Journal
AMERICAN COLLEGE OF DENTISTS

IN THIS ISSUE:

Boston 1942-1947  By the Editor
Presidential Address  Wm. N. Hodgkin
Inaugural Address  L. R. Main
Amelogenesis  James Nuckolls,
Henry M. Leicester and
Benjamin Dienstein

Dental Education: Objective and Purpose

American College of Dentists:
Meeting of the Board of Regents
Minutes of the Convocation

American Association for the Advancement of Science

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Journal

AMERICAN COLLEGE OF DENTISTS

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Announcements

Next Meeting, Board of Regents: Chicago, Feb. 7, 8, 1948.
Next Convocation: To be announced.

Fellowships and awards in dental research. The American College of Dentists, at its annual meeting in 1937 [J. Am. Col. Den., 4, 100; Sep. and 256, Dec., 1937] inaugurated plans to promote research in dentistry. These plans include grants of funds (The William John Gies Fellowships) to applicants, in support of projected investigations; and also the formal recognition, through annual awards (The William John Gies Awards), of distinguished achievement in dental research. A standing committee of the International Association for Dental Research will actively cooperate with the College in the furtherance of these plans. Applications for grants in aid of projected researches, and requests for information, may be sent to the Chairman of the Committee on Dental Research of the American College of Dentists, Dr. Albert L. Midgley, 1108 Union Trust Bldg., Providence, R. I. [See “The Gies Dental Research Fellowships and Awards for Achievement in Research,” J. Am. Col. Den., 5, 115; 1938, Sep.]
AMERICAN COLLEGE OF DENTISTS

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Journal

AMERICAN COLLEGE OF DENTISTS

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DANGER WITH OPPORTUNITY

While this is the most dangerous era the world has ever known, it is also incomparably the greatest opportunity to build and develop a future that will far transcend anything in the past.

—Dr. John R. Mott.
FOR A PERIOD OF FIVE YEARS, THE EYES OF THE DENTAL WORLD HAVE BEEN LOOKING TOWARD BOSTON. IT MAY APPEAR A LITTLE BOASTFUL TO MAKE THE ABOVE STATEMENT AS BEING TRUE IN 1942, FOR AT THIS TIME PERHAPS IT WAS THE EYES OF THE DENTISTS OF NORTH AMERICA ONLY OR AT LEAST, CHIEFLY. HOWEVER, IN CONSIDERATION OF ALL THAT HAS HAPPENED ALL OVER THE WORLD DURING THIS FIVE-YEAR PERIOD, IT IS TRUE NOW THAT THE "EYES OF THE DENTAL WORLD" WERE LOOKING TOWARD BOSTON.

It proved to be strategic that Boston should be the meeting place this year. It was in Boston that the first act leading toward the Revolutionary War and American Independence was committed—forever to be remembered as "The Boston Tea Party." It was in Boston too, that Paul Revere, a dentist, became the messenger arousing a citizenry to action. It was in Boston too, that education in the United States had its beginning. Dental education skipped Boston landing in Baltimore, but not so very far away. Boston takes second place in this. However, in the year of our Lord, 1947, Boston was, for a period of two weeks, the center of all there is in dentistry. It was really a dental mecca. It was a mecca and only recently the British Foreign Minister, speaking at a Fourth of July dinner in London referring to our acts of those years gone by said, "we are glad you did it."

Beginning on Monday, July 28, with a meeting of one of thirty associated groups and concluding on Saturday, August 9, with the closing session of the Federation Dentaire Internationale, there was but one continuous round of activity. Add to this the fact, that many of us had not met during those years, and had therefore, to renew old acquaintances and make new ones. Including the House of Delegates with five sessions and the Trustees in almost constant session, there were twenty agencies, commissions and committees, holding
meetings. It was a busy time and a busy place. It may not be out of order to consider the meeting in its results through its various aspects.

SOCIAL ASPECT

The College (American College of Dentists) is in its nature a social organization, that is to say, its chief function is the promotion of professionalism and ethical relationships. These are to a degree promoted through research promotion. The College will not continuously finance research, but it will promote by financing over a short period of time. The results of this have been and are apparent as reference to the journal over the years will show.

The convocation, the first in five years, was well attended. A class of sixty-five was inducted into Fellowship and the appreciation of all was apparent. The colors, the platform, the procession, the intent, the seriousness with which it was taken and the carrying out of the ritual, all conduced to the emotional pleasure of Fellows and friends. It brought about full realization that we were returning to our regular practices, it brought hope out of despair, and it sent us out for the week and for the year, with renewed faith and desire. The College is truly most helpful in an arduous life.

The morning program was devoted to a round table discussion on the subject of dental education, followed by a luncheon and speaker. In the evening dinner was followed by introductions, a speaker and the induction of Dr. L. R. Main into the office of President. It was a good day in which great good was accomplished. Addresses, and committee reports will be published in the Journal in due time. Among the committee reports, it is probable that the one most interesting and the most vital, was that submitted by Dean Sloman of the College of Physicians and Surgeons, San Francisco, on the subject, Socio-Economics. Herein one will see, succinctly stated, possible future trends. It is well to be warned. From the standpoint of the purely social, the Fraternities played their usual part.
ORGANIZATIONAL ASPECTS

The American Dental Association, of course, heads the list. Because the Association held a meeting, all the rest did too. The attendance was good—the program was full—every place was crowded. The atmosphere was full too—full of heat. The master of the furnace turned it on full force. But the temper and the temperaments of all were splendid and everyone learned something. Out of it all there seemed to be manifest three principal needs and one obligation.

The needs are:
2. Better care of older people (dental geriatrics).
3. Public Relations.

The obligation is:
1. To balance the budget.

These are days of high prices, high salaries, yes, high everything, except ladies’ skirts—they are being lowered, but at that they are higher—more cloth, more cost. Income doesn’t come up to outgo in many cases—the ADA is one—the two stand apart by $300,000.00. The trustees and officers were told to manage affairs, and balance out, with a resolution passed by the House of Delegates to raise the dues to $6.00 per year beginning January, 1949.

In view of all that we are doing and need to do; in view of all that we have and want to have; in view of the need for research and the value to dentist and patient; and in view of our needs and obligations, in so many ways, this seems well to do, and little enough as to cost.

RESEARCH ASPECT

Much research is being carried on and in many different fields. That, in the Bureau of Standards is, of course, outstanding and of real value. The most recent has to do with the silicate cements and it does seem that their greater usefulness is now possible. Much is
being done in other places, referring particularly to fluorine and penicillin and their use in caries prevention. Watch your journals for reports.

INTERNATIONAL ASPECT

With all the organizations, committees, and so forth, in session; with all the reports of all the various kinds—from research on; with all the papers and discussions read; with all the clinics presented; with all the social enjoyment and consideration of possible social trends; with all of this and much more if presented in detail, there was one which stood out above all others—the International Aspect.

The Federation Dentaire Internationale (F.D.I.) held its 35th session and included with or a part of it, the 10th International Dental Congress.

These meetings were made possible by and through the courtesy of the American Dental Association and which was done with great pleasure, indeed. Forty-one nations were represented in this gathering. Probably the presence of those from other nations provided greater interest among us than any one thing. It was pleasant to fellowship together and this personal touch meant much to everyone. They were eager to know what we are doing in the professional field and many of them (nationally) having been shut off from progress for so long a time, found themselves in great need and here was a feast. It is a fact that if we in the U.S.A. or of the North American continent felt the possible loss of the years, how much more did they!

The President of the F.D.I., Dr. A. E. Rowlett of England, has been here several times and is quite well known now. Henceforth, we shall know him better and we shall know his associates. We know more now of other nations, and with travel and communication time reduced so greatly, what may we expect in the future?

The meetings are now history. The results are with us for our assimilation and use. May it all conduce to the betterment of us all—both doctor and patient!
PRESIDENTIAL ADDRESS
WM. N. HODGKIN, D.D.S., President

Warrenton

Custom has dictated that the president of the American College of Dentists shall outline plans for the year's activities in his inaugural address. Hence, in usefulness and taste, it appears to follow that the indicated duty of the retiring officer is to report,reserving for his successor the natural and helpful privilege of outlining his policies and plans for the coming year.

Indeed, insofar as the immediately passing administration is concerned, that too may be dispensed with quite briefly and sufficiently as merely a faithful attempt, in cooperation with the other officers and Regents, to encourage as far as possible the obvious and reawakening spirit of the College over the past year. It is, however, both instinctively fitting and incumbent to express personal appreciation and congratulations to the committee members and others who have contributed so splendidly to dentistry through the medium of the College. The outstanding contributions of many are held gratefully in mind.

The program which has been arranged for the twenty-second Convocation of the College is one offered with a heartening and genuine feeling of satisfaction by your officers and Regents. The round table discussion on the theme of "Dental Education" and the committee reports to which you listened this morning—coupled with future reports of this afternoon—will reflect accurately the alertness and sound approach with which several committees have undertaken studies, and will further indicate the extent to which their thinking and work have been projected in pursuing the purposes of the College. Balanced by additional features and addresses, the program seems certain to lend admirably to the work for which our organization was founded and to the profession we seek to serve.

1Delivered at the Convocation of the College, Boston, Aug. 3, 1947.
In this year of renewal of annual convocations after a considerable lapse, there was a common view among the officers on the opportuneness and helpfulness of a review of the purposes for which we are organized and the mechanics under which we operate. Accordingly, acceding to this view, Secretary Brandhorst will in a succeeding address, acquaint you with much information touching the objectives, the functional organization and the long-range influence of the College. That address will serve a double purpose. It will make clear many sound procedures about which presently there is likely confusion, and it will free me from traditionally imposed presidential duties in interpretation of objectives to follow my own bent in observations.

Since this is the initial Convocation not only for those who have today been admitted to Fellowship but also for those of our Fellows of the past five years, it would seem that we might approach a sort of family discussion of the ceremonial and the appointments of the College as used in annual Convocations and the induction of Fellows. Though I confess no great confidence in giving more satisfactory expression to deep feelings and inspirational values in this instance
than in many other rooted ideals by which we live, it does seem a peculiarly appropriate time to attempt such discussion—just when we have completed a ceremony which was performed in taste, in dignity and in stateliness.

Here, in what we believe a fitting manner, we have shared in conferring Fellowship on a number of our confreres in recognition of their accomplishments and their known adherence to the highest ideals; and in so doing we have renewed our fidelity to those same ideals. Yet, to an outside observer or to one scarcely attuned to the spirit of the moment and lacking appreciation of its real meaning, such a ceremony might be regarded as a vainglorious pursuit for serious professional men. Here, symbolic of a daily cherished attachment to the ideals represented, we have followed the torch and mace of the American College of Dentists. To the uniformed they could be merely ornamental objects of a meaningless ritual; to the informed they could, and should, be instruments of symbolism through which the highest ideals of a profession are set forth and embraced in constancy. To the end that we may be informed, permit a review of the salient details and symbolism of the torch and mace as related at the time of their dedication on July 16, 1939.

