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Historical Perspectives of Oral Biology: A Series

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I. INTRODUCTION

The origins of medicine and science coexist with the gradual domination of Earth by Homo sapiens and the ability of this species to communicate by the use of oral and written language, a quality that seems to be unique in the animal world. All science disciplines, including the physical and natural sciences, trace their origins to the abilities of individuals to use language and symbols to represent needs, observations, concepts, and experimental data. We really cannot know who might be considered to be the "first scientists on earth", but it is probable that such individuals emerged quite independently in different areas of the ancient world, e.g., China, Egypt, Arabia, and Greece. However, the term "scientist" only came into being in the 19th century.[1] Descriptors such as "cognescenti", "virtuosi", "intelligentsia", and "naturalists" were terms employed in early times in Western Europe to describe those who pursued what we consider today to be the fundamental questions of life.

The pace of modern science has led, unfortunately, to a depreciation of the importance of the history of science in the education of scientists. For example, there is little formal teaching of the development of the various biomedical disciplines in graduate education, and there is little effort in medical or dental education today to teach these students about the rich history of their professions — a great loss for the future of the health professions.

This series of articles is an attempt to trace certain major events in the history of medicine and dentistry. We describe the emergence of what we termed the two streams of medical history and explain the origins of the separation of dentistry from medicine due to the explosive increase in the demand for dental treatment in the 19th century. This rich history provides the background for understanding the emergence of oral biology as a biomedical discipline, a discipline rooted in the original separation of dental education from medical education. We hope that our efforts to explain these various relationships may provide general insights, first of all, into how the *science* of medicine developed over a long period of history as a very different entity from the *art* or practice of medicine. Secondly, this first article provides a framework for understanding how and why *all* biomedical disciplines developed and how these disciplines became legitimized and incorporated into the foundation of the health-care systems evident in society today.

II. THE GREEK PHYSICIAN-PHILOSOPHERS

There is general agreement that the ancient Greek teachers and philosophers were among the first individuals on Earth who left adequate written records to justify comparing them with scientists of today. Intellectual giants such as Aristotle, Socrates, and Hippocrates readily come to mind. We suggest that it is more than coincidence that these early wise men considered the human species to be the primary focus of their studies. More importantly, these Greek philosophers were often considered by their contemporaries to be healers or physicians. These early Grecian intellectuals were, indeed, in the mold of the modern physician-scientists and, more importantly, are considered by most scientists today to be their progenitors.

The physician-scientist Galen (circa A.D. 138 to 201), often considered the father of experimental biology, is the historical centerpiece of this viewpoint. History records that Galen was the first to dissect animals and record anatomical information in a systematic way.[2] He discovered that arteries contained blood and not air as had been taught at the time. He thought that the heart set blood in motion, but did not discover how blood circulated in the body. Further, he compared the organs and tissues of his experimental animals to human anatomical findings. Galen also produced the earliest systematized recording of biological data. In addition to these accomplishments, he was the first recorded teacher who used the results of his research in his teachings. Historians have traditionally ranked Galen second to Hippocrates in importance in the history of medicine. We would support a reversal in those rankings based on Galen's initiation of the methods of observational research. However, Galen's initiative in the realm of research did not have the impact on medicine and science that we might have expected, certainly nothing close to the impact that the work of Andreas Vesalius had nearly 2000 years later.

However, it is important to comprehend the significance of Galen's work, especially in light of the environment of today in science and the use of animals in research. Galen's efforts to understand human anatomy through the dissection of animals launched important practices that, in retrospect, can be recognized as the four keystones of both bioscience and modern medicine. First, as mentioned, was the use of animal research models. Second, was the systematic recording of such data. Third, and perhaps most important, was the application of animal findings to humans. Finally, by bringing all of these together in a teaching environment, Galen set the stage for all that was to follow in the history of medicine from antiquity to the era of modern bioscience. He was certainly *the* ancient progenitor of the modern biomedical scientist-practitioner-teacher.

Thus, at least as far as Western civilization is concerned, Galen's work and writings — some 400 books of which approximately 80 remain[2] — must be considered to be the principal origin of the great river of knowledge that now includes every facet of biological science and medical practice. We may also discern with Galen the beginnings of the division of medicine into two distinct "streams" of human endeavor. We are referring, first, to the health *practitioners* who are concerned primarily with treating and caring for the diseased and the ill of society. Individuals who perform these functions date from antiquity in every society, culture, and tribe on Earth. In this article, this historical stream will be referred to as "Stream H" — for "the healers". We considered designating this stream as "Stream T" for "the treaters", since their primary impulse has always been "to treat", even when it has not been clear that the treatment is efficacious. Of course, "healers" is an infinitely more acceptable term to those who treat, and we decided to stay with "the healers" because this term is, now at least, justifiable.

From the very beginnings of human history, the healers have represented what is recognized as the "art" of medicine. In contrast are the *scientists*, who now form the research constituency of the health sciences. Individuals of such leanings diverged very early in history as a very different historical stream that we will refer to as "Stream S" — for "the scientists". This dichotomy in the essential origins and thrusts of medicine has long been expressed in the vernacular characterization of its practice as being both an *art* and a science (Figure 1).

In the more recent history of medicine and dentistry, significant advances and deviations in the course of Stream H have occurred as a direct outcome of the advances in knowledge, originating with the constituents of Stream S. However, this has not always been the case. For many hundreds of years after Galen, the practice of medicine that was carried out in the various societies up to and beyond the middle ages bore more resemblance to the "medicine man" of various tribal cultures than to the science-based practice that we enjoy today, and most "medical education" took place in the form of apprenticeships to other practitioners. In fact, as late as the 12th century, there were only two educational institutions that included courses of study related to medicine. Both were in Northern Italy — Salerno and Bologna; of the two, Salerno had a much greater reputation for medical studies. Bologna dominated the study of law. These two institutions might be considered to be the first of what we today term a "university".

Thus for more than a 1000 years after Galen, the physician was concerned primarily with treating the symptoms of a disease and with providing a prognosis of its eventual outcome or resolution. However, as far as we can discern today, the physician typically exhibited little or no interest in the basic causes of the diseases of mankind. Therefore, as we begin to map the course of our metaphorical river of biomedical knowledge, Stream H preceded Stream S by perhaps thousands of "miles" before it was evident that they were on clearly divergent courses. These early streambeds of medicine eventually became a very different set of occupations or professions, each encompassing many subdivisions (see Figure 1).

III. INFLUENCE OF MASS PRINTING ON MEDICINE AND SCIENCE: ESTABLISHING THE METHODS OF OBSERVATIONAL RESEARCH

Undoubtedly, one reason for the lack of a widespread influence on early medical practice by Galen was that his writings were relatively inaccessible until the middle of the 16th century. At that time, the famous Venetian publishing firm, Guinta, conceived of a plan to edit and print the complete works of Galen.[2] In 1541 and through 1542, Guinta published, in seven massive volumes, the *Opera Galeni*. Interestingly, it was immediately after this, in 1543, that perhaps the single most important publication in the history of medicine and biology was issued: *De Humani Corporis Fabrica* by Andreas Vesalius of Brussels. The publication created a sensation, first because of the outstanding quality of its format, text, and woodcuts (Figures 2 and 3) and second due to major differences in the exposition of human anatomy from that of Galen. The significance of the appearance of the *De Humani Corporis Fabrica* is that it launched, with startling suddenness, a clear exposition of the methods of *observational research* (sometimes referred to today as "descriptive research" — unfortunately in a pejorative sense). At any rate, this publication established observational research at the very foundation of medical education during the 17th century. The development of the *experimental method* in medicine began to develop somewhat later as a logical extension of the observational methods. Of course, the experimental method has since become the dominant method of bioscience research. However, its earliest champion was Galileo Galilei, the founder of experimental physics and astronomy during the 17th century.

IV. PRIMARY IMPETUS FOR EMERGENCE OF A DISCIPLINE: THE SCIENTIFIC PARADIGM

As far as the natural sciences are concerned, the experimental method can be argued to have begun with the ingenious experiments and observations of Harvey on blood circulation in man.[3] Then, too, Claude Bernard's experiments on blood flow and functions of the liver in dogs in the middle of the 19th century[4] contributed significantly to the development of the experimental approach. However, the contributions of Harvey and Bernard went well beyond advancing the experimental method. Their research led to the emergence of two of the

