and continuing in compound multiplication. These cells are mechanically held in place by surrounding tissues, or float in plasma. Even bone, built and maintained as a sturdy framework to support the entire structure, is subject to cell change and can tear down and rebuild itself according to necessity. This seems to us to be one of the most striking examples of the transformations of matter and energy, previously alluded to. Bone in all of its aspects is subject to change in accordance with the mechanical pressure applied to it. All of the structures and most of the functions of all vertebrate animals cause mechanical forces to be exerted upon the bones of these animals,—forces both kinetic and static.

Muscles, more than any other tissue, exert force on bone. Any muscle contraction produces kinetic force on the bones to which the muscle is attached. Muscles, like bones, also have other mechanical aspects for they, too serve as vehicles for carrying other structures. Each muscle fibre, each bundle of fibres and the muscle as a whole are surrounded and intertwined with sheaths, which act not only as mechanically limiting membranes, but also as mechanical supporters and connecters with adjacent structures.

Other important manifestations of mechanical force are found in the vascular system such as the heart beat and the elasticity of blood vessels. Then there is the motion of cilia, thought by the mechanistic school to be due to the change of colloids from a gelatine to a solution and back to a gelatine again.

The Human Denture from a Mechanical Standpoint

Passing from so brief and general a consideration of mechanical manifestations in biologic bodies to the more specific consideration of those of the human denture, with which we are more concerned, we are at once met with an array of natural mechanical actions, so complicated and yet so balanced and harmonious, if normal, as to be bewildering to the uninitiated. Without doubt, the human denture serves more diverse functions than any other structure or series of special structures within the body. It consists of more interrelated parts; it is more dependent upon proper arrangement and function for normality than any other organ and it is more susceptible to disarrangement. There are two reasons for this susceptibility. First, the denture is active in and associated with a number of fundamental bodily functions, i. e., mastication, deglutition, respiration, speech, taste, secretion, and the innumerable changes in facial expression which are visualizations of thought and emotion. Second, the normal size, shape and function of the denture is dependent upon the development and arrangement of thirty-two hard, unyielding, structurally unchanging, interlocking teeth, which are anchored in yielding, changeable structures composed of bone and soft tissues. Upon the relationship of these structures of directly opposite natures, depends the balance of the entire denture which, to be normal, must be centered around the correct mechanical occlusion of the teeth. Further complicating the matter is nature's plan of supplanting the deciduous by the permanent dentition during the formative and growth periods. The eruption of the individual teeth at different times and, in the case of some teeth, in different positions, adds to the liability of abnormality. It is, then, not surprising that we find so many malocclusions when these all-important mechanical factors are considered and their tremendous influence on all other structures of the denture. With all of this, function must go on as usual during this transitional period which adds more mechanical forces to both the teeth and soft investing tissues. How correlated must be the functions of these soft investing tissues and free from hyper or hypotonicity in order to assist in guiding the hard teeth along their route until they have reached a locking influence with opposing teeth, and are, finally, mechanically placed by the physical influence of the surrounding structures in function.

If the normal arrangement of these hard tooth substances, embedded in soft investing tissues, is dependent upon the mechanical locking of the teeth, then why is it not logical to say that orthodontic treatment consists of mechanically placing the teeth in their correct positions—occlusion—according to their size and shape? If this is done and the investing tissues have the ability to change their form and function to conform to this ideal occlusion, granting the elimination of all perverse habits, then nature's plan will have been realized. A hard tooth, erupting through soft tissues, being guided into place by a mechanical opposition and apposition of other similar hard teeth, produces a kinetic force, and the yielding softer investing tissues must conform to this influence just the same in orthodontic treatment as in natural processes. Did anyone ever see an arrangement of teeth, even in exaggerated malocclusions, in which the investing tissues had not conformed, in the main, to the teeth unless hampered by disease or excessive trauma? If not, then the softer investing tissues are entirely subservient to the teeth and the mechanical aspect of the denture determines the vital aspect. Nature's vital forces cannot operate normally unless the mechanical conditions are likewise normal. We grant the psychological and vital aspects of uneliminated habits, but any result either good or bad, will produce a mechanical force and the vital forces—the biology—of the denture will be influenced thereby.

The structure of the denture, with its stationary upper maxillae and its lower movable mandible, the joint which permits its diverse movements, together with the bracing where needed, the compactness and yet the lightness, the attachment of the muscular tissues,—all these illustrate a mechanical mill, built to withstand mechanical stresses and at the same time to produce mechanical force of a complicated yet harmonious nature.

Another manifestation of mechanical force and one of particular interest to the orthodontist is that associated with the development, growth and eruption of the teeth. The formation of the dental buds, with their compound multiplication, and each cell division, mechanically forcing the surrounding tissues aside until the germ has reached its place and formed its crypt, is a striking example of force, by cells. When these buds of teeth have reached their appointed positions and have formed a mechanical barrier around themselves, they begin the work of forming tooth structure. This is also of particular interest to us. Here we find the building of enamel going on in a similar way that the builder of a brick building would proceed. The laying of enamel rods and cementing them together with a mortar; the architectural act of beginning this work at the dento-enamel junction and working outwardly, thus establishing a mechanical "tying in," the same as any builder would do; the similar yet different formation of dentine and cementum,—all manifest mechanical processes. Similar action, also, is apparent in the eruption of teeth. When the crown of the tooth is formed and root formation begins, the crypt needs enlarging. So, by a continuous force from the cells in laying new substance on the end of the part formed, the tooth gradually arises from its crypt until this process finally forces the tooth through the bone and mucosa where it comes under the influence of the adjoining teeth, the tongue and the buccal or labial tissues and is thus guided along its route until it reaches the more dominant influence of the opposing teeth.

All of these processes are mechanical in action. Naturally they are induced by the power of energy. The unknowable quality behind this energy, which defies our investigation, is a debated question, so far as science is concerned. Nevertheless, it should offer no excuse for neglecting the forces which so clearly show themselves and from the study of which we may learn so much of value in our work. How much more scientific, how much more helpful it would be if we studied thoroughly these forces and their sequence of action and thus educated ourselves to interpret the vital reactions arising from our corrective efforts than to cover such neglect with the evasive phrase, "it is purely a biological problem!"

550 Jackson Street.