THE TORCH

The torch is of bronze, gold plated. On it are engraved the names of the organizers and founders of the College. When dedicated in impressive ceremony at Milwaukee, the then living organizers and founders present, seated in groups at the four points of a darkened room, arose carrying lighted candles and with measured steps moved to the center of the room. Here they joined and moved up to and in front of an altar to the unlighted torch and simultaneously touched their lighted candles to it, thus lighting for the first time the symbolic torch of the American College of Dentists. The President then spoke:

"On behalf of the Fellows of the American College of Dentists, I accept
this torch and consecrate it to the high objectives to which the College is committed, and dedicate it to the memory of those constructive builders who have passed to their reward, and in honor of those who have been and are now active in the advance of dentistry. Those well known and likewise those who, in modest careers of usefulness, have done what they could to elevate dentistry in public respect and appreciation.\textsuperscript{2}

THE MACE

Forming the upper hemisphere of the mace, the seal of the College is emblematic of the principles and objectives of the College. The figures immediately below the hemisphere represent the College Officers and Regents, and show them actively supporting the College seal, which is emblematic of their duty to keep ever aloft the College principles and objectives.

The figures stand on, and are firmly supported by, the lower hemisphere of the head of the mace, representing the College membership, and is emblematic of the whole-hearted support by all the Fellows of the College in all its undertakings. The College itself is symbolically indicated by rose and lavender crystals, the College colors.

The stem or shaft of the mace is divided into three parts: The upper end represents the dental profession as a whole, and indicates the intimate relationship it has with the College and the College has with it, namely, that of service to the profession at large. The middle of the shaft is ornamented on one side with clasped hands and on the other with a replica of St. Apollonia, the patron Saint of Dentistry. The former symbolizes the College’s friendly attitude toward all sincere and worthwhile endeavor and suggests that the friendly touch of human hands builds in time a mutual esteem. The replica of St. Apollonia is to remind us that the spiritual phases of life’s activities are essential to progress, human comfort and happiness. Immediately below is placed a row of green crystal inserts. The color, green, represents the profession of medicine and is used

\textsuperscript{2}J. Am. Col. Den., 6, 207; 1939 (Sept.).
to denote the interdependent relationship between medicine and dentistry:

The President, in accepting the mace, spoke as follows:

"On behalf of the Fellows of the American College of Dentists, I accept this mace and dedicate it for all time to come, to unselfish and inspirational leadership. May it ever be found in the vanguard of every righteous cause; may it ever lead us onward to more noble objectives, and, should the occasion demand, may it be used like its prototype, as an instrument of destruction against all influences subversive to the forward march of dentistry in all of its activities."

On the spirals of the mace are inscribed the names of the Immortals of Dentistry. Possible inscriptions are recommended, with supporting citations, by the Committee on History for the approval of the Board of Regents, and are authorized only after such searching and careful study that likely it becomes the outstanding and most select honor extant in dental records.

The names thus far inscribed are:


1940 (Baltimore Centenary)—Solyman Brown, Eleazar Parmly.

1940 (Cleveland)—Jonathan Taft.

Such then is some of the symbolism which is embodied in the ceremony we have just shared. Despite its lofty challenges it has not always been fully approved by all, and has even been the subject of public criticism. Whether such public outburst has been a sequel of the College journalistic policy—since the criticisms have appeared in periodical pages presumably affected by such policy—I am not prepared to say; nor do I impute them as being prompted by a sort of defense mechanism. Perhaps it would be more helpful if we regarded them as sincere and genuine reactions.

The reaction of individuals and of groups to formal observances is an interesting study, and those varying reactions have engendered

\(^3\)J. Am. Col. Den., 6, 211; 1939 (Sept.).
differences from earliest times. Especially in our own democracy was there developed almost from the beginning an inherent resentment by many to any deviation from the common way; in a sizable segment of the citizenry any refinements in customary manners or any departure from the simple crudities has at once been labelled pretense, high-hat and undemocratic. While such study in reactions is interesting, it may not here be pursued at length. Let me cite but one illustration which may be in point, and at the same time, I fear, may stamp my own provincialism.

In the Commonwealth of Virginia, as likely, in contiguous territory, there has persisted from earliest Colonial days a dislike of the high-church practices which mark the services of the Church of England. Among many the dislike appears to have diminished but little since Patrick Henry inveighed against the clergy sent from England by the established church. Despite the prevailing and traditional low-church leanings of Virginia, quite naturally others of high-church tendencies have joined as citizens. One of the distinctive practices of the high-church, as you doubtless know, is a genuflection—a bending of the knee, accompanied by a slight bowing of the head—as the name of Jesus Christ is voiced in the recital of the Apostles Creed. Now there were two venerable gentlemen in my church, quite as reverent as any in the parish and stronger in faith than most. But so steeped in tradition were they and so positive in their reactions that, when others at the proper juncture in the services practiced the genuflection, they made certain that they performed not the slightest observance by instinctively stiffening up and actually rearing back.

The instinctive and amusing performance of these two gentlemen we see often repeated in reactions to observances that touch our ways, and there seems no reason to be too concerned about them or to contend strongly pro or con. Criticisms stemming from such reactions I think may be passed as of not particular concern save as they are echoed and shared within our own group, and as they affect
the spirit of that group. It is necessary only that we maintain a sense of proportion and fitness, coupled with informed understandings.

In the foregoing there is no connotation or concession that ceremonial and formal observances which carry with them dignity, taste and inspiration are useless. A strong argument may be made for the use of tangible objects of symbolism which enable man to seize on and to strengthen the profound and inexpressible ideals which lie deep within him. Precious and of tremendous value is anything which captivates the intellect and enlists the heart in loftier manner. To scoff at all symbolism is to scoff at the cross and the flag which throughout history have inspired men to their greatest and noblest heights.

As touching our individual reactions and our response to recognition as well, how many of us here, in becoming modesty, may have asked ourselves the question: “Why was I selected to Fellowship in the American College of Dentists?” We may get part of our answer from an attentive and reflective reading of the inscription on the Certificate of Fellowship, which indicates that the honor was conferred—“In recognition of his contributions and devotion to the science and art of dentistry.” This studied expression, in which devotion as a measure of worthiness to Fellowship is in parity with contributions, is significant. It indicates a belief that those chosen for this honor will become increasingly responsive to the highest ideals of professional conduct; it implies a confidence in continuing accomplishment in keeping with those ideals. It unquestionably means that a mere satisfying of any supposed requirements in contributions, without the coupled unselfish devotion to a profession, is not a determinant qualification for Fellowship. Does it not also connote the expectation that an existing devotion will be heightened when shared and recurrently expressed with others of a like cherish of the fullest professional life?

In any searching and detached study of reactions to observances, and criticisms born of those reactions, it is perhaps well to remember
that the only genuine and valid criticism against which history finds a true indictment is that of making a fetish of observances to the neglect of the spirit and the performance of works. The fault of the Pharisees, for instance, was not that they "made broad the phylacteries upon their foreheads, and enlarged the borders of their garments," but rather in substituting utterly those outward observations for good works.

It must be conceded that the stated elevated aims and tenets of the College make incumbent that we as Fellows portray those standards as faithfully as is possible in our daily professional lives. If there were a noticeable lack of such careers, we could be seriously concerned about the health and the intended influence of the College. But allow me, as one privileged to have served in several capacities in the College, over a period of time, to observe that I have seen generally just such faithful portrayal by devoted men. I, and you too, have seen the unselfish service of the College at work.

This being true, we may think of the College as representing a dignity in achievement to which young men, starting their careers, may aim; something to bolster their hope and spur their determination to so practice and live as to be deemed worthy of recognition by inclusion in its fellowship. If the College has that meaning—and I am persuaded it has—we can see readily its incalculable and splendid influence. If we can keep it with that meaning, we may join in warm enthusiasm in its works and with confidence in its unbounded usefulness to dentistry.
INAUGURAL ADDRESS

L. R. MAIN, D.D.S., President-Elect, St. Louis

I wish first to acknowledge the honor conferred upon me last October in Miami, Florida, by making me president-elect of the American College of Dentists. That action gives me the privilege of standing before you on this occasion in the city of Boston, a city and a community steeped in the traditions of patriotism and national pride and rich in leadership in the fields of education and research.

The opportunity afforded us today to discuss dental education from many angles indicates that dentistry has advanced tremendously in its scope and influence. New vistas have appeared on the horizon which beacon us on to even greater heights. In such an atmosphere as this, I wish to thank you for the honor which is mine, as I assume the leadership of the College. For the coming year, I covet the loyal support which you have given my predecessors, and which support and cooperation has made possible the successes which we all enjoy.

"History repeats itself," is an old and well known phrase. And so it is that here in Boston, the College was founded in 1920. From birth on through the years of adolescence and young adulthood, our forefathers have paved the way of progress for the College, until today its beneficial influence is felt wherever dentistry is practiced. We have returned to the place of our birth for this, the first post-war convocation, and are proud of a membership of some 1,200 well and carefully selected men, who have already made some definite contribution to the advancement of the profession in a personal way. And we believe also that the College has increased the prestige of dentistry everywhere by the concerted effort of the entire organization.

From time immemorial the health of the people has engaged the attention of the best minds of every age and that is still a quest. For more than a century, dental education has endeavored to cope with the ever advancing spread of dental diseases. Through some

1Delivered at the Convocation of the College, Boston, Aug. 3, 1947.
channels, especially in restorative dentistry, marked successes have been realized. In other fields of dentistry much remains to be accomplished. Of course the College does not speak for the profession in any official capacity, but it can initiate investigation in some fields, and, by recording results and through publication, this effort can be and is of service to the entire profession. This applies to several avenues of endeavor. I might say that to carry forward investigative effort of a research nature represents one of the finest channels through which the College gives expression to the ideals for which it was organized.

The program of the College presented today was built around dental education. What a challenge that is. This represents, however, but one foot of the tripod upon which dentistry has been solidly established during the first century of its organized existence. Dental education, thus conceived is that important. As such, it is usually limited to the confines of the class room, the laboratory and the clinic of the dental school. However the borders of dental teaching are not limited to these confines. Blauch\(^2\) says, "The character and progress of a profession depends very largely upon its teachers. Through the teachers, the future practitioners have their first intimate contact with the profession. The teachers determine in a large measure what these young men will learn, what professional attitudes they will develop, what ideal they will espouse."