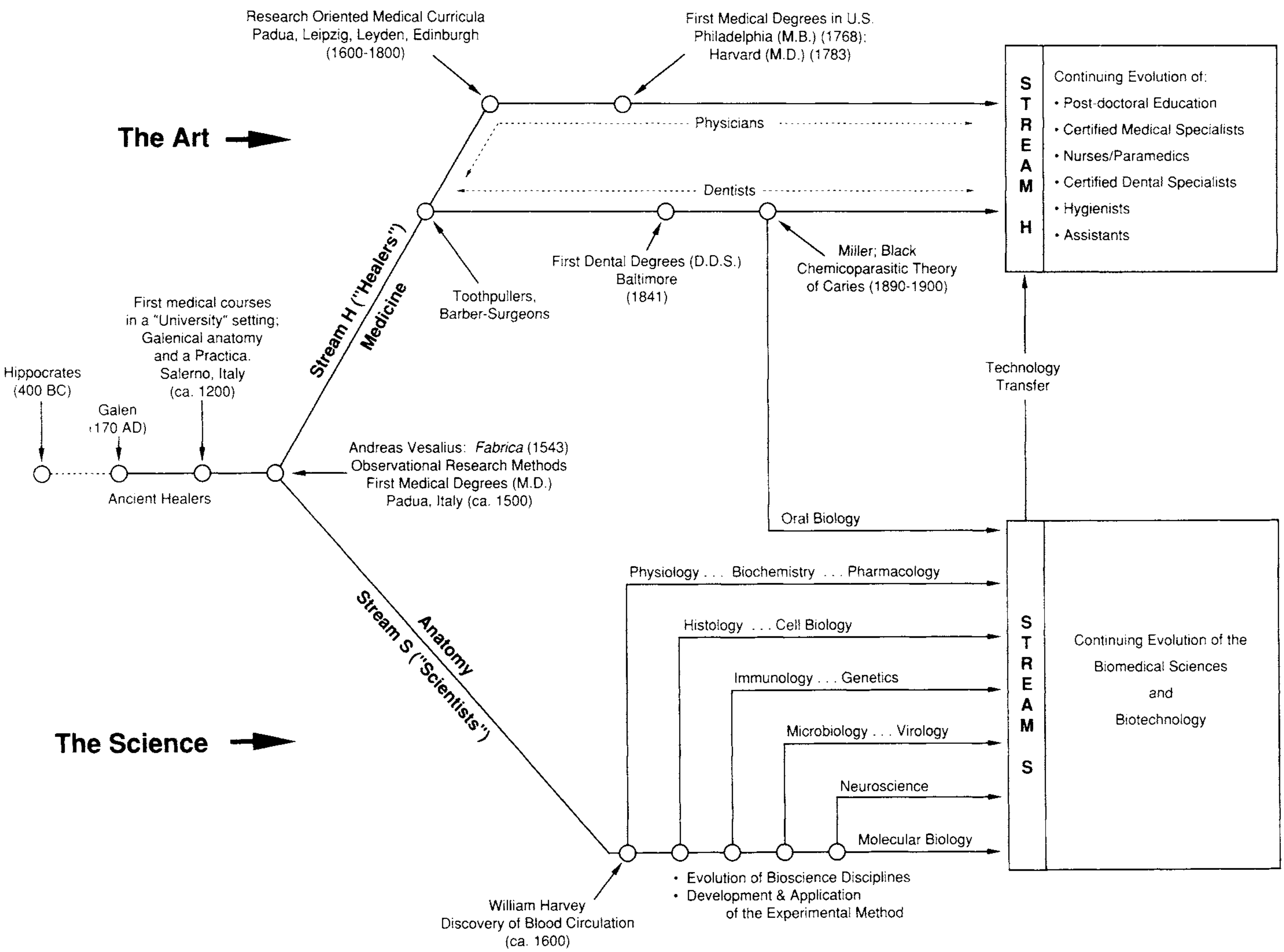
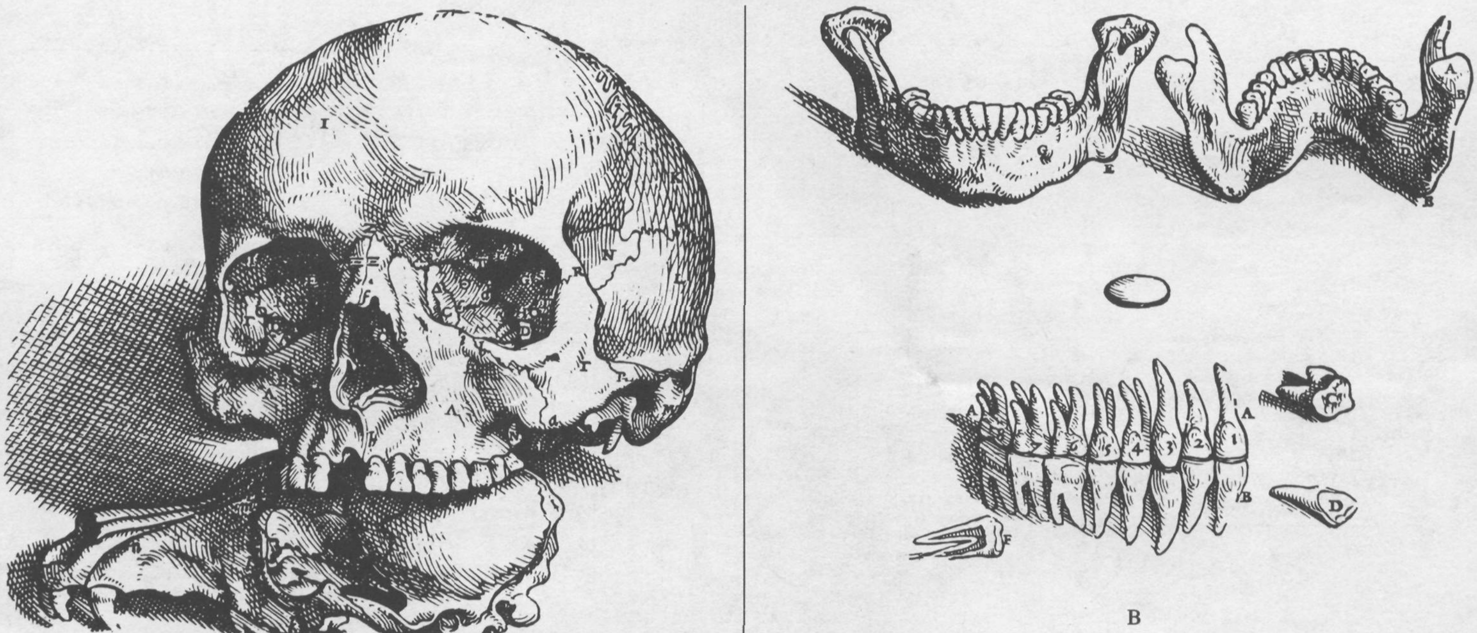


FIGURE 1. Evolution of the art and science of medicine and dentistry. Major historical events and trends are depicted in the metaphor of a small stream of human endeavor that divides very early into two distinct branches: Stream H, encompassing the healers (who practiced and defined the "art" of medicine), and Stream S, known in recent times as the scientists (who practiced and defined the "science" of medicine). Today the H and S streams have each become the metaphorical equivalents, in terms of earthly significance, of the Amazon and Nile Rivers. Their combined impact, not only with respect to obvious effects on the health of individuals, but also in terms of the very course of the history of the human species and the planet itself, has continued to increase throughout history.

central paradigms of modern physiology and medicine. First was Harvey's demonstration of the unidirectional circulation of blood — from the heart pump to the arteries, to the veins, and back to the heart. Second was Bernard's concept of the "fixity of the *milieu intérieur*". The latter was developed fully by Walter Canon in the early 20th century. Canon coined the term "homeostasis" to describe those processes that contribute to the ability of the body to maintain a relatively constant internal environment.

From the perspective of today, the development of powerful new biological concepts or paradigms appears to be virtually a prerequisite to the definition and emergence of each of the modern disciplines (Figure 4). The Galenical paradigm — generalizing specifics of the anatomy of animals to humans — established anatomy as a field of study; it also proved eventually to be erroneous and was the source of many of Galen's errors regarding human anatomy (e.g., see Figures 2 and 3). However, the emergence of a paradigm, which can be a relatively sudden event in the historical stream, has always provided the necessary focus of study for a group of individuals, who in turn form the nucleus of the emerging discipline.

As far as development of the scientific method in the natural sciences, others such as Antonie van Leeuwenhoek (1632 to 1723), inventor of the first microscope (interestingly, considered to be an amateurish accomplishment by the virtuosi of the period), and Louis Pasteur, who discovered the basic concepts of metabolism in bacteria, contributed not only to the refinement of observational research, but also to the early devel-



A

B

FIGURE 2. Illustrations of the human skull and teeth from Vesalius' historic *De Humani Corporporis Fabrica*, first published in 1543. (A) From Vesalius' Plate 8. Vesalius' representation of the anterior aspect of the human skull shown resting on the skull of a dog. This illustration was of great significance to Vesalius. Its primary purpose was to reveal that Galen could not have been familiar with human anatomy because he had described the premaxillary bone and suture of man in terms of dog anatomy, which was an error. This was one of the major factors leading to the overthrow of Galenical anatomy. (B) From Vesalius' Plate 9. Vesalius' depiction of the teeth of the upper and lower jaws on one side of the head (the first such representation in this manner that anticipated the quadrant depiction of the dental arches favored by modern dentists). Set apart are upper and lower molars sectioned in cross-section on the upper and longitudinally on the lower to expose the pulp cavities. This also controverted Galen, who said that the teeth were solid. Despite this, Vesalius' treatment of the teeth was mediocre and was completely superseded a few years later by the monograph of Bartholomaeus Eustachius.[2]