This conception of the responsibility of the teacher in the dental school is weighty indeed. But a measure of that responsibility devolves upon every man engaged in practice. We of the College particularly, should recognize and assume this responsibility, which is, to set such an example by precept before the young practitioner of dentistry in our community, that he will endeavor to emulate his neighbor dentist because of his high idealism for the profession and for the character of services rendered to his fellow man.

The influence of example in every walk of life is one of the most compelling forces for advancement in any realm. A dentist chosen to become a Fellow of the College has already shown traits of leadership and ability to carry responsibility; otherwise, he would not fit into the company of the College. Dentists become members by invitation and not by application, and that invitation suggests the necessity of having already done more than the average practitioner in his community. In fact, that by so doing, his services attract the attention of other high minded men. In this connection, I should like to suggest a theme for the coming year. A theme may serve as a directing hand to guide us upon the highway of professional life. This theme is the result of a recent conversation with an educator in one of our leading universities. I asked this college professor, "What do you think is one of the weaknesses in dentistry today?", and after due thought he replied: "One of the weaknesses which I occasionally note is the lack of a true conception of a professional man's position in life." He implied by his remark that a professional man's outlook on life should be more idealistic and that to render service to mankind, especially to suffering mankind, is really one of the great privileges and one of the great opportunities of life; therefore a great responsibility. Hence the theme for the coming year is Professionalism vs. Commercialism.

I am cognizant of the fact that there are certain business principles involved in maintaining a dental office, but these principles must be a means to an end and that end is to better serve the patients who honor us by placing into our hands their personal health problems. We are not selling them a tangible commodity, the value of which they are in position to judge, but we are rendering a service and they are forced to trust to the integrity of the professional man as to its worth and value to them in meeting a certain deficiency from which they are or may later be suffering. This dignifies the calling of a profession and places it on a higher rung in the ladder of success. It also indicates that an additional responsibility is placed upon our shoulders.
For the Fellows of the College, I should suggest that we assume some such conception of responsibility towards our younger practitioners, so that we might influence them to a greater and better appreciation of true professionalism.

While in school the student usually becomes imbued with high ideals and looks upon a forthcoming practice as a great privilege and opportunity to serve his patients. Sometimes after graduation he may become disappointed because he discovers that the building of a practice is a longer process than he had anticipated. Cutting corners and cutting prices is a temptation to which he may succumb. Let us make it our real concern as older and more experienced men to help such an one to recapture his high idealism so that when practice finally comes to our young friend, he will be able to render a service in keeping with the principles of the College and the precepts of his teachers.

The danger of becoming too commercialized during the war days was a real threat to many, because of the tremendous pressure under which service was rendered. With plenty of patients and all able to pay, the tendency to get, while the getting was good, could easily have turned many otherwise true professional men into paths of lowered vision, lowered ideals and lowered service. The principles which undergird the framework of the College are high and noble, placing above everything else the spirit of true professionalism.

I would urge, Fellows of the College, that you support the sections to which you belong. An occasional meeting of your section at an appropriate time can do much to deepen our interest in the best that the profession has to offer. Such associations enable us to maintain a level of service much above the average, and is conducive to personal improvement in the things that count most in life.

These are busy days, too busy to give time to things of secondary importance, as the main issue of life. Let us weigh well our heritage, our lofty idealism, put first things first and draw the line consistently sharp between professionalism and commercialism.
AMELOGENESIS

AN INTEGRATION OF THE KNOWN FACTORS CONCERNED WITH THE DEVELOPMENT, FORMATION AND MINERALIZATION OF ENAMEL.

JAMES NUCKOLLS, D.D.S., HENRY M. LEICESTER, Ph. D. 
and BENJAMIN DIENSTEIN, D.D.S.

I. PREFACATORY STATEMENT

The histology and biochemistry of teeth have been presented in the literature, for the most part, as two almost unrelated sciences. Although there is a growing application of biochemistry to the field of histology, to date no concise attempt has been made to present these sciences in a way so as to inter-relate them with the subject of tooth development.

The purpose of this paper is to present the known factors concerning the histochemistry of amelogenesis in as complete a picture as possible, depicting the events in enamel development as they occur and integrating the many and often isolated researches in biochemistry and histology. It should be emphasized that all of the changes which occur in enamel development cannot be explained through the medium of a single science but require a working knowledge of many sciences.

It is recognized that many of the processes which have to do with enamel formation are not clearly understood at this time; however, it is felt that a fairly complete overall picture can be presented, and a definite attempt has been made to interpret and integrate the facts as they are now known.

The authors have attempted to include in this paper the many considerations necessary for a basic understanding of the processes which obtain in amelogenesis. They have drawn their material from

aFrom the College of Dentistry, University of California and the College of Physicians and Surgeons, San Francisco, California, and supported in part from the Robert Nuckolls Research Fund.

bNuckolls, James, Professor of Operative Dentistry, Lecturer in Oral Pathology and Chairman of the Division of Preclinical Sciences, University of California, College of Dentistry; Leicester, Henry M., Assistant Professor of Biological Chemistry and Librarian, College of Physicians and Surgeons; and Dienstein, Benjamin, Instructor in Operative Dentistry, Section of Oral Pathology, University of California, College of Dentistry. See end of article for footnotes and illustrations.
many sources and have made a sincere attempt to give full credit to those whose work has been utilized; however, they assume the sole responsibility for the interpretation of these papers.

We should like to acknowledge the contributions of Dr. John Eiler, Associate Professor of Biochemistry, College of Dentistry, and Dr. J. B. de C. M. Saunders, Professor of Anatomy, School of Medicine, University of California, and many others who, by their counsel and criticisms, have made this paper possible. We would also like to express our appreciation and indebtedness to Mr. Walter Schwarz for his excellent schematic portrayal of the processes herein described and to Mrs. H. Whitaker for secretarial assistance.

II. INTRODUCTORY REMARKS CONCERNING THE PROBLEM OF AMELOGENESIS.

At varying intervals of time and at definite positions in the developing maxilla and mandible, specific organizers act in the basal cells of the oral epithelium causing these cells to proliferate into the mesenchymal tissue and establish the precursor of the tooth bud. The embryonal structure does not continue to undergo a uniform expansion, but the deeper part does begin to invaginate. The peripheral cells of this epithelial mass may be divided into two parts; those of the deeper part continue to invaginate to form an inner layer called the inner enamel epithelium (Fig. 1-M), while those of the remaining portion of the periphery assume the appearance of cuboidal epithelial cells and form the outer enamel epithelium (Fig. 1-C). The cells between these layers undergo a change which is characterized by an increase in their cytoplasm. The small amount of intercellular substance together with the relatively greater amount of cell cytoplasm tend to give the area a stellate appearance. This structure is called the stellate reticulum (Fig. 1-B). Concomitant with the development of the stellate reticulum those cells nearest the distal end of the inner enamel epithelium undergo a morphological rearrangement and appear as several layers of low
squamous epithelium. This layer is called the stratum intermedium (Fig. 1-D). The cells of the inner layer of the bud establish the morphological contour of the crown. They undergo further differentiation to form tall, columnar cells, or ameloblasts. This histodifferentiation is accompanied by a change in the cell polarity; the nucleus shifts to the distal end of the cell (Fig. 1-G). This site of change first occurs at the apices of the cusps, at which time intercellular bridges may be seen extending between the cells. It is at this stage of development that the first elements of the enamel matrix are laid down and the first mineralization of this matrix takes place.

Although it is the undifferentiated cell which enters into the formation of the dentino-enamel limiting membrane, full maturity of the cell is required for the formal elements of the organic rod to make their appearance. The enamel-forming cell now has become a highly specialized structure whose function is the formation of an organic matrix which is keratinous in nature. The matrix undergoes a progressive maturation in the region of Tomes’ process (Fig. 1-E) to form the adult rod and inter-rod matrix. Following maturation the organic rod undergoes a mineralization.

The process of enamel formation is carried on by the ameloblast, which in its primitive form constitutes the stratum germinativum of the oral epithelium. The enamel-forming cell begins to deposit the organic matrix of the enamel at the dentino-enamel membrane (Fig. 1-O). As the matrix is laid down, the ameloblast extends outwardly from the dentino-enamel membrane until the entire thickness of the enamel is complete. It has been shown that each ameloblast is responsible for the deposition of one column of enamel which, in its final form, is called an enamel prism. When the formation of the enamel is complete, the ameloblast undergoes a striking reduction in size and a change in its cytological characteristics. The nucleus becomes progressively pyknotic and the cytoplasm contains many vacuoles (Fig. 1-L). Just prior to reduction the cell forms the organic matrix of the primary cuticle as its final
product (Fig. 1-K). This cuticle is continuous with the ends of the calcified organic rods and inter-rod matrix substance. The matrix of the cuticle is homogeneous in character and undergoes a dense mineralization which, in the end, exceeds that of the main body of the enamel. With its calcification, the hard, surface layer of the enamel is formed and covers the ends of the calcified rods and inter-rod substance.

The adult enamel rod is regarded as a product of ameloblastic function, being in part a transformation and secretion of the cell to form the organic matrix which undergoes mineralization. These rods are separated by an organic interprismatic matrix which also becomes mineralized.

Mineralization of the organic matrix begins shortly after the formal elements of the matrix are laid down. The deposition of the calcium complex in the organic matrix progresses from the dentino-enamel membrane toward the surface as the matrix is formed (Fig. 1-V, W). The calcium gradually increases in density as the enamel matures, until the greatest density is reached in the mineralization of the primary cuticle. The process of mineralization of the enamel is distinct from that of matrix formation, although both processes may be regarded as a function of cell metabolism. A more detailed consideration of these processes will be taken up in subsequent paragraphs of this paper.

III. THE AMELOBLAST

In the teeth of man and other animals the dentino-enamel limiting membrane (Fig. 1-O) or matrix is a positive structure laid down shortly after the ameloblasts begin to undergo differentiation and assume their characteristic tall, columnar appearance. The earliest evidence of cellular activity preceding matrix formation is an increasing granulation of the cytoplasm of the future ameloblastic cell followed by the appearance of a large terminal vacuole (Fig. 1-P) juxtaposed to the dentino-enamel membrane. This change in the functional end of the cell appears as the nucleus commences to retreat to the basal, or outer end of the cell. The
change in cell cytoplasm at the functional, or enamel-forming end is the progenitor of Tomes' process and is closely associated with the reversal in porality of the cell and the beginning of the development of that portion of the enamel matrix which will form the dentino-enamel membrane.