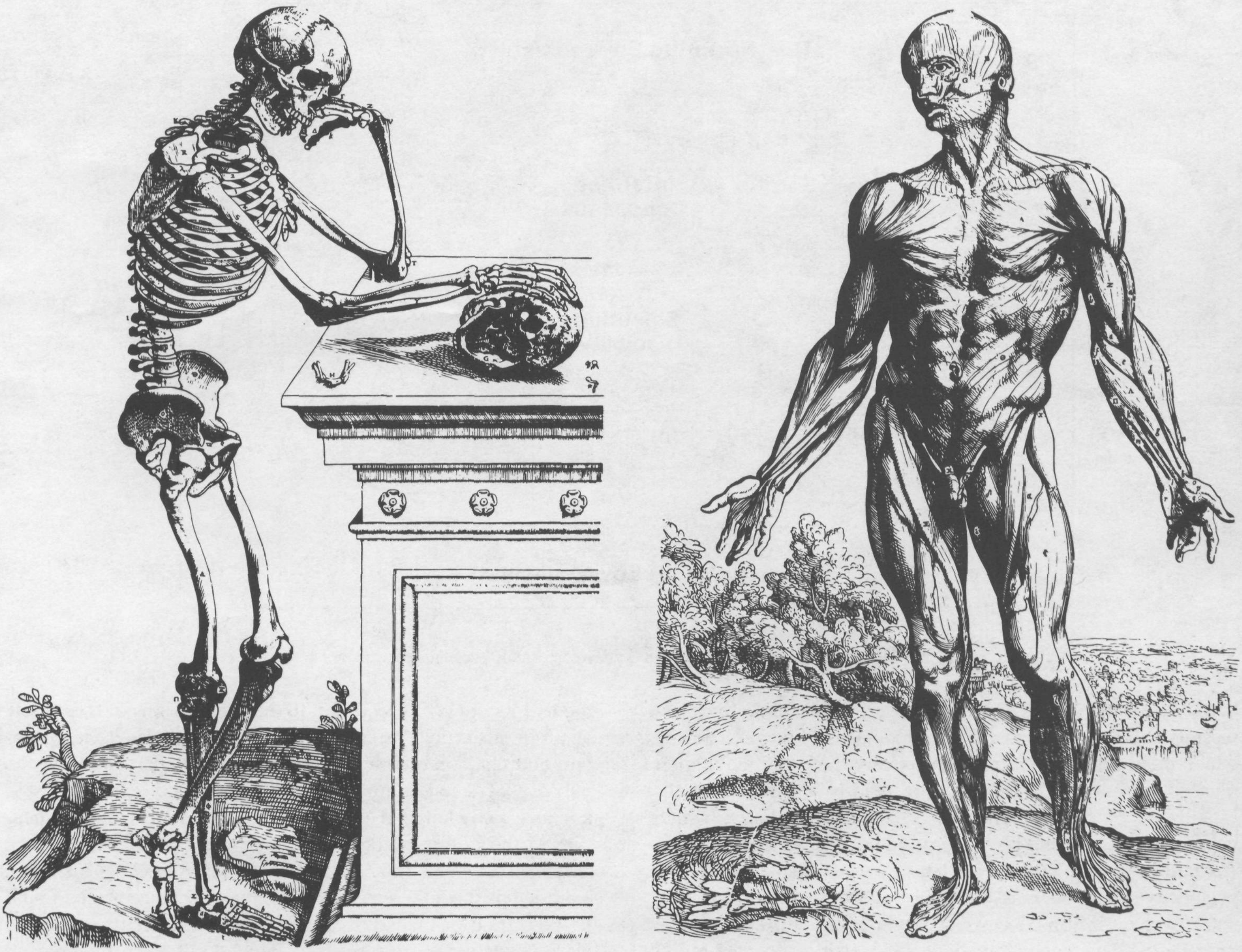
opment of the experimental method as the basic tool of biomedical science. Observational research and the experimental method form the bedrock of all science today, especially when considered together with fundamental and applied mathematics such as statistical theory. In addition, the bioscientist can tap extremely powerful tools for research into biological processes today, such as computerized molecular modeling, which themselves represent the products of basic research in the physical sciences.

V. THE AGE OF SPECIALIZATION AND ITS EFFECTS

We are now in the age of specialization in science and medicine and, indeed, in all fields. The explosion of knowledge in biology, biochemistry, molecular biology, and genetics, as well as in the applied technologies that biologists employ to study their respective areas, has forced research pursuits into ever-narrowing and well-delineated problems. Paradoxically, the actual volume of knowledge, or ''information load'', that must be gathered, assimilated, and analyzed for the pursuit of these narrow problems has become much larger in each circumscribed area than was the case when the more global and philosophical level problems of the whole human organism were pursued by the ''original physician-scientists'', the ancient Greek philosophers.

These realities present a growing problem to all of us in the biosciences. The place in history and especially the relative importance of specific research projects become more difficult to judge not only in the immediate context, but in the overall progression of science itself. So, as specialization increases, the need to transcend the pressures toward an ever-narrowing focus becomes more, not less, important. Thus, those who represent each field of knowledge must continue to strive to retain a clear view of the origins of their field in the larger body of human history, and they should maintain a record of the key events that led to and define their present position not only in the history of science, but in the history of the human species. However, up to now at least, there has been little need to exhort these efforts; they seem to be a basic human drive of the ''virtuosi'' in every field of human endeavor. This tendency has led, in the case of the history of medicine and bioscience, to the organization of the scientific and professional societies.

However, always preceding the science societies has been the emergence of certain paradigms to explain natural phenomena within defined areas. The definition of a paradigm is



A B

FIGURE 3. Illustrations of the bones (A) and of the anterior muscles (B) of the human body from Vesalius' *De Humani Corporporis Fabrica*. (A) From Vesalius' Plate 22. Typical of Vesalius' simple prose descriptions of the remarkable plates of the Fabrica is the following description of Plate 22 (shown in its entirety): "A delineation from the side of the bones of the human body freed from the rest of the parts which they support, and placed in position."[2] This is the most admired of Vesalius' osteologic series, depicting the skeletal Hamlet soliloquizing beside the tomb of some poor Yorick. These illustrations also represent the power of art to influence history. The Renaissance required that the artist become thoroughly acquainted with the structure and physical properties of natural phenomena to ensure representational correctness and objectivity. Other historical artistic giants of the Renaissance, such as da Vinci, Michelangelo, and Raphael (to mention only a few), also became enthusiastic scholars of the structure of the human body. (B) From Vesalius' Plate 26. The third plate of the muscles presents Vesalius' depiction of the anterior view of the body in which the skin is entirely removed to show the muscles. In his description, Vesalius indicates that this plate "displays the muscles constituted of fleshy membrane, and also several of the facial muscles completely freed of fat." While Vesalius was able to demonstrate the existence of certain of the more obvious facial muscles, he was obscure in details and this plate is regarded as one of the poorest in his treatment of myology.[2]

the uniform acceptance and acknowledgment of such explanations by others engaged in the same field of study. Together, the emerging paradigms and the human need for consensus have provided the foundation for each of the science disciplines (see Figure 4).

VI. INFORMED CONSENSUS — RAISON D'ÊTRE OF THE BIOMEDICAL DISCIPLINES

Whenever a general consensus exists among scientists of the key events in a given area of knowledge, this consensus defines

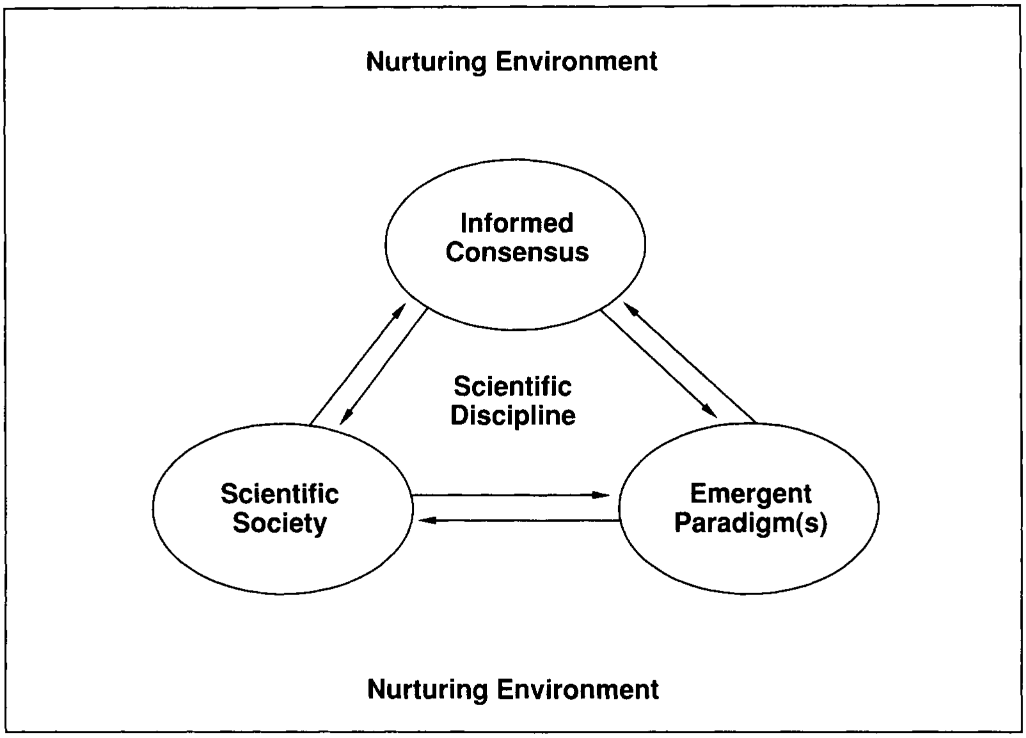


FIGURE 4. Elements involved in the development of a scientific discipline.

both the history and the present state of the field. Such assessment also presents an agreed upon base of knowledge from which those who will come after us may trace and judge their own contributions. These facts are readily apparent in well-established biomedical disciplines, such as anatomy, which began with Galen, and physiology, identified with Harvey and Bernard more than 1000 years later. We can also describe this perspective of science as the desire and the struggle to reach some sort of informed consensus about the current state of knowledge. This perspective is at least tacitly accepted by all of the recognized biomedical disciplines today and, in fact, is their *raison d'être* (whether or not recognized as such).

Usually, the key events and scope of the best established disciplines are set by the textbooks adopted for teaching purposes. Authors and editors of texts have become the judges and arbiters of both the historical traces and current status of the respective fields of science. In fact, the science textbook is usually the instrument that firmly establishes the paradigm(s). In effect, the emergence of one or more paradigms and the development of informed consensus represent two sides of the same coin — the coin being the discipline itself (see Figure 4).

The best and most widely used texts become *de facto* the preferred description of the discipline. Even more importantly, besides the authors and editor, the critics of such texts usually belong, also, to the tightly defined membership of a major scientific society dedicated to advancement of the subject of the text itself. We shall return to the implications of these facts again in this article, because these implications present a problem and challenge to science. The common perception of the purpose of science among both laymen and scientists is to advance knowledge. Hence, while scientists espouse dedication to the notion of openness to new ideas, this is an ideal that has not been fully achieved. Perhaps the best historical example of this inherent schizophrenia of science can be found in the difficulties faced by Galileo Galilei, not only among the clergy, but among his peers, when he put forth his concept that the Earth revolved around the sun — which directly opposed the Copernican paradigm.

VII. POLITICAL DIMENSIONS OF THE BIOSCIENCE DISCIPLINES

We have been using the term ''scientific discipline'' essentially as a synonym to ''field'' of science. However, as the preceding analysis implies, scientists go well beyond the notions implied by this broad descriptor when they refer to their fields of study as ''disciplines''. The term ''discipline'' definitely suggests that the origins, key events, and individuals that previously pursued such areas of study are known and understood and, most importantly, sanctioned in some manner by those currently engaged in the same area of study.

Beyond this, the term ''discipline'' clearly introduces a political dimension into descriptions of the various areas of science. The truth of this statement is verified by the thriving existence of the discipline-based scientific societies, such as (in the U.S.) the American Physiological Society, the American Society of Biochemists, and so on. The Federation of American Societies for Experimental Biology and Medicine (FASEB) is an umbrella organization of six such science societies, the members of which are employed primarily in medical educational institutions in the U.S. FASEB thus represents a large proportion of the current body of biomedical scientists in dealings with government and civil agencies — largely for the purpose of supporting public funding for biomedical research.

All scientific societies today serve as the meeting grounds of scientists for purposes of communication of their work and also to organize as advocates and representatives of these disciplines in various arenas, such as education, government, foundations, and so on. Most importantly, however, as mentioned, the very existence of a given scientific society signifies that the members recognize a common history of the origin of the field and of the key events that currently define the field (see Figure 4). New members of such discipline-centered societies usually acquire this knowledge through the mechanism of various formal educational programs that grant Ph.D. and M.S. degrees.

VIII. EVOLUTION AND GROWTH OF THE BIOMEDICAL DISCIPLINES

The root origins of each of the basic biomedical disciplines that we recognize today were in fact much more mundane than we might have expected. Each "basic discipline" sprang, one by one, from increasingly organized attempts by physicians in institutional settings to educate other physicians about the practice of medicine and, eventually, about the basic causes of human diseases. This is why the first of the recognized biomedical disciplines was human anatomy in which the object was simply to better understand the structural elements of the human body. Since the physician's primary instinct was to treat his patients, the periodic emergence of a few physicians willing to structure a set of educational experiences and requirements for the "guild" was a decided benefit to promoting their legitimacy and maintaining the status of their occupation as physicians.

From the viewpoint of the evolutionary path of bioscience disciplines, anatomy preceded all others by more than 1000 years. Physiology took shape as an outgrowth of anatomy. It began to take on some formality in the early 1600s at the University of Leyden. In fact, published in Leyden in 1708 was Herman Boerhave's small textbook, *Institutione Medicae*,[5] which became the 18th century guide for the teaching of the basic sciences to medical students. Boerhave specifically covered anatomy and physiology and several other topics. Thus, anatomy and physiology began to emerge in a more formal sense at this time. Histology required the invention of the microscope to become a reality, and the same can be said of microbiology. Both of these disciplines arose in the 18th century. Interestingly, both were probably the first instances in history where a technological advance launched a biomedical discipline.

As an example of a well-established biomedical discipline in the sense of the term today, the field of physiology emerged slowly over hundreds of years. However, typically, its emergence has come to be identified with singular identifiable events. William Harvey's discovery of the circulation of blood and his calculations of the amount of blood pumped by the heart in unit time are the events that most biomedical historians mark as the beginning of modern physiology. Harvey's 1628 publication *Exorcitatis Anatomica de Motu Cordis et Sanguinis in Animalibus* can be considered to be the effective birthdate of modern physiology.[3] However, some historians consider our old friend Galen to be the father of physiology, as well as anatomy, by virtue of his recognition that the pumping heart was the source of the pulse. Yet Galen did not understand the basic concept of blood circulation. He believed that the heart simply pumped the blood into the vessels in a "to and fro" motion, the pulse arising from the forward thrust and its release.

As the scope of each of the early biomedical disciplines increased, it became necessary to continually define new subdivisions, which eventually became "disciplines", as the knowledge pool expanded. Physiology gave birth first to "physiological chemistry" (or biochemistry)[6] and then to pharmacology, endocrinology, and eventually, neuroscience. Microbiology gave birth to virology, and, certainly, the *de facto* existence of bacteria and infections gave immunology its start. However, immunology was launched as a clinical entity even before microbiology began to take shape. Immunology was born when the English physician Edward Jenner discovered, essentially by accident, a method of vaccination against smallpox in England in the late 1700s.

As mentioned earlier, two of the strongest underlying drives for development of each of the biomedical disciplines were first to understand the fundamental bases of life processes and the underlying causes of various diseases, as well as to develop the basis for complete prevention of the disease, and, second, to provide a mechanism for communal reassurance that the contemporary members were pursuing the right questions and, further, were reaching answers that had collective agreement. In the purely clinically oriented disciplines of medicine and dentistry, at least up to rather recent times, much if not most clinical research has been directed primarily toward therapy of the disease once it became manifested (obviously, the "treaters" syndrome is still alive and well) — not toward complete prevention. However, the same human drives and purposes that drive the Stream S societies, again whether or not explicitly recognized, governed the Stream H healers and their modern professional organizations, i.e., the need to seek informed consensus in not only their treatment regimens, but in their research endeavors.

IX. DENTISTRY — A PARALLEL PATH OF DEVELOPMENT TO MEDICINE

There have been many excellent books and reviews about the history of dentistry, and we refer the reader to these for full treatment on this subject.[7-11] Our intent here is to simply summarize the earliest records of interest in dental disease. More importantly, we recognized a need to explain how the dental healers embarked on a different course from that of the medical healers very early in human history — a viewpoint that differs from that of many current dental historians and academicians. Yet, it is a viewpoint that provides a basis for understanding not only why dentistry split from the mainstream of medical education, but how the discipline of oral biology developed as an independent biomedical discipline. The reasons why formal dental education developed much later than medical education are the key to understanding the viewpoints developed in this article.

X. CARIES, AN ANCIENT THOUGH BENIGN DISEASE

Tooth decay and the accompanying pain provided the earliest impetus to render dental treatment, and these rudiments remain the cornerstone of dentistry even up to the present time. Perhaps the earliest reference to tooth decay and its pain comes from the ancient Sumerian text, discovered on a clay tablet, known as the ''Legend of the Worm''.[12] The clay tablet was excavated from an ancient city in the lower Mesopotamian area of the Euphrates Valley, which dates from about 5000 B.C. The cuneiform text refers to the creation of the heavens, the Earth, and the marshes; the latter created the worm (Figure 5).

The medical historians of ancient India, Egypt, Japan, and China also make reference to the worm as the cause of toothache. The Chinese developed and used acupuncture as early as 2700 B.C. to treat various diseases, including the pain of dental decay. The legend of the worm is also found in the writings of Homer, as well as the great surgeon of the middle ages, Guy de Chauliac (1300 to 1368 A.D.), who still espoused the belief that worms caused dental decay.[13] The Egyptians were perhaps the most advanced of the ancient civilizations prior to the Greco-Roman age. The Papyrus Ebers, written about 1500 B.C., is one of the most important medical papyri to be discovered, containing ideas copied from older papyri extending back many centuries. Of the 50 sections of the Papyrus Ebers, only *one* is devoted to the diseases of the teeth, which were treated by incantations (see Figure 5) and local applications of chemical and vegetable substances.[13] However, such therapies, as well as others such as fumigation, were essentially the same common treatments that were applied to a variety of the human illnesses then prevalent. In fact, the ancient physicians of both the Egyptian and Greco-Roman civilizations also treated the pain of tooth decay. As we shall see,