A further cytoplasmic change appears as the ameloblast approaches full functional activity and manifests itself in the development of an ovoid group of granules (Fig. 1-H) which occupy the interval between the nucleus and the distal extremity of the cell. These granules make their first appearance after the ameloblast approaches its maximum length and some matrix has been laid down. When the function of the enamel-forming cell is almost over and it becomes reduced in length, the granules appear to be fewer in number or may be absent (Fig. 1-L). Since earlier studies, there have been no additional researches to clarify their functional significance; however, their appearance and full development are, in some degree, evidence of high activity of the ameloblast.

Mitochondria and Golgi Apparatus: No cellular components have aroused more controversy than mitochondria and the Golgi apparatus. Their association with physiological reactions within the cell makes it imperative to consider them in any cytological or histological study. It is realized that the researches on these bodies in the ameloblast have been limited to a few studies. Their occurrence, however, makes it necessary to consider them at this time.

1. Mitochondria are elements of definite form in the cytoplasm of all cells. They lie freely in the cytoplasm and possess the power of independent movement and may take the form of filaments or rods and granules. They were originally described (1880-1889) by Altman and were for a time called Altman's granules.

Mitochondria can be seen quite clearly in tissue-culture cells under dark-field illumination. Here they appear in a state of constant movement. This movement consists of two types: a transposition of the whole mitochondrion from one part of the cell to
the other and a wriggling movement by the mitochondrion itself. In addition, filaments may break up into rods, and these rods may disintegrate into granules. Granules and rods may join up again to form filaments and the filaments may form temporary networks. Mitochondria have been seen to make a series of journeys from the nucleus to the cell membrane and back again. They tend to aggregate around the spindle in cell division, and as the result of the pinching of the cytoplasm, they are divided between the two cells in approximately equal granules. Fewer numbers of mitochondria are found in dividing cells, and a similar condition obtains in less healthy cells.

Mitochondria contain appreciable amounts of fatty material and probably adsorb an outer layer of protein.

That mitochondria are respiratory centers of the cells has been a popular thesis with cytologists for some time. Evidence in support of this contention is that young red blood cells of vertebrates have a higher respiratory rate and more mitochondria than older red blood cells. This concept, however, is disputed by some investigators who consider the evidence in support of this theory unsatisfactory.

Mitochondria are known to have considerable oxidizing and reducing power. There is also evidence that mitochondria possess enzymatic activity and probably proteolytic activity. There is apparently no connection between mitochondria and the Golgi apparatus; however, there is evidence that mitochondria give off material which is absorbed by the Golgi apparatus.

Mitochondria in the ameloblasts do not show any striking characteristics. They are in the form of filaments, short rods and granules which are fairly numerous and distributed throughout the greater part of the cytoplasm. Mitochondria in both the ameloblasts and odontoblasts seem to show little change in form in the region of the Golgi apparatus. From the evidence in the literature it may be assumed that mitochondria may contain vitamin A and
vitamin C, proteolytic enzymes and oxidases and are probably concerned with proteolytic activity.

2. The Golgi Apparatus has been described at various times as consisting of a fibrous reticulum network. In different cells the Golgi apparatus varies considerably in size and shape and is usually well developed in the stage of cytomorphosis. It tends to decrease in size as the cell becomes older. In gland cells the apparatus is noticeably large. As a general rule in vertebrate somatic cells the Golgi apparatus is in the form of a dense network situated near the nucleus. It may, however, vary according to the physiological state of the cell. In the developing germ cell the apparatus may be in the form of rods or granules. The extreme variability in the form of the Golgi apparatus makes it likely that the apparatus in life is in a state of constant slow movement.

In mitosis the Golgi apparatus usually breaks up into small particles or granules which are distributed more or less evenly throughout the cytoplasm. Cytoplasmic division causes an approximate halving of the Golgi substance.

The Golgi apparatus consists of two parts, an outer part which absorbs osmium and silver, and an argentophobic inner portion. There is a parallel increase in the Golgi apparatus and the vitamin C staining area in the liver after injection of Vitamin C. In scurvy in the marmot there is a roughly parallel decrease in the Golgi apparatus and vitamin C staining area in kidney and liver cells. From the above observations it appears that vitamin C is associated with the Golgi apparatus and appears to be intimately associated with cellular synthesis. It has been known for some time that in scurvy synthetic processes of cell are inhibited. Vitamin C is present in the Golgi apparatus in a wide variety of differentiating embryonic cells, and it appears to be concentrated in the Golgi apparatus of cells which are engaged in active synthesis of various substances. The apparatus appears to play some part in the differentiation of primitive cells, for it is active during histogenesis.

It will be recalled that during the transition of the primitive
ameloblast to the active state, there is a change in polarity and the nucleus retreats to the basal end of the cell (Fig. 1-A, G). The Golgi apparatus is net-like in form in the undifferentiated cell near the cervical loop and occupies a position in the cell cytoplasm between the nucleus and the outer end of the cell toward the stellate reticulum (Fig. 1-A). This position of the Golgi apparatus is similar to the position it has in the cells of the basal layer of the oral epithelium. During change of polarity, there is a striking migration of the Golgi apparatus to the opposite pole of the nucleus, or toward that part of the cell which approximates Tomes' process. The Golgi apparatus is transposed into the form of lengthened cords or strands as it passes along the sides of the nucleus to take up a position in the functioning ameloblast between the nucleus and Tomes' process (Fig. 1-A, F). This change in the apparatus is rather abrupt. Following the change in cell polarity it again assumes a rather compact, net-like structure which gradually becomes less compact with the lengthening of the cell. In the fully developed ameloblast the Golgi apparatus assumes the appearance of long, anastomosing strands which extend for some distance throughout the greater part of the cytoplasm between the nucleus and Tomes' process (Fig. 1-F). This striking change in the form of the Golgi apparatus might be interpreted as representing an increased activity on the part of the ameloblast. The apparatus remains constantly on the side of the nucleus toward Tomes' process in a general position comparable to the secretory zone of many gland cells. Each functioning cell possesses a compact, localized Golgi apparatus. Apparently no observations have been recorded as to the ultimate disposition of the Golgi apparatus when the functional life of the ameloblast terminates in its final reduction which accompanies the formation of the primary cuticle.

A summary of the literature seems to indicate that the Golgi apparatus appears to be involved in the passage of vitamin C across cells. The apparatus is concerned with changing polarity of the ameloblast and is closely associated with high functional activity.
in the cell. Because of its relationship to vitamin C and functional activity of the cell, it might be postulated that the Golgi apparatus may be directly related to the gelation of the matrix at Tomes’ process.

IV. THE ORGANIC ENAMEL MATRIX

(Fig. 4)

It has been previously stated that the formation of the enamel matrix commences with the laying down of the dentino-enamel membrane. The ameloblasts at first lie in contact with the underlying layer of differentiating odontoblasts with which they are imbricated giving rise to the well-known irregular appearance frequently exhibited at this junction. They are, however, separated from the odontoblastic layer by a delicate membrane which is apparently of ameloblastic origin (Fig. 1-O). Associated with the dentino-enamel membrane or matrix and seemingly continuous with this structure is another type of cell, a supporting cell or kinoblast. It has been shown to be a more slender cell than the ameloblast, with a narrow nucleus and its cytoplasm to be finely granular but more uniform. With routine stains it gives a more basophilic reaction. In the early stages of amelogenesis these cells are found either singly or in groups of as many as four or five at intervals between the ameloblasts. Because of their observed relationship to the dentino-enamel junction, they are considered to be modified epithelial cells which function as supporting cells in the development of this membrane. It is more difficult to distinguish these cells from the ameloblasts in the later stages of enamel development, but they may be recognized if special staining procedures are employed.

1. The Tomes’ Process

(Fig. 1, 2): Upon completion of the dentino-enamel membrane, the first elements of the enamel matrix can be determined. The cell membrane begins to thicken where it lies in juxtaposition to the dentino-enamel membrane (Fig. 1-N). A large terminal vacuole forms within the thickened membrane
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(Fig. 1-P). This vacuolated area is the beginning of Tomes' process. Shortly thereafter a substance similar to that found in the terminal vacuole is deposited on the lateral walls of the cell membrane between the cells. This deposition initiates the formation of the inter-rod substance.

The cytoplasm of the ameloblast in direct relation to the developing Tomes' process undergoes a definite condensation (Fig. 2-C). This condensed cytoplasm is succeeded by the clear area called Tomes' process, which contains minute refractile bodies spoken of as secretion granules4 (Fig. 1-Q, 2-I). These granules occur with the first appearance of the inter-rod matrix. The clear area is conical in shape with the base toward the ameloblastic cell. The conical part of the process appears to project for a variable distance into the core of the rod. This conical appearance of Tomes' process is accounted for by the consolidation or maturation of the lateral sides of the forming rod to a greater degree than in the center (Fig. 1-R, 2-H).

As the cell extends away from the dentino-enamel junction towards the outer enamel epithelium, it continues to elaborate the organic matrix of the rod which is first evidenced by the consolidation of the cell cytoplasm at the functional end of the cell (Fig. 2-C). This consolidation of the cell cytoplasm is closely followed by the elaboration of Tomes' process (Fig. 1-P). The lateral wall of this structure undergoes a maturation to a greater density than its core, which in the mature rod becomes the cortex of the organic rod (Fig. 2-L). The beginning maturation of the lateral wall of Tomes' process is first seen just short of the condensed cytoplasm of the functional end of the ameloblast (Fig. 1-R, 2-H). It appears as a delicately staining structure of greater density than the center of the vacuolated, clear, central area. As maturation of the lateral wall of Tomes' process proceeds, it forms the more densely appearing rod cortex of the mature rod (Fig. 2-H, L). This part of Tomes' process is called the pre-enamel process5-8 (Figs. 1-R, 2-H).
2. The Organic Rod$^{1,2,3}$ (Figs. 1, 2): The organic enamel rod consists of three portions from the surface toward the center: (1) the rod membrane which is continuous in its relationship to the cell membrane (Fig. 2-K), (2) the rod cortex (Fig. 2-L), and (3) the less dense center, or the core (Fig. 2-M), and an inter-rod matrix which occupies the intervals between the rods (Fig. 2-G).