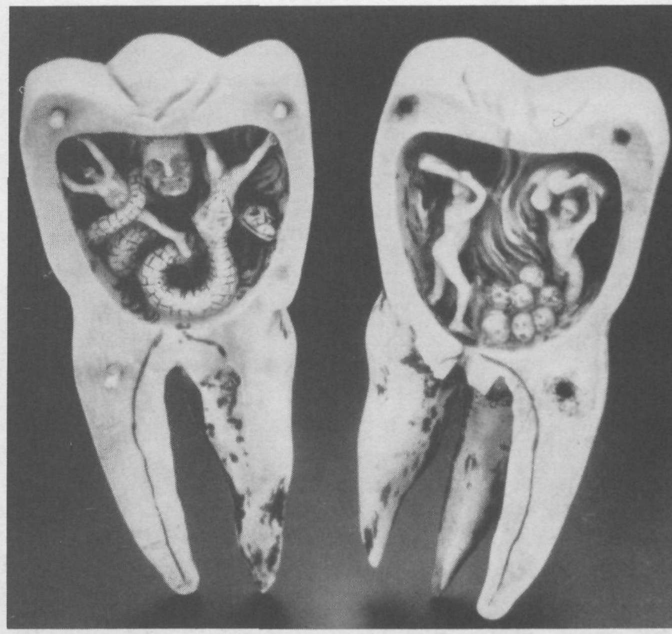


FIGURE 5. The toothworm. Perhaps the earliest document that referred to the ''toothworm'' as the cause of toothache and dental disease is an incantation inscribed on a Babylonian tablet dating from about 7000 years ago.[14,15] About 1780, an artist in Southern France carved a replica of a human molar tooth about 4 in. high. It can be opened into the two halves displayed here to reveal, on the left, a toothworm devouring a man and, on the right, the torment of hell.[11] The text of an incantation from a Babylonian tablet, of which the following is the translation,[9] is an appropriate accompaniment to this carving:

After Anu created the Heavens
The Heavens made the earth,
The earth made the rivers,
The rivers made the canals,
The canals made the marsh,
The marsh made the worm.
The worm came weeping unto Shamash,
His tears flowing before Ea:
''What will you give me for my food?''
Shamash answered
''I give you ripe figs and apricots.''
The worm responded
''What good are dried figs and apricots to me? . . .
Set me amid the teeth and let me dwell
Between the teeth and gums, so I may suck the . . .
Blood of the tooth and chew the meat of the gums . . .
So shall I hold the latch of the door!''
To this Shamash said
''Since you have said this, Oh worm,
May Ea strike you with her mighty fist.''

This is the magic ritual: Mix together beer, millet meal and oil . . . Repeat the incantation three times and then place the salve on the tooth.''

Anu was the God of Heaven and head of the Council of Gods. Shamash was the Sun God and God of Justice, and Ea was the God of Earth and Water. Similar incantations against toothworms appear in the Egyptian Papyrus Anastasi dating about 3150 years ago (Townsend, 1938).

the treatment for this affliction was perhaps the earliest, predictably effective therapy in the history of medicine, and this led to what may well be considered to be the first "specialty practice" of medical antiquity.

XI. DRAMATIC INCREASE IN THE PREVALENCE OF DENTAL CARIES IN THE 19th CENTURY

Archaeological and anthropological evidence indicates that both dental caries and periodontal disease existed in all the ages of civilized man. However, by more recent standards, caries occurred relatively infrequently in early man — probably due to a much different diet than eaten by modern humans. It follows, therefore, that the treatment needs for dental diseases, compared with the treatment demands for all of the other diseases and afflictions suffered by humankind, and all treated by the physician, were proportionately very small until about 1850.

Studies by Moore and Corbett[16-19] of the dentition of Britons in various periods, extending from the Anglo-Saxon Era of the Iron Age, up until the late 19th century, are very revealing (Figure 6). Their studies, summarized by Nikiforuk,[20] demonstrated that until about 1850, overall caries prevalence was quite low and, further, that gum line lesions (a disease that we now associate with an aging population) made up a major proportion of the caries experience. After 1850, coinciding with the increasing availability of cane sugar and refined flour, much of the diet of the newly industrialized English working class consisted of bread, jam, and highly sweetened tea. From that point in time, there has been an explosive increase in dental caries lesions, especially in the occlusal fissures. It has only been within the last decade or so that this high prevalence of the disease has shown a decrease, at least in the advanced countries.

The explosive increase in dental caries, and therefore dental pain, abcesses, and their sequelae, which began during the 19th century as demonstrated by Figure 6, produced a great demand for therapists who could deal with this problem. In an earlier era, the event that marked the beginnings of a separate and parallel path of development for dentistry as a healing profession was the discovery that a toothache could be overcome by the extraction of the offending tooth or teeth. This discovery was undoubtedly made independently scores of times in human history and passed on from generation to generation in the various societies and tribal cultures around the world by word of mouth and then taught by the apprenticeship method. The explosive increase in caries during the 19th century created a great demand for individuals trained in tooth extraction and dental restoration. Such individuals became, essentially, a distinctly separate branch of the healers' stream (see Figure 1).

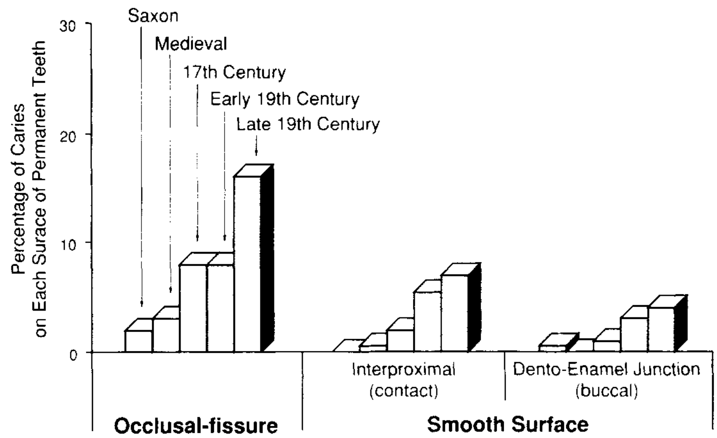


FIGURE 6. Natural history of caries in British populations since the Saxon Era. Percentages of carious lesions on specific surfaces of the permanent dentition from jaws retrieved from graves representing progressive eras of British populations. In sequence for each of three tooth surfaces are the mean caries percentages of the Saxon Era, Medieval, 17th century, early 19th century, and late 19th century Britons. (Modified from Nikiforuk,[20] which in turn was modified from Moore and Corbett.[16-19])

XII. THE EMERGENCE OF THE BARBER-SURGEONS

Interestingly, one of the earliest known references to the therapeutic extraction of teeth as a method not simply to relieve toothache but to treat systemic disease comes from the writings of the physician to the king of the Assyrian Sargonid dynasty (668 to 626 B.C.). He wrote as follows: "The inflammation wherewith his head, hands, and feet are inflamed is due to his teeth; his teeth must be extracted . . . "[12] This was surely the first recognition of the fundamental biological identity and connectivity of the teeth with all other body tissues. So, in a sense, it might be the very earliest reference to knowledge by an individual that today would be considered to represent "oral biology and oral medicine". Yet, the Assyrian physician's perceptions were well beyond the historical mainstream of development of medicine and dentistry of his period.

As mentioned above, the event that thrust the development of dentistry as a healing profession onto a separate — though parallel — path to that of medicine was the fact that toothache could be cured by the simple extraction of the tooth/teeth causing pain. Compared with the many ills and pains of our ancestors, many of which continue to plague us today, here was a health problem for which there was a simple and almost invariably successful treatment and cure. The treatment was direct, visual, and mechanical. It involved learning how to perform a relatively simple manual skill. The therapist used his hands, instruments, and techniques to rid the body of the offending tooth, disease, and pain by simply "pulling" or "drawing" the tooth. In contrast to almost all systemic illnesses that occurred before the relatively recent (during this century) discoveries of insulin and penicillin, the dental diseases that caused pain — tooth decay and periapical/periodontal abcesses — could almost invariably be cured by the toothpuller without the use of drugs. This fact led to the class of therapists in the middle ages and well beyond known as the ''barber-surgeons''. As the term implies, these individuals were often barbers by primary occupation and learned how to extract teeth through limited apprenticeships to others.[21] No matter how painful tooth extraction may have been, the barber-surgeons were eminently successful health practitioners in that they stopped the continuous agonizing pain of the chronic abcess. Their treatments must also have prevented a multitude of systemic complications from such oral foci of infection (though the latter was not recognized as such).

Campbell[22] has described both the itinerant tooth drawers who plied their trade in Europe throughout the 16th to 18th centuries and the trained barber-surgeons who practiced in Scotland during the same period. He noted that large towns in Scotland had guilds of barber-surgeons trained in Edinburgh. The barber-surgeons provided services in minor surgery, including tooth drawing, dressing wounds, shaving, hair cutting, and wig making. Campbell[22] contrasted the barber-surgeons to the itinerant tooth drawers of 17th century Scotland. The latter were characterized as '' . . . arrogant mountebanks — who promised cures for every disease including toothache — (and who provided) — lively entertainment for the credulous mob.''

By the 19th century, the practice of dentistry in both Europe and North America was highly variable and generally of low quality. The better-educated dentists (though still not educated *as* dentists) were very few in number and had to compete with many poorly trained barber-surgeons and tooth drawers. Early 19th century dentists in North America commonly combined their dental practice with another skill or trade, such as blacksmith, shoemaker, tailor, photographer, or even beer seller.[22]

No matter how poorly the barber-surgeons might be viewed when compared with modern dentists, they served the needs of the times. They also represented a very different class of ''healers'' from the physicians of their time; the barber-surgeon's treatments were simple and mechanical, but almost always successful. In contrast, beginning with the ancient Greeks, the physicians' therapies were based on entirely different models and expectations. From the age of classic Greece, the physician had always been well educated in the broadest sense of the term. Also, by nature of their often ambiguous tasks, physicians have been very adept in the ''comforting'' or bedside role. However, until the relatively recent development of an effective scientific base of therapy, such as the use of insulin and penicillin mentioned above, the physician's healing role was primarily the same as that of the nurse today, essentially providing the time and psychological support that enabled natural healing to take place. Until the 20th century, there were only two therapies as direct and certain in the physician's repertoire as the simple extraction of a tooth to treat a debilitating disease: one was the setting and immobilization of a simple fracture or dislocation and the second was the amputation of a gangrenous or otherwise grossly infected limb. Even amputation could not have been very successful until the advent of general anesthesia and the development of antiseptic surgery. The latter was made possible by the efforts of the physician Lister, while anesthesia in the form of nitrous oxide and ether was first administered by the dentists Wells and Morton, respectively.[21]

This dichotomy — the early recognized efficacious treatment of dental disease by tooth extraction by a class of workers perhaps best characterized as mechanics vis à vis the historic role of the physician in ''treating'' the widely varying symptoms of systemic disease, with widely varying degrees of success — accounts for our contention that medicine and dentistry separated very early in history as different health professions. One was very pragmatic, direct, and mechanically oriented: the other was more subjective and ''people-skills'' oriented. Of equal importance, each profession became rooted increasingly in separately developing bases of information. It was not until about 100 years ago that the evolving basic biomedical knowledge base began to become equally useful to both professions.

Today, there are huge differences between a ''basic biomedical discipline'', such as physiology or oral biology, and the healer-oriented clinical professions of medicine, dentistry, and nursing. In the latter cases, the basic relationship is between the sick individual ''patient'' and the individual ''healer'' who counsels and intervenes in a fundamentally private and nurturing manner, often employing the most subjective and private methods. A biomedical discipline, in contrast, is impersonal and highly focused. Its basic purpose is to understand the scientific basis of life itself, as well as the basic causes of the diseases that threaten life. The hypotheses, methods, experiments, and data that form the fabric of the scientists professional life must be published and continually reexamined. In recent years, neuropsychological research has indicated that even the basic personalities and cognitive style of the modern Stream H and Stream S practitioners are markedly different.[23-25] This fact, perhaps startling to some, is apt to become an increasingly important consideration in decisions concerning medical/dental education and research, especially with respect to programs directed toward the training of personnel. Interestingly, these major differences in the fundamental cognitive development, style, and the personality characteristics of the two streams of practitioners may also explain the early divergence of Stream S from Stream H in history. Certain physicians in history (some of the most prominent examples being individuals — such as Galen, Vesalius, Harvey, and Bernard discussed earlier) found themselves drawn to seek the fundamental questions of the biology of the human species and the basic causes of the diseases that afflicted the species, rather than to blindly accept the prescribed treatments of their era.

XIII. BEGINNING OF DENTAL EDUCATION: FORMALIZING THE HISTORICAL SEPARATION OF DENTISTRY FROM MEDICINE

The modern, institutional era of dentistry began with the establishment of the Baltimore College of Dental Surgery in 1840. The Baltimore College was the first dental college in the world.[21] However, during the explosive growth in population and geographic expansion of the U.S. during the 19th and 20th centuries, numerous proprietary dental colleges or schools sprang up in the new and growing towns and cities of the U.S. The peak number of such schools perhaps exceeded 100 near the turn of the century. (Some of these small schools may have left no historical trace.)

The initiation of formal, university-affiliated dental education provided the environment that eventually led to the development of those individuals who were interested in dental science and research and who would eventually launch the field of oral biology (see Figure 4). At the same time, dental education in the U.S. was divided between a few high-quality institutions and a relatively large number of proprietary schools of widely varying quality. The latter educated individuals through apprenticeship methods focused largely on the techniques of tooth extraction and denture construction. Thus, in the last half of the 19th century, U.S. dental education appeared to have led the world in innovation, perhaps because it was undergoing a period of continual reassessment and volatile and exciting growth.

Several major forces were at work in the U.S.: there was movement toward affiliation of the best proprietary dental schools with established universities; there was at times resistance by the medical faculties of the same institutions toward this new class of university-affiliated health professional; there was resentment by those proprietary dental schools that had no chance of achieving university affiliations. Eventually, the enhanced status of those dental schools that were achieving university affiliations produced increasing public concern about the quality of training provided by proprietary dental schools, leading to their inevitable failure. The demise of the proprietary dental schools in the U.S. marked the beginning of the end of the barber-surgeon era of dentistry worldwide (with the exception of the Far East).

XIV. THE BEGINNINGS OF ORAL BIOLOGY: WILLOUGHBY D. MILLER

With the benefit of hindsight, we can detect hints of the emergence of oral biology as a biomedical discipline with the publication of the book *The Microorganisms of the Mouth* by Willoughby D. Miller.[26] Miller was an American dentist living in Germany (Figure 7). He was one of the early graduates (1879) of the Philadelphia Dental College and thus one of the earlier formally educated dentists in the world. He also may have been the first dentist up to that time who had a thorough training in the natural sciences[27] and who was interested in understanding the biological basis of the dental caries process (in short, a Stream S personality). Miller had studied mathematics and physics at the University of Michigan, Ann Arbor, from 1871 to 1875. Initially intending to follow this interest, he went to Edinburgh and then Berlin, but found himself in severe financial straits. Befriended in Berlin by an American dentist, Frank Abbot, the course of Miller's life became dramatically altered. He married Abbot's daughter and Abbot financed his return to the U.S. to pursue his dental education in Philadelphia.[27]

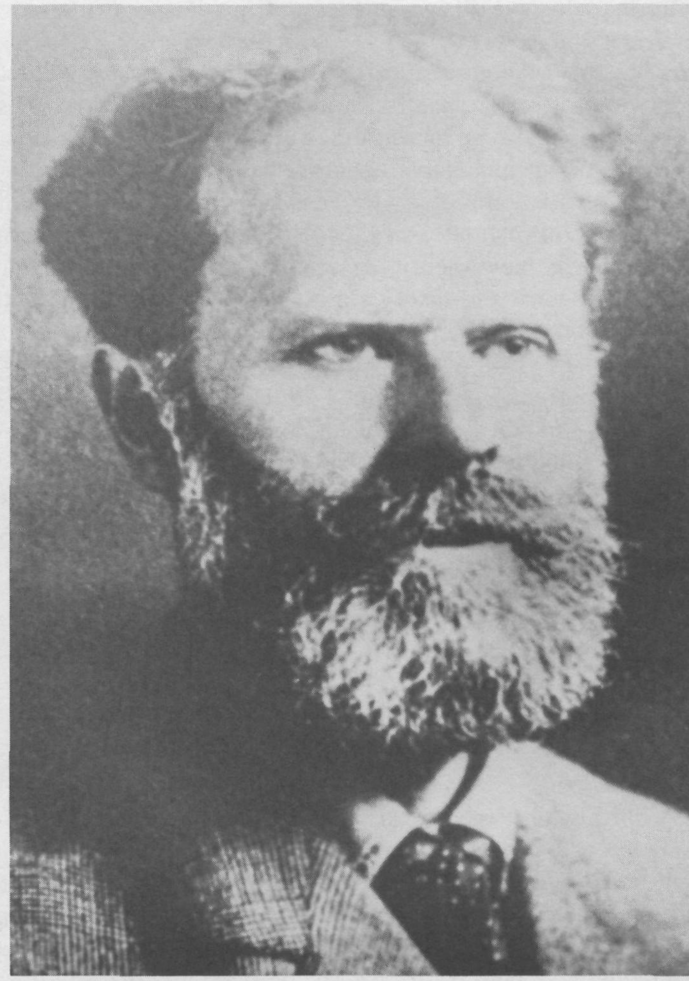


FIGURE 7. Photographic portrait of Willoughby D. Miller.

After receiving his dental degree, Miller returned to Berlin, where he became an associate practitioner in the office of his father-in-law and continued his studies in science — especially microbiology. The science of microbiology was in the process of enormous advance under the influence of Robert Koch. The vicinity of Miller's small laboratory to Koch's institute may explain the interest that he developed in Koch's work, especially in light of Miller's background in science at the University of Michigan.

In his small laboratory, Miller performed extensive studies of the oral microflora and its relationship to dental caries. His residence in Europe exposed him to the discovery by Pasteur that microorganisms convert sucrose to organic acids. By integrating this key discovery by Pasteur into his knowledge of the oral microflora and caries, Miller coined a "catchy" term to describe his new theory of caries — the *chemicoparasitic theory*. The term and theory simply assigned the role of acid production (i.e., "chemico") to the oral microflora (i.e., "parasitic").

In his book, Miller[26] examined critically the earlier theories of caries formation. In general, there were three main ideas at the time about the origin of caries. One was that it was provoked by excessive or improper food consumption, resulting in the putrefication of protein food fragments. This supposedly gave rise to ammonia that subsequently oxidized to nitric acid that destroyed the teeth (the "chemical" or acid theory).

A second theory was an outgrowth of the "tooth worm" concept described earlier. By this time, it was felt that the worms were very minute and that they bored holes in the teeth. Later, this concept evolved into the "parasitic theory", following the discovery that microorganisms can have toxic effects on tissue.

A third theory, the "vital theory", had been advanced toward the end of the 18th century; this theory postulated that tooth decay originated from within the tooth similar to bone gangrene ("bone caries"). Miller[26] provided cogent reasons to reject all three of these theories.

Among the citations provided by Miller[26] was that of Leber and Rottenstein,[28] who had also combined the two concepts embodied by the acid and parasitic theories. Miller suggested, however, that Leber and Rottenstein had wrongly concluded that the bacterial acids softened the enamel and that bacteria of the leptotrichia class invaded the enamel to further soften and extend the lesion.[26,28] Miller[26] contended that there was no such acid softening and bacterial invasion of the enamel.