The cortex is the thickened lateral wall. It is homogeneous and dense in its appearance and results from a progressive maturation first observed in the pre-enamel processes. It is the first part of the organic rod to undergo complete maturation and the first to undergo mineralization. The core, in contrast to the cortex, is at first not so completely matured when compared with the center of the rod. After an appreciable length of the rod has been formed, the cortex and the rod core undergo an almost equal degree of maturation. The organic substance of the rod core is not quite so homogeneous as in the cortex; in the inter-rod matrix it is even less dense. In the newly erupted tooth all of these early structural characteristics of the matrix can be identified and are identical with those of the developing stages. In older teeth the identification of the structures of the rod are more difficult since the histological staining is less intense. These changes indicate a progressive maturation of the matrix after eruption. If fixation of the protein matrix is incomplete in older teeth, parts of the core of the rod will tend to go into solution along with the mineral content of the rod during the process of decalcification. This intermittent loss of rod core, through incomplete fixation and acid erosion, tends to give the appearance of segmentation. In a matrix where the fixation of the organic constituent is complete, the picture is one of the core being less dense than the cortex, but a continuous structure.$^3$

Isolated rods$^5$ do not always show a corresponding degree of development. In some rods interrupted areas of incompletely matured matrix may be found deep within the core. (Figs. 1-T, 2-O). These areas have staining reactions identical to the center of Tomes$^6$.
process and may be surrounded by the more mature matrix of the cortex. In extreme examples the entire rod is apparently immature so that the core stains identical with the central area of Tomes' process (Figs. 1-U, 2-R). This immaturity or failure of maturation of the organic matrix may extend to the end of the rod. It is assumed that these rods have failed to mature because of a possible disruption in the sequence of events leading to the gelation of the matrix. Gelation of the matrix must necessarily precede mineralization. These immature uncalcified rods may occur singularly or in groups and are considered as being responsible for the occurrence of the organic lamella of the enamel.

V. REDUCTION OF THE AMELOBLASTS; THE ELEIDIN GLOBULES AND THE FORMATION OF THE PRIMARY CUTICLE.¹

(Fig. 1, 2)

When the ameloblasts have completed the full width of the enamel, they undergo a progressive reduction in size (Fig. 1-L). There is a generalized hyalinization of the cytoplasm of the cells, a greater number of vacuoles appear and their nuclei become progressively more pyknotic. An increase in the number of secretion granules in the vacuoles is also found. As the reduction of the cell continues, these granules fuse to form globules which, because of their staining reaction, seem to be composed of eleidin, and for this reason are called eleidin globules (Fig. 1-I). The presence of the eleidin globule is evidence that the ameloblast is entering its final stage of enamel formation and that its functional activity is on the wane. The pre-enamel processes are reduced in length or cannot be distinguished. As the last function of the cell, Tomes' process undergoes a maturation and becomes continuous with the inter-rod matrix to form a thin, homogeneous organic matrix over the ends of the rods and inter-rod substance. This matrix undergoes a mineralization to form the hard surface of the enamel and is called the primary cuticle (Fig. 1-K). With the formation and mineralization of the cuticle¹ no further calcification takes place.
VI. MINERALIZATION OF THE ORGANIC MATRIX

(Fig. 1-V, W)

Mineralization of the organic matrix begins in the dentino-enamel membrane soon after that structure is formed (Fig. 1-O, X). The calcium complex first appears as small microscopic granules, smaller than those of dentin and bone. The mineral density of this layer rapidly increases until, in the final product, the density of this layer is exceeded only by that of the primary cuticle.

Mineralization of the individual rods and inter-rod substance begins as soon as the central core begins to undergo maturation. The calcium crystals in the rod are exceedingly minute. The crystals grow in size until they fuse by coalescence, or they may be deposited in such numbers as to form a uniform mass. It is this minuteness and close packing of these crystals which may account for the extreme density of enamel. The mineral complex is first deposited in the lateral walls of the maturing rod or the rod cortex at the transitional area where the pre-enamel process becomes the cortex of the rod. The cortex is the first to undergo mineralization (Fig. 1-S); the core commences to mineralize a little later (Fig. 1-V). The density of the core is never quite so great as the cortex of the rod. Mineralization of the inter-rod matrix begins slightly later than the rod (Fig. 1-W). The calcium complex is likewise deposited in fine granular form in the inter-rod matrix which also undergoes coalescence to form larger particles.

Mineralization of the enamel matrix is definitely progressive from the dentino-enamel junction toward the surface (Fig. 1-V). It proceeds in an orderly sequence, following the establishment and maturation of the dentino-enamel limiting membrane. The first part of the rod to become mineralized is the lateral wall of Tomes' process called the pre-enamel process. In mineralization of the enamel matrix, Tomes' process may be regarded as a transitional area from cell to mature rod, and, hence, may be compared to predentin and the provisional area of calcification in bone.
During the process of mineralization the greatest deposition of the mineral occurs in the cortex. The core has less mineral content and the inter-rod substance has the least. The main body of the enamel progressively increases in density toward the surface (Fig. 1). Mineralization of the primary cuticle (Fig. 1-K) or surface layer is the final product, and its density exceeds that of the main body of the enamel—with the possible exception of the dentino-enamel junction.

As it was previously mentioned, histological studies show that the epithelial cells of the inner enamel epithelium at the level of the cuspal region are the first to differentiate into ameloblasts and the first to lay down enamel matrix.\textsuperscript{1,8} The cells at the end of the cervical loop are still undifferentiated and proliferate and extend toward the cervix of the crown. Mineralization follows the maturation pattern; thus the cuspal matrix is the first to undergo mineralization, in contrast to the matrix of the cervical region where development is as yet incomplete and still in the maturation stage. When the full width of the enamel is complete, the ameloblasts atrophy and undergo a striking reduction in size (Fig. 1-L). Their last product is the primary cuticle which is formed by the maturation of Tomes' process. When the primary cuticle has completely sealed off the ends of the rods and inter-rod intervals, the mineralization of that portion of the crown is complete. No further mineralization takes place. However, there is a continuous change in the matrix throughout the life of the tooth which is probably associated with a loss of water in the structure.

Studies in light refraction, such as Grenz\textsuperscript{8,9,10} rays and passing polarized light\textsuperscript{11} through sections of teeth, when correlated with histological and histochemical studies on enamel development, reveal a parallelism of processes. Each of these studies in a different way allows for an integration and a more complete understanding of the many factors concerned with enamel development.

The Grenz-Ray patterns, when compared with undecalcified histological sections, also show a greater degree of calcification in
the cuspal region (Fig. 3-A) which gradually become less dense as the cervical line is approached (Fig. 3-B). The greater density of the mineral is found at the extreme tip of the cusp in the outer surface of the primary cuticle. That part of the enamel which is progressively less dense toward the cervical line and which shows no evidence of the primary cuticle is still undergoing a progressive mineralization. The role of the ameloblast in the biochemistry of mineralization will be discussed in subsequent parts of the paper.

VII. THE MINERAL PATTERN OF THE MATRIX

In forming the matrix the ameloblasts lay down a keratin-like material which contains fibers definitely oriented in the direction of the long axis of the rod. Between the fibers of this protein matrix are minute spaces filled with a fluid-like substance. This fluid disappears early in the process of mineralization. The precipitating crystals of the calcium complex are oriented in relation to the long axis of the rod in conformity with the previous orientation of the matrix and within the submicroscopic spaces. Precipitation of the salts in crystalline form is more or less continuous so that gradually a regular layer of connected, oriented mineral substance is formed in the matrix.

In summary, with maturation of the fundamental organic matrix there is an orientation of the fibrous structure of the protein followed by the appearance of submicroscopic spaces filled with fluid. This fluid content is soon replaced with crystals of the mineral complex which occupy the fluid intervals within the organic structure. Mineralization of the dentino-enamel membrane occurs first, then the rod cortex; the core follows closely behind, and the inter-rod substance comes last.

VIII. MATURATION OF THE MATRIX

At this time it is important to emphasize that the matrix development and mineralization are two different processes and that hardening of the enamel following its complete mineralization is more than a crystallization or maturation of the inorganic salts.
already present. When the matrix first undergoes mineralization, there is a marked reduction in the organic content. This might be accounted for in part by the early loss of fluid from the submicroscopic spaces in the maturing matrix. The protein that remains stays relatively constant even at high mineral densities.

There is a progressive increase in the inorganic constituent of the enamel up until the time the primary cuticle is formed (Fig. 1-K) at which time the ameloblasts atrophy in the more mature portions of the crown of the tooth (Fig. 1-L). Qualitatively, this influx of the mineral complex is compensated for chiefly by the loss of fluid content in the later phases of mineralization. These events suggest that a phase of enamel hardening is an exchange of fluid for inorganic material while the protein content of the matrix remains constant, for this increase in hardness occurs only in the period during which water is lost. However, water is lost throughout the life of the tooth. Although hardening of the enamel continues, it is not due to a constant increase in the mineral content. This continued hardening in the adult enamel could be attributed to progressive change in the organic constituents. Another factor to be considered is the rearrangement of the inorganic molecule which, with additions and substitutions of other ions, modifies the crystalline structure. These changes will be discussed at greater length in the following section.

IX. BIOCHEMISTRY OF MINERALIZATION

The processes which result in the mineralization of an organic matrix are, in all probability, essentially the same in enamel, dentin, cementum and bone. Although this discussion deals with enamel formation, it will be necessary to make comparisons and utilize evidence advanced through researches in bone and cartilage.

In its simplest form, mineralization of the matrix is the precipitation of a basic calcium phosphate from the calcium, phosphate and other ions present in the extracellular fluid circulating in the minute spaces of the tooth or bone matrix. In the blood serum the con-
centrations of calcium, phosphate, hydrogen, bicarbonate and protein ions are inter-related and dependent upon one another in a manner giving rise to a complex equilibrium. The calcium, phosphate and hydrogen ions inter-relationship is such that in the range of calcium and phosphate ions concentrations commonly observed in biologic fluids there is a hydrogen ion concentration at which the solid phase of basic calcium phosphate complex will go into solution. This particular hydrogen ion concentration is frequently referred to as the critical pH. Above this pH the extracellular fluid is over-saturated with respect to calcium and phosphate ions and, accordingly, new solid phase will be deposited.

This critical hydrogen ion concentration is in the region of pH 7.4. The inter-relationship of the several ions is obviously much more complex than herein presented. For example, there will be a critical pH for each of the various levels at which calcium and phosphate ions may be maintained.

In the process of mineralization of an organic matrix the main consideration is the accumulation of sufficient calcium and phosphate ions to exceed the solubility of the extracellular fluid at the existing pH.

Among the first to associate an enzyme with the bone cell in calcification were Robison and co-workers. By his researches Robison concludes that two mechanisms are concerned with calcification. The first is considered to be an enzyme of the alkaline phosphatase group which acts on organic phosphate to liberate inorganic phosphate ions. The inorganic ions in some manner accumulate in the extracellular matrix. The exact site for these reactions in the cell is not as yet clearly understood. His second mechanism is concerned with a rapid and orderly deposition of a calcium phosphate in the matrix substance of the tissue undergoing mineralization. Although he apparently offered no suggestion as to the nature of the reaction, the mechanism might be presented in the following way:
Schematic Outline of Glucose Phosphate Cleavage in the Bone Cell

Mechanism 1

Glucose phosphate
phosphatase reaction
liberating

Bone Cell

Mechanism 2

Glucose

$\rightarrow HPO_4^{2-} + Ca^{2+} \rightarrow CaHPO_4$ Deposited in the matrix

Inorganic phosphate
from the cell

Inorganic calcium
From the intercellular fluid

1. The Role of the Phosphatase Enzyme in Mineralization (Figs. 4, 5, 6): From the foregoing outline, the bone cell, as well as the enamel cell, must be looked upon as a chemical laboratory in which a multiplicity of reactions can take place. The reactions which will be discussed are those concerned with the mineralization of the organic matrix, namely, those involving carbohydrate metabolism and the activity and localization of the phosphatase enzyme.

Following the enunciation of the Robison theory, it became apparent that glycogen was also involved in the process of mineralization. Both glycogen and phosphatase occur together in the cells of tissues prior to the onset of calcification. As calcification proceeds, the glycogen and phosphatase content of the formed trabeculae in the interior of bone decreases and these substances are found in greater concentrations in the periosteum. In calcifying cartilage the glycogen at first increases to a maximum and then falls off as calcification proceeds. It is pointed out (on a teleological basis) that the purpose of the phosphorylation of glucose is that the resulting glucose phosphate serves as a storehouse of readily available phosphate; phosphate is brought from a region of low concentration and placed in a position to effect a high local concentration. The carbohydrate phase serves as an accumulator of phosphate.
The above concept necessarily pre-supposes that glycogen and phosphate are involved in the calcification mechanism. The enzyme is considered to act in a specific way bringing about a cleavage of glucose phosphate in the cell to liberate inorganic phosphate ions into the extracellular matrix. There is some question as to whether this cleavage occurs at the glucose-6-phosphate level or whether the bone phosphatase acts on the glycerol phosphate linkage, since cleavage may readily occur at the latter level in carbohydrate metabolism. However, there is little doubt that these reactions are involved in mineralization and indeed represent a process by which the phosphate ion is accumulated.

The conversion of carbohydrate to glycogen involves the formation of several phosphorylated compounds. The conversion of glucose within the cell is dependent on the energy-rich phosphate bonds in adenosinetriphosphate, referred to as A.T.P. The reaction between adenosinetriphosphate and glucose is catalyzed by a hexokinase; an enzyme which accounts for the transfer of one phosphate group from A.T.P. to glucose. The steps in the synthesis of glycogen are as follows:\textsuperscript{25}

\[
\text{Glucose} + \text{A.T.P.} \xrightarrow{\text{hexokinase}} \text{Glucose-6-phosphate} + \text{adenosine diphosphate (Fig. 4)}
\]

The glucose undergoes a phosphorylation which results in glycogen storage in the cell. These reactions are reversible and are catalyzed by specific enzymes. They are illustrated by the following steps:\textsuperscript{25, 26} (Fig. 4).

1. Glucose + adenosinetriphosphate
   \*hexokinase

2. Glucose-6-phosphate + adenosinediphosphate
   \*phosphoglucomutase

3. Glucose-1-phosphate
   \*phosphorylase

4. Glycogen + H$_3$PO$_4$
   Cell storage
Since the small amount of acid-soluble phosphorus in the plasma is hardly sufficient to cover the requirement for bone calcification, a sufficient source could be provided through the medium of glycogen breakdown which occurs in young cartilage, bone and enamel cells. Calcification would, therefore, involve the degradation of glycogen to glucose and the uptake of inorganic phosphate to form glucose-6-phosphate. The glucose-6-phosphate is further catalyzed by the phosphatase enzyme to yield glucose and phosphate ions. In the latter the \( \text{H}_4\text{PO}_4 \) furnishes the extra ions necessary for calcification. The degradation of glycogen is illustrated in the following manner:

\[
\begin{align*}
1. & \quad \text{Glycogen} + \text{H}_3\text{PO}_4 \quad \text{Phosphorylase} \\
2. & \quad \text{Glucose-1-phosphate} \quad \text{Phosphoglucomutase} \\
3. & \quad \text{Glucose-6-phosphate} \quad \text{Alkaline phosphatase} \\
4. & \quad \text{Glucose} + \text{HPO}_4^- + \text{Ca}^{++} \rightarrow \text{CaHPO}_4 \text{ which undergoes a series of changes to be deposited in the organic matrix as tricalcium phosphate.}
\end{align*}
\]

2. *Deposition of the Calcium Salts in the Organic Matrix* (Fig. 4): As previously stated, the phosphatase hypothesis assumes that the phosphatase enzyme catalyzes the degradation of glucose-6-phosphate. This cleavage liberates inorganic phosphate ions in sufficient amounts and in specific areas to bring about a local supersaturation of the salt. When local supersaturation has been achieved, there is a deposition of the mineral in the matrix. This hypothesis in its simplest form assumes that the blood serum calcium and phosphate are normally in equilibrium with the bone salt, and that the condition of supersaturation of this salt is produced locally in cartilage and osteoid by the catalytic action of the enzymes present in the cells of these tissues. The equilibrium level of calcium in the blood serum and bone is reflected in the extracellular fluid which circulates throughout the interstices of the bone matrix fibers.
thereby furnishing the calcium necessary for the formation of the bone salt.

An extension of the above process is proposed by Roche and his co-workers. According to Roche, calcification proceeds in different stages: (1) Phosphate and calcium ions are fixed simultaneously, but independently, to the “pre-osseous substance,” (2) the “pre-osseous substance” undergoes a transformation whereby it becomes the organic matrix of bone, and the calcium and phosphate ions are then liberated, and (3) are fixed to the proteins of the organic matrix. The phosphate fixed in the immature organic matrix in the first stage is presumably liberated by the activity of phosphatase. In this respect the concept of Roche coincides with that developed on the basis of Robison’s early work.

The concept of Roche would tend to emphasize the fact that the appearance of the bone salt in the matrix is dependent on the maturation or transformation of the pre-osseous substance to mature matrix. The maturation process is accompanied with the liberation of calcium and phosphate ions which are deposited as inorganic salts in the fluid spaces of the matrix.

Observations in general seem to concur with this hypothesis in that in human costal cartilage, chondroitin sulphuric acid is present in greater amounts as the cartilage syncytium is undergoing gelation, but decreases later as calcification proceeds. The role of vitamin C in the maturation and the maintenance of the collagen background of bone matrix is probably indirectly but closely associated with the calcium phosphate content of the extracellular substance. The patterns of calcification of enamel and dentin, as well as those of bone and cartilage, suggest that the Roche concept is an advance over Robison’s hypothesis.

In the foregoing discussion, it was shown that in order for the calcium phosphate compound to be precipitated in the matrix, the serum must be definitely supersaturated with the salt. Experiments conducted on the healing of fractures indicate that this supersaturation takes place at an alkaline pH which may reach the
The phosphatase enzyme is most active in an alkaline medium. After the formation of the calcium phosphate compound in the matrix, further alterations in the structure take place, rendering it more stable at the normal hydrogen ion concentration.

While it is by no means certain that the following description is a correct account of the events as they occur following the precipitation of the salt, it does illustrate the current conception of the changes which may take place in the formation of bone and enamel apatite.

1. CaHPO$_4$ is aggregated, presumably in submicroscopic particles.
2. Three molecules of CaHPO$_4$ condense to form one molecule of Ca$_3$(PO$_4$)$_2$ leaving one molecule of H$_3$PO$_4$.
3. Ca$_3$(PO$_4$)$_2$ is unstable but (OH)$_2$, CO$_3$, and other ions are quickly added to complete the crystal structure characteristic of apatite minerals which has the formula of Ca$_{16}$(PO$_4$)$_6$(OH)$_2$.
4. Further additions and substitutions in the molecule in the form of fluorine, magnesium and iron during the period of maturation of bone and enamel modify the crystalline structure and render it more stable at the normal pH of 7.4. Both magnesium and fluoride ions are more stable than calcium. The continued increase in particle size of the crystals in enamel and bone to form a confluent mass in the final product is no doubt another factor in stabilizing the salt.

X. THE ROLE OF FLUORINE IN CARBOHYDRATE AND MINERAL METABOLISM

It is well known that fluorine is a strong enzyme poison and that if excessive amounts are ingested, a deformity in enamel formation will result. In normal cell function of tissues undergoing mineralization...

---

"The recent but little known work of Brasseur, Dallemagne and Melon points out that the carbonate apatite is localized in the enamel prisms while tricalcium phosphate is found in the interprismatic substance. Should further researches confirm these findings, it would naturally influence the concept with regard to enamel mineralization as presented in this paper. It should be pointed out, however, that these authors are concerned with mineral patterns and that their researches are not at the biological level.

"The inadequacy of this reaction is pointed out since it leaves unexplained the fate of the H$^+$ in H$_3$PO$_4$."

---
zation (as well as all other cells) an energy output is required of
the metabolic process. This liberation of energy is brought about
through the extension of carbohydrate metabolism along the glyco-
lytic pathway, glucose-6-phosphate undergoing transformation to
pyruvic acid, a chemical unit from which energy is derived. It
should also be pointed out that a considerable amount of energy is
accounted for from the dephosphorylation of various glucose phos-
phate compounds in the process of glycolysis. Pyruvic acid then
undergoes a degradation by the way of the tricarboxylic acid cycle
and cytochrome cycle (Fig. 4, 5). In this manner energy, carbon
dioxide and water are liberated as normal end products of carbo-
hydrate metabolism (see charts of metabolic pathways and the
cytochrome system). The fluoride ions in all probability inhibit the
action of enolase,87 (Fig 4) a catalyst necessary in the glycolytic
chain for the formation of pyruvic acid. By this reaction the fluoride
ion not only inhibits energy metabolism but may also interfere with
the mineralization process. The characteristic discoloration of the
enamel structure in enamel fluorosis may then be accounted for on
the basis of an irregular crystalline structure which gives a different
refractive index. In severe cases when a deformity results from
a fluorosis the mineral pattern is not only abnormal but cell function
is disturbed as well with the resultant inability of the cell to develop
a normal matrix, since a normal matrix which will receive the mineral
complex is the fundamental basis for the formation of mineralized
structures.

XI. CONCLUDING REMARKS ON THE HISTOCHEMISTRY
OF AMELOGENESIS

The above discussions assume that the blood serum phosphorus
and calcium are in equilibrium with the bone salt. In order to bring
about a supersaturation of the salt in a localized area, which is
the theoretical requirement for its precipitation, the enzyme phos-
phatase catalyzes a cleavage of the glucose phosphate compound,
liberating inorganic phosphate ions. The calcium requirement of
bone salt is supplied through the medium of the extracellular fluid. Whether they be in enamel, dentin or bone, the processes which cause the precipitation of the phosphate and calcium from the tissue fluid in the minute spaces of tooth and bone matrix are fundamentally the same. The mechanism of matrix formation is a different process than that of mineralization of enamel matrix and is in all probability essentially the same in all three calcified tissues. The chief difference between enamel and bone is that when the full width of the matrix is formed, the enamel matrix has undergone mineralization and the ameloblasts undergo a change in character and no further alteration in the basic mineral content occurs; whereas in bone there is a constant metabolic adjustment due to the activity of the bone cells, the degree of which is directly influenced by endogenous metabolic factors.

The enamel cell before reduction, like the bone cell, must be looked upon as an individual chemical unit capable of a multiplicity of reactions, especially those reactions involved in the metabolism of carbohydrates and the enzyme phosphatase. The demonstration of both glycogen and phosphatase in the ameloblast permits this cell to be considered in the same light as the osteoblast, the same cell mechanisms operating in enamel mineralization as in bone. The presence of glycogen in the cells of tissues undergoing calcification provides a source of phosphoric esters necessary for the local concentration of the phosphate in the calcification process.

Although the situation in the teeth is not so clear as in bone or cartilage, investigations have shown that following the onset of calcification, glycogen can no longer be determined in the ameloblast, and it is postulated that in mineralization tooth glycogen is broken down too rapidly to be recognized. Another consideration is that the glycogen may serve as a trigger mechanism which sets the reaction in motion at the onset of mineralization. Once initiated, the reaction might conceivably proceed directly, bypassing the re-
actions concerned with glycogen storage. The important consideration, however, is that glycogen, phosphatase and other enzymes which are necessary for the calcification mechanism have been demonstrated in the ameloblast (Figs 4, 5, 6). 27, 39, 40, 41

Tomes' process may be compared to pre-dentin and to the areas of provisional calcification in bone. It may be looked upon in part as a secretory product of the ameloblast in which the phosphate and calcium ions are fixed independently. As maturation of this area progresses, the pre-enamel substance (Tomes' process) undergoes a transformation to become the organic matrix of the enamel rod. The phosphate and calcium ions are then liberated and become fixed within the keratin-like structure of the organic matrix. Thus during the maturation of the matrix, phosphate and calcium ions are being liberated continuously. The ameloblast continues to elaborate an organic matrix as the cell moves outward from the dentino-enamel membrane until the full width of the enamel is formed. The maturation process continues until all of the mineral ions have been liberated and combine to establish the final density of the enamel. A mechanism which should be considered as operating a little later but almost simultaneously with calcification is the final hardening of the mineralized enamel prior to eruption.
REFERENCES TO LITERATURE


Eiler, John: Lectures in Biochemistry, University of California, College of Pharmacy, San Francisco; 1946.


Roche, J.: *Presse Med.*, 52, 50-51; 1944.


AMELOGENESIS


REFERENCES TO CHART ON METABOLIC PATHWAYS (Fig. 4)


Eiler, J.: Lectures in Biochemistry, University of California, College of Pharmacy; 1946.


Upjohn Company: (a) Energy Release from Food. (b) Water-soluble Vitamins in Amino Acid Metabolism.
REFERENCES TO CHART ON THE CYTOCHROME SYSTEM (Fig. 5)


Fig. 1. Schematic drawing illustrating the progressive development and reduction of the ameloblast. The figure includes the phases which are discussed in the text: the function of the cell, the formation and maturation of the enamel matrix and its mineralization.
Fig 2. A schematic drawing illustrating the ameloblast, Tomes' process and rod in continuity. The figure illustrates the phases concerned with the formation and maturation of Tomes' process to form the enamel matrix.

A. Ameloblast.
   a. Basal granules
   b. Cytoplasmic vacuoles
   c. Condensation of cell cytoplasm
   d. Intercellular substance

B. Pre-enamel Matrix.
   e. Position of so-called terminal bars
   f. Tomes' process
   g. Inter-rod matrix
   h. Pre-enamel process
   i. Secretion granules

C. Enamel Matrix.
   I. Completely matured rod.
      k. Rod membrane
      l. Rod cortex
      m. Hyalinized rod core

   II. Partial maturation of rod.
      n. Extension of Tomes' process into rod core
      o. Remnants of Tomes' process in rod core

   III. Incomplete maturation of rod.
      p. Delayed development of pre-enamel process
      q. Delayed development of rod cortex
      r. Delayed development of rod core
A. Shows complete mineralization at the tip of the cusp. Note the dense surface area at the extreme apex indicating the mineralization of the primary cuticle. In this area the life cycle of the ameloblastic layer is completed and no further function on the part of the cells takes place.

B. Illustrates the enamel matrix undergoing maturation and early mineralization. This is best shown in the area between A and B. Although the mineral complex is not demonstrable in the matrix at B by the Grenz-Ray technic, it is possible to show the presence of inorganic calcium by staining thin, undecalcified histological sections after Von Kossa's method.

C. Illustrates the "Mackie-line" at the dentino-enamel junction. The appearance of this structure in Grenz-Ray pictures has resulted in considerable controversy as to whether it is an artifact or a true image of the beginning of mineralization. Histological studies in which precise technics were used and subsequent analysis point out that the "Mackie-line" is not an artifact, as was formerly supposed, but represents the first structure to undergo mineralization.


Fig. 4. A schematic representation of the metabolic pathways in carbohydrate metabolism.
Fig. 5. A schematic illustration of the cytochrome system.
Fig. 6. A schematic illustration of the biochemistry and histology of the ameloblast in the development and mineralization of the enamel matrix.
DENTAL EDUCATION: OBJECTIVE AND PURPOSE

Continued from the March and June issues of the Journal, p. 37 and p. 72, respectively; references may be made to pp. 7 and 12 of the March issue for further details. (Ed.)

Presentation of Schools of the United States

OHIO STATE UNIVERSITY

College of Dentistry

WENDELL D. POSTLE, D.D.S., Dean, Columbus

Dental education in Columbus, Ohio began in 1890 when the Department of Dentistry was established in the Ohio Medical College. This affiliation continued until 1907 when a merger was made between the Ohio Medical College and the Starling Ohio Medical College. At that time the Department of Dentistry was again established in the new college. In 1914 the Starling Ohio Medical College became a part of the Ohio State University. At that time, by an act of the legislature, the College of Medicine and the College of Dentistry were established in the University. The College has had University affiliation since 1914 but it was not until 1925, when the present building was completed, that the College was moved to the campus of Ohio State University.

The Dental College is housed in the same building with the College of Medicine and we have a very close relationship with them. All of our fundamental science subjects are taught in their departments. However, dentistry has retained its autonomous position and the Dean of the Dental College is directly responsible to
the President of the University. We think this is the best arrangement for the interests of the public and the dental profession.

There have been some attempts throughout the country to put dentistry under the jurisdiction of medicine, but we believe that the dental schools and the dental profession should do everything possible to discourage such affiliations.

We believe that the objectives of dental education have broadened beyond that of merely undergraduate education and should include post-graduate training, graduate training and research. We further believe that the dental colleges should take the responsibility of developing and training auxiliary groups such as the dental hygienists and technicians.
Dentistry, quite as much as any of the medical specialties, is logically a branch of general medicine, although traditions, which have separated medicine and dentistry and which operate against the public welfare, have prevented due recognition of this fundamental fact. It is obvious that dentistry cannot render its highest service to the individual, or in the interest of public health, unless dentists are thoroughly educated in the knowledge of general medicine and of dentistry as a medical specialty.
The objectives of Dental Education include:

a. The training of general practitioners of dentistry which deserves a preferred position in the program of most dental schools.

b. Continuation of education for graduate dentists or post graduate instruction.

c. Training of specialists, which demands additional foundation and clinical courses largely upon a graduate basis.

d. The development of dental teachers, particularly qualified for effective conduct of education, pro-
motion of the facilities, creation of the environment and the training of the personnel for research, which means contribution to the body of knowledge of dental science.

The pre-dental education should furnish not only a foundation for the dental curriculum, but also, a cultural background anticipating the restricted horizon of instruction within a limited phase of Health Science and in this way provide a foundation as well, for life in a world of people contemporaneous with performance of a useful service. Each division of educational activity, as well as each course within these divisions should be tailored to the measure of the specific objectives rather than attempt to "cover the water front" in the first two years of dental education. It seems unwise to construct a foundation for any and all restricted fields from medicine to research.

With the passing of time the objectives of dental education tend to tarnish and erode in the atmosphere and interests of academic expediency. It is essential that these objectives not only point the way, but also assist in the approvement of accomplishment in dental education.
Every person has a philosophy with respect to everything he does or thinks about. The science which comprises ethics, aesthetics, logic, metaphysics, and the theory of knowledge, together with industry, is the basis of dental teaching and practice.

The general practice of dentistry has always been largely devoted to the reconstruction of the teeth and the replacement of those that have been lost. Although the more thoughtful practitioner in our profession has not only striven to be a good technician but also a good oral physician and a doctor in the theoretical understanding of the term.

Whether we are instructors in a dental school or practitioners, our
ethics requires that we shall teach and practice the art and theory of preventive dentistry.

Dentistry has become a vital unit in the total field of preventive medicine. While techniques are always alluring to students as they are to practitioners, research in the basic subjects, preventive dentistry and therapeutics are of increasing significance to teachers and students. The two major phases of dentistry—one biological, the other the technique of reconstruction are inseparable; they must always constitute a strong independent working unit in education designed to develop sound dental practitioners and to a further end, teachers and investigators.

UNIVERSITY OF NEBRASKA
College of Dentistry
BERT LESLIE HOOPER, D.D.S., Dean, Lincoln

Our objective in dental education is stated briefly as follows:

To so organize our faculty, our curriculum and our facilities that the very finest dental training may be available. To so conduct our teaching program that basic and technical knowledge may be disseminated efficiently, that manual dexterity may be promoted, and that a complete and well-rounded dental education may result.

To so select the entering students that only those who possess aptitude and ability, personality and character, mental capacity and educational background adequate for a professional career may be encouraged to pursue the course.
To so educate and train these select students that dentistry may be progressively raised to higher standards and levels.

To so launch our graduates on their careers that they will ever uphold the dignity and honor of the profession, that they will ever desire to serve better, develop more fully, and advance themselves and the profession each succeeding year; and that they may realize their full measure of duty and obligation to their patients, to their communities and to the nation.
Dentistry is charged with, and has assumed responsibility for, the scientific care adequate for the oral health, in all of its organic and systemic interrelationships, of the public. Dental education likewise assumes the responsibility of preparing those who aspire to be personal units of oral health service to the citizens of the great commonwealth. A gigantic responsibility is thereby imposed on those who are administering and imparting Dental education.

A strong, adequate faculty, coordinated scientific curriculum, put
into action through lectures, technics and clinics; supported by a well planned physical plant, are mandatory. We advocate the highest possible preprofessional attainment, as to academic hours and particularly as to quality. We would like for all who enter the study of dentistry to be first fortified by a quality degree. The more quality preprofessional attainment, the better the product expectation.

Profound basic sciences student qualifications, amplifies and promotes clinical understandings and attainments. We advocate strong faculty and curriculum, academically administered.

UNIVERSITY OF CALIFORNIA
College of Dentistry
WILLARD C. FLEMING, D.D.S., Dean, San Francisco

The story of the progress of dentistry has been highlighted by a willingness to change its objectives and accept added responsibilities.

The first objective and responsibility of dentistry was the relief of pain—no educational program was required at this state. The second objective was the restoration of teeth and parts of teeth. Here the apprenticeship method of education was all that was necessary. The next objective and responsibility accepted by the profession was the elimination of infection which followed closely the realization that the teeth were related to general health. This responsibility was assumed in the early part of this century and brought about a change
in the dental educational program which now requires professional preparation at the college level.

In or around 1920, a fourth responsibility was adopted by the profession. This was the control of dental disease. It was accepted that dental disease, like cancer and diabetes, could not be classed as preventable diseases, but rather as diseases that could be controlled. The technic of control is the same in all of these diseases. Early examination, early diagnosis, with early and adequate treatment.

The dental profession has added these responsibilities without relinquishing the other responsibilities. The dentist of today is practicing release of pain, restoration of teeth, elimination of infection and control of dental disease.

The changes taking place in our knowledge regarding the cause and mechanism of dental disease processes leads one to believe that the fifth responsibility, or prevention of dental disease, will shortly be added to the list of our objectives. This poses a major problem in dental education. It is necessary for the dental schools to properly
prepare their students to meet the above mentioned four responsibilities of dentistry, and at the same time to prepare their students in such a way that they will be able to practice the prevention of dental disease when that time arrives.

There is little doubt but what our approach to this problem of prevention will be upon a biological basis, requiring a comprehensive knowledge of the basic sciences and their clinical application.

The question dental educators must answer is how to hold to our present objectives which require a high degree of technical skill and clinical experience and at the same time prepare our students to meet our new responsibility.

UNIVERSITY OF SOUTHERN CALIFORNIA
College of Dentistry
JULIO ENDELMAN, M.S., D.D.S., Sc.D., Dean, Los Angeles

Being limited to a total number of words not to exceed two hundred, it is not to be expected that more could be accomplished than to summarize briefly and rather superficially our concept of the objective of dental education which we take it should aim to train men and women to practice dentistry from the preventive, curative, and reparative standpoints as a health giving specialty and not merely as mechanic art with only a smattering of the related biologic sciences, without, however, sacrificing thoroughness in the technical aspects of the curriculum. It is, therefore, that we consider it of the greatest importance that before candidates for admission are accepted as
dental students, they should be carefully scrutinized to ascertain if they possess those qualifications and aptitudes that will make it possible for them to develop into just this type of desirable dental graduate with an adequate degree of general culture and with a clear understanding that dentistry cannot be practiced as the profession, which we aim it to be, if divorced from its foundational requirements in the field of biologic and other related sciences. The Council on Dental Education through its Division of Educational Measurements, in our opinion, holds the answer to the problem of admissions if its methods of determining the required aptitudes were to be instituted in a period of time that would be established between a temporary and a final acceptance of students.

University of Southern California
AMERICAN COLLEGE OF DENTISTS
MEETING OF THE BOARD OF REGENTS
AUGUST 2 AND 4, 1947, BOSTON, MASS.

(Abbreviated)
O. W. BRANDHORST, D.D.S., Secretary

FIRST SESSION

The first session of the Board of Regents of the American College of Dentists was held in the Statler Hotel, Boston, Mass., on Friday, August 1, 1947, convening at 9:30 a.m., with President Hodgkin presiding. Eight Regents were present.

The Minutes of the meeting of the Board of Regents of Feb., 1947, were read and approved.

Reports of Officers: The Treasurer's report, together with the report of the Auditors, James C. Thompson & Company, were presented and received.

The Secretary reported on interim activities, the state of the College and the following deaths:

- Eben J. Carey, Milwaukee, Wis. (Honorary) June 5, 1947
- T. E. Carmody, Denver, Colo. August 30, 1946
- C. J. R. Engstrom, Los Angeles, Calif. March 5, 1947
- Milo Hellman, Far Rockaway, N. Y. May 11, 1947
- Edgar A. Honey, Sr., Kalamazoo, Mich. April 13, 1947
- Ernest A. Rogers, Carr, Colo. June 4, 1947
- L. Langdon Sheffield, Toledo, Ohio June 4, 1947
- Jas. F. Spencer, Grand Rapids, Mich. May 16, 1947
- Arthur E. Wrigley, Eureka, Calif. Nov. 27, 1946

The Secretary presented the names of those who had qualified for Fellowship, which was to be conferred upon them on Sunday, August 3. (See list in Convocation minutes.)

Adjournment, 11:45 a.m.

SECOND SESSION

The second session convened at 2:20 p.m., August 1, 1947, with eight regents present. The session was devoted to hearing and
discussing the reports of various standing and special committees.

The Board was honored by a visit of the President of Federation Dentaire Internationale, Dr. E. A. Rowlett of Leicester, England. Adjournment, 5:00 p.m.

THIRD SESSION

The third session of the Board of Regents was held at 5:00 p.m., Saturday, August 2, to hear the report of the By-laws Committee. Adjournment, 6:30 p.m.

FOURTH SESSION

The fourth session of the Board of Regents was held on Monday morning, August 4, this being the first session of the new board. Dr. L. R. Main presided. Eleven were present, two by invitation.

Committee appointments for the coming year were considered. It was voted that the Committee on Journalism cooperate with the New York Section Committee in the hope of agreement on specific problems in journalism.

The budget for the ensuing year was adopted, indicating a probable net balance of income over expenditures of $1254.98.

Dr. J. Ben Robinson was elected editor of the JOURNAL, effective January, 1948, succeeding Dr. John E. Gurley.

The next meeting of the Board will be held in Chicago in February, 1948.

Adjournment, 12:15 p.m.
convocation held since 1941, regular meetings having been interrupted by World War II.

The minutes of the Houston, Texas, meeting in 1941 were read and approved.

The ad-interim report of the secretary was also approved.

The secretary reported on the activities of the Board of Regents which had been in session all day Friday, August 1.

The treasurer's report was read by the secretary, in the absence of the treasurer. This report showed a balance on hand and in the bank as of June 30, 1947, of $14,926.00 and securities amounting to $14,000.00 (par value). The report also indicated an amount of $3,206.00 in the H. Edmund Friesell Endowment Fund. Report received.

The theme for the meeting was Dental Education.

Dr. S. Ellsworth Davenport, Jr., Chairman of the Committee on Education, presented the report of his committee, which was accepted and ordered published.

A round table discussion on Dental Education followed, with the following participating:


Subjects discussed:
The Selection of Dental Students.
The Training of Dental Teachers.
The Need for Revised Curriculum.
Graduate Work and the Training of Specialists.
Research.
The Training of Auxiliary Groups.
The Need for Financial Support of Dental Education.

Participants:
Shailer Peterson, Ph.D., Director of Educational Measurements, Council on Dental Education, American Dental Association, Chicago, Ill.
S. Ellsworth Davenport, Jr., D.D.S., New York, N. Y.
John Thomas O'Rourke, D.D.S., Tufts College Dental School, Boston, Mass.
Thos. J. Hill, D.D.S., Western Reserve University, Cleveland, Ohio.
Dr. Paul H. Jeserich, Ann Arbor, Mich., listed on the program as a discussor, was unable to be present.
An open discussion followed the formal presentation, with adjournment at 11:45 a.m.

LUNCHEON SESSION
The luncheon session was held under the auspices of the New England Section of the College, with Dr. John E. Tyler presiding. The Rev. Thos. E. Shortel, S.J., was the guest speaker. His subject being “Trends in Labor Legislation.”

AFTERNOON SESSION
Following an academic procession from the Assembly Room to the Ballroom, with impressive ceremony, regular Fellowship was conferred upon the following persons:

Amundson, Frederick A., Duluth, Minn.; Anderson, Percy Gordon, Toronto, Can.; Arnold, Eugene K., Kansas City, Mo.
Callahan, Vincent D., Brooklyn, N. Y.; Casey, Leo J., Chippewa Falls, Wis.; Clark, Clifford Fremont, Menomonie, Wis.; Clough, Oliver Wendell, Richmond, Va.; Cogley, Elmer Anthony, Great Falls, Mont.; Crum, Walter Allen, Richmond, Ind.
DeYarman, Lester, Cedar Rapids, Ia.; Diehl, Crown O., Hagerstown, Md.; Duncan, George W., Richmond, Va.
Edwards, Zeno Lester, Washington, N. C.
Fenner, Clarence L., Cedar Rapids, Ia.; FitzGerald, Don J., Mason City, Ia.
Gibb, Hugh, Jr., New Haven, Conn.; Glascock, Campbell Hopson, Pasadena, Calif. (Army—regular); Glenn, William Lloyd, Sr., Galveston, Tex.; Goad, Grosvenor McKinley, Hillsville, Va.; Grant, Edmund A., Toronto, Can.


Jacobs, Max H., Boston, Mass.


MacKnight, Thomas Stephenson, Newport, R. I.; Maddox, Ray A., Sr., Abilene, Tex.; Martin, Bernard A., Indianapolis, Ind.; Miller, Donald Henry, Elmira, N. Y.; Minges, Clyde E., Rocky Mount, N. C.; Morris, James Harold, Poughkeepsie, N. Y.

Neuber, Augustine, Schenectady, N. Y.

Padelford, Donald Charles, Rochester, N. Y.; Pallardy, Sumner, Upper Darby, Pa.; Perry, Chester, Detroit, Mich.; Pincock, Douglas Fowler, Ogden, Utah.


Walter, Raymond Charles, Philadelphia, Pa.; Webster, Raymond Lesley, Providence, R. I.; Westhoff, Henry F., St. Louis, Mo.; Williams, Phillip Earle, Dallas, Tex.; Worman, Harold G., Minneapolis, Minn.

Following this