In fact, 7 years before the publication of his book and theory, Miller[26] stated that "I am not an advocate of the pure acid theory of caries nor of the pure germ theory; I believe rather that both acids and fungi are concerned in producing caries."[29] In his classic book, Miller[26] set forth his chemicoparasitic theory based on several years of additional experimentation and on the works of others, as mentioned above. Another example of the full citing in his book was his credit of the work of Milles and Underwood,[30] who had stated in their 1881 paper that acids produced by germs caused decalcification.

Miller's investigations identified carbohydrate as the probable bacterial substrate of caries and he distinguished between the decalcification produced by bacterial acids and the proteolytic destruction of the organic phase.[26] He also noted that decalcification results in total destruction of enamel (irrespective of proteolysis) because of its low protein content.[26]

Thus, Miller[26] significantly enlarged on the Milles and Underwood[30] concept. However, more importantly, the details of his work, the publication of his book, and his term *"chemicoparasitic"* captured the attention of those interested in understanding the cause of dental decay. Further, he became viewed as a formal student of Robert Koch, which ensured that his work would receive appropriate attention from the evolving scientific community. In fact, it appears that Miller had been only a keen student of Koch's work. Oddly, Miller ignored Koch's specific infectious agent concept of disease as it would apply to dental caries. Of course, the specific infectious agent concept was the foundation of Koch's famous "postulates". Instead, Miller maintained that any and all of the acidogenic microorganisms of the mouth contributed to the caries process. Equally strange, Miller did not identify dental plaque as an entity in caries, although he was well aware of the presence of microbes on the tooth surfaces and in carious lesions. He assumed instead that fermentation of impacted carbohydrate foodstuffs occurred *in situ* by salivary microorganisms throughout the mouth, and he considered starch to be more detrimental to the teeth than sugar.

XV. IDENTIFICATION OF DENTAL PLAQUE AS THE CAUSE OF CARIES

In the 17th century, Antonie van Leeuwenhoek had observed by means of his microscope (which he invented as noted earlier) the living, wiggling "animalculi" that he had scraped from his own teeth. Also, in the landmark book discussed above, Miller[26] had quoted the observations of both Erdi[31] and Ficinus,[32] who had both described microorganisms in the "membrane" on teeth. However, it was not until Black[33] published his findings in 1898, that the entity of dental plaque and its full implications were realized. Black's work was based on many years of clinical experience and experimentation.[33] Both he and a contemporary researcher, J. L. Williams, described the "gelatinous microbic plaques", and each was of the opinion that caries was due wholly to attack from acids produced by bacteria in these plaques.[34] As we will discuss, Black's overall standing in dentistry at this time undoubtedly contributed to the attention that his work on dental plaque received.[33] Thus, the juncture of Miller's[26] chemoparasitic theory, with the description of the dental plaque by Black[33] and Williams,[34] provided the key elements for our modern concept of the etiology of dental caries. This concept has since stimulated considerable scientific investigation and as a result it has become one of the essential paradigms of oral biology.

XVI. G. V. BLACK: PIVOTAL FIGURE IN THE HISTORY OF DENTISTRY AND ORAL BIOLOGY

Born in Illinois in 1836, G. V. Black became, in our view, the most influential figure in the history of dentistry (Figure 8). His only rival in this respect was Pierre Fauchard, the French dentist, who wrote and published the first comprehensive dental textbook.[7] While Pierre Fauchard has probably remained more renowned worldwide, we suggest that G. V. Black's contributions, in the long run, will place him in the premier position in the history of dentistry and oral biology. Black's range of interest and knowledge was impressive, participating in musical and dramatic arts as well as in traditional medical problems. While there is little doubt that his primary interests in dentistry lay in the traditional clinical arena, he also pursued areas that we consider today to fall under oral biology. In fact, the historical impact of both Black and Miller (who were contemporaries) in dentistry and oral biology is somewhat analogous to that of Galen and Vesalius in medicine and anatomy (who were definitely *not* contemporaries). Galen launched the separation of the two streams of medicine in the intellectual sense. Vesalius consummated Galen's creative genius by virtue of his careful attention to detail, his access to the artistic virtuosi of his time, and mass printing. Both Galen and Vesalius were physicians, but their efforts resulted in the development of an entirely new enterprise of medicine — bioscience (in their day — anatomy). In a similar vane, Miller and Black were two of the earliest formally educated dentists in the world (and this has occurred only within the last 100 years!). With the acceleration of advances in every field brought about by mass printing, Miller and Black benefitted from all of the preceding history of science, yet they still remained products of the much earlier traditions brought about by the separation of the practice of dentistry from practice of medicine that we have described. Since the first ''biomedical scientists'' were physician-anatomists, then, later, physician-physiologists, and so on, it is not surprising that the first oral biologists were dentists. What is surprising is that the corporate body of modern dental educators has not reached an ''informed consensus'' that the ever-growing stream of oral biology knowledge *must* become incorporated into the foundation of dental education — in the same way that medical education embraced the earlier developing biomedical disciplines.

This is one reason why G. V. Black is such an important historical figure. Very early, dental educators recognized Black's genius in the traditional clinical realm. Black's clinical contributions were not only very important in their own right, but they came at an opportune moment in the history of dentistry. First of all, his continual experimentations with the mixtures and contents of the silver amalgam restoration brought about a recognized methodology for producing uniform excellence in this restorative material (perhaps the first ''standard'' in dentistry). He also set forth concrete steps and principles for the preparation of the teeth for dental restorations.[21] Black's methodological work in restorative dentistry came at a critically important time for dental education — just when the universities were tentatively embracing dentistry as an independent health profession. The principles and techniques that he de-

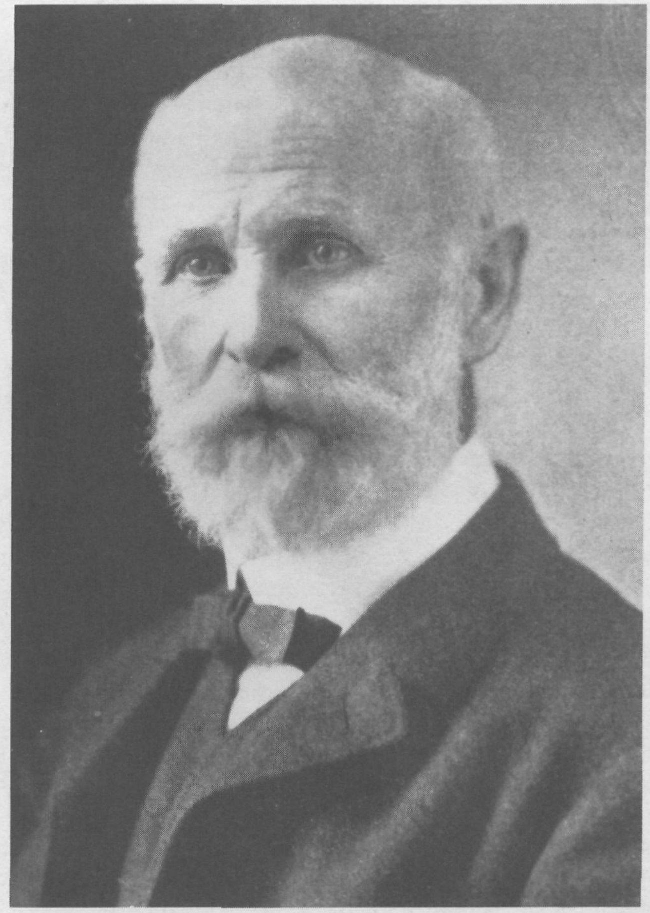


FIGURE 8. Photographic portrait of G. V. Black.

scribed for dental restorations were of the same order of detail as the surgical principles and methods then being taught in the medical schools. These facts helped to ensure for dental education its incorporation into the university family, along with the ''other professional disciplines'' of the period, exemplified by medicine and law.

It is interesting that Black's contributions to restorative dentistry were, in a sense, in consonance with the traditions of the barber-surgeons. As was the case for tooth extraction, good restorative dental techniques also relieved toothache; restorations, too, were mechanical, and they were very effective, although the excellent dental restorations developed by Black were certainly not as simple or as easily executed as the treatment of the barber-surgeons. The point is, however, that these effective mechanical treatments remained in the tradition that originally led to the separation of the healers of dentistry from the healers of medicine.

As mentioned, however, Black was interested not only in perfecting the treatments of the dental diseases, but in understanding their causes. He was certainly among the first to use a microscope to study the intricate internal structure of the tooth. Some of the principles of his cavity preparation precepts rested on these findings. In fact, his use of the microscope to examine the structure of the teeth led to his observations of the presence on the surfaces of teeth of a densely matted bacterial coat. As noted earlier, it was the eventual merger of Black's dental plaque concept into Miller's chemicoparasitic theory, which provided the basis for the central paradigm of oral biology regarding the basis of dental caries. However, this key contribution of Black (and of Williams) did not receive the attention that it deserved. It was finally the identification of the microbial agents involved in the caries process that eventually provided the keystone that cemented the contributions of Miller, Williams, and Black into the modern paradigm of the etiology of dental caries.

This series of events provided the initial thrust that contributed substantially to the eventual emergence of oral biology as a recognized biomedical discipline. However, this perception of oral biology as a biomedical discipline clearly was not evident in Miller's and Black's era. Rather, recognition of oral biology as a discipline required a series of developments and events that we will discuss in a future article.

Another contribution by Black, sometimes overlooked today, was his collaboration with McKay in describing the condition of fluorosis.[35] From our perspective today, it appears that McKay may have approached Black to lend credibility to his original observations. This is indicative of Black's standing in the world of dentistry during this period of its history. The McKay-Black alliance will provide our entré into the story of how fluoride came to be recognized as an effective decay-preventive agent.[35] The alliance of these two perceptive and inquisitive men, both born in the mold of the Stream S traditions, will be an important part of the next story in this article of historical perspectives of oral biology.

XVII. EARLY 20th CENTURY REFORMS IN MEDICAL AND DENTAL EDUCATION

This chronicle of medical and dental history has provided evidence for our suggestion that very early in its history medicine began to develop a gradual demarcation in the practice of its art from its science. It was not until the early 20th century that this evolutionary movement became formalized with the organization of the earliest biomedical societies, together with their impact on medical education. The dawn of the 20th century also coincided with the beginnings of great ferment in medical education in the U.S. Many historians believe that the major impetus for this ferment was the formation of the American Physiological Society (APS) in 1896.[36] Of the 28 original founders of the APS, many became deans of medical schools in the U.S. (including most of the "elite schools"). Their concern over the uneven quality of U.S. medical education led eventually, with the support of the American Medical Association, to the formation of the Carnegie Commission on Medical Education and the appointment of Abraham Flexner to head a study of U.S. medical education.[37] The commission's work culminated in what has become known as the "Flexner Report" issued in 1910.[38]

By far, the most important recommendations of the Flexner Report were related to what we have described here as the two major streams of biomedical science knowledge. The commission recommended that the curriculum of medicine must include a thorough grounding in what we have termed in this article "Stream S" knowledge — in other words, the "basic sciences" of Flexner's day. Yet there is no indication that this prestigious commission recognized the very early origins of the two major streams of biomedical knowledge and practice that we have described. Instead, the Carnegie Commission's impetus derived essentially from their perception of the political exigencies of the times. They understood that they *must* incorporate the burgeoning basic sciences, whose presence and impact were already obvious in the best medical schools of the day, into the structure of medical education as a whole. Thus, the fundamental reform of American medical education in the first half of this century is a dramatic demonstration of the political impact that the great societies of science can have on the course of human events. In this case, the effect has been the dramatic improvement of medicine from a "treater" to a true, "healer", profession.

Just as U.S. medical education began to emerge from this time of ferment, there began a similar period of reexamination and turmoil in dental education. There were several outcomes of these efforts. One was the Gies Report, issued in 1926, which was very similar to the Flexner Report in its recommendations regarding the incorporation of the "basic sciences" into the dental curriculum.[39] Since dental education made its historical entré into the university environment long after medical education (see Figure 1) and since the Stream S biosciences were already established in the medical schools, the obvious path of compliance for dental educators to correct the deficiencies identified by the Gies Report was simply to utilize the already established basic science departments of the medical schools for the biomedical science instruction of the dental students.

There is no doubt that the Flexner Report has set the course for medical education in the decades since its issuance. However, the Flexner Report had a much greater impact on medical education than the Gies Report had on dental education. The Flexner Report guaranteed that the medical schools would not only remain the certified *home* of the developing "basic sciences", but that medical schools would continue to attend to and enlarge on their support of the basic sciences to retain their legitimacy. While the Gies Report also recommended a foundation in dental education of the same basic sciences that were recommended by the Flexner Report, universities and their newly acquired dental schools were forced by fiscal realities to utilize the basic science departments already established and staffed by the medical schools for the instruction of the dental students (a logical position from the viewpoint of the universities, especially when unchallenged). Hence, dental clinical faculties and administrators never took basic science instruction of the dental students quite as seriously as their medical school colleagues. Furthermore and perhaps even more damaging is the effect that all of this has had on the progress of basic research on the two primary dental diseases. The corporate body of dental education in this country has required an inordinate amount of time to mount a serious, strong, and sustained effort on the basic causes of the two primary dental diseases. Were it not for the essentially serendipitous discovery of the beneficial effects of the fluoride ion on dental caries, there may well have been little perceptible advance today in the prevention of dental disease.

Thus, the acquiescence by dental schools to engage the faculties and facilities employed and developed by a different administrative unit of the universities contributed to how the priorities and agenda for dental education have been set since the issuance of the Gies Report. In other words, these priorities were set in the essential absence of the corresponding Stream S scientists in the decision-making councils of the dental schools. This fact produced a very different *Zeitgeist* (or intellectual environment) in the dental schools compared with the medical schools in the U.S.

It was not until the emergence of the first departments of oral biology in the dental schools at the University of Manitoba in Canada in 1959 and the University of Buffalo, now the state University of New York at Buffalo, in 1960 in the U.S. that a different concept began to emerge of how dentistry might be able to better incorporate biomedical science into both dental education and research. In the 1960s and early 1970s, there was a steady growth of oral biology departments or programs in U.S. and other dental schools.[40,41] Since then, along with slower university growth in general, there has been a slowing of this movement. Other reasons for this slowing have been a shortage of properly trained oral biologists and a shortage in funding for such training. There has also been resistance in some dental schools to incorporate oral biology into the dental curriculum. This resistance seems to stem from an insufficient understanding of how medicine, dentistry, and the biomedical sciences have evolved and are likely to develop, as well as the inherent difficulty always encountered when established views and positions are being challenged by new ideas.[42] This response is ironic because oral biology is the only biomedical science discipline whose origins are clearly traceable to dentistry and whose natural home should reside in our dental schools.

More importantly, from the health economics viewpoint, slowing the pace of development of oral biology is probably also responsible for retardation of the pace of development of a modern concept of dental practice, i.e., one that involves understanding and dealing with the dynamics of oral disease and preventing it or treating it in its earliest stages of development rather than focusing almost exclusively on repairing the ravages of readily visible and established dental pathology.

XVIII. SUMMARY

From antiquity, individuals, tribes, and cultures have sought the abilities of singular individuals to try to heal them or to help them to endure the onslaughts of disease. For thousands of years before recorded history, these services were provided by the medicine man or shaman of the tribe, whose secret treatments were passed from generation to generation by the apprenticeship methods of teaching. For the most part, their therapies were at best palliative and their effects were placebo and psychological in nature.

Reliable written records of healing practices began with the ancient Greek civilization about 400 years before Christ. The written recording of rational therapies and practices established the "physician" as one of the premier occupations (or "professions") of ancient Greek society. About 160 years after Christ, the Greek physician Galen began the practice of examining the post-mortem anatomy of various animals and extrapolating his findings in an attempt to understand the structure of the human body. This was the first well-recorded and documented effort in what we, today, would term "biomedical research".

While Galen's efforts and written production were massive, his impact on medical practices beyond Greece was minimal due, at least partially, to the lack of mass printing and distribution methods. Ironically, at almost the same time that Galen's complete works were published, Andreas Vesalius of Brussels published the most startling and exquisite book in the history of medicine. Vesalius' *De Humani Corporporis Fabrica* (1543)[2] was a lavish and beautiful exposition of human anatomy. This event, for all intents and purposes, formalized the separation of the science of medicine from its art. We suggest that this event established the division of medicine into two historical streams — the "healers" and the "scientists" (or Streams "H" and "S"). However, even to the present, the biomedical scientists remain dependent on the established institutions of the healers for their very existence and continuity.

Very early the dental healers developed as a distinctly separate branch of the H Stream, due to the efficacy and directness of the therapy of tooth extraction and the need for mechanical aptitude for its execution. This was exemplified in the long and successful history of the barber-surgeons, or their earlier equivalents, as therapists in every society on Earth, including the U.S., up to nearly the turn of the 20th century.

The final separation of the dental healers from their medical colleagues was consummated by the beginnings of formal dental education with the establishment of the Baltimore College of Dental Surgery in 1840. The beginnings of oral biology as a biomedical discipline though not recognized as such occurred not long after this with two publications — W. D. Miller's book *The Microorganisms of the Human Mouth* in 1890[26] and G. V. Black's descriptions in 1898 of dental plaque.[33] Both men were dentists and therefore they followed the traditions that initiated each of the earlier biomedical disciplines. In other words, as we have described, the first anatomists, the first physiologists, and those who launched each of the succeeding biomedical disciplines were, almost invariably, physicians. However, the events and studies that marked the beginnings of each of these disciplines were often not recognized as such for very long periods (e.g., hundreds of years).

The early separation of the practice of dentistry from medicine, and the eventual establishment of formal dental education, essentially ensured that dentistry would have to develop a basic science discipline of its own devoted to the study of the biology of the mouth, in order to undergird its educational separation from medicine. Certainly, the earlier "basic science" disciplines, which had become firmly rooted in the medical schools, exhibited very little interest in the biological processes of the mouth. This lack of interest was rooted in the early separation of dental practice from medical practice.

From the small beginnings of the Miller and Black era, oral biological knowledge has burgeoned and such knowledge has opened the door to new approaches and techniques to reduce the prevalence of caries and periodontal disease, while at the same time developing a base for dealing with other oral and systemically related disease conditions. There is little doubt that the Stream H, healing side of the health professions will continue to be required for *individual* treatment and care of members of a society, but more certain is the fact that the health of *populations* will be increasingly more dependent upon knowledge of causes and dynamics and therefore on the biomedical scientists of Stream S. In dentistry, many of these scientists refer to themselves as "oral biologists".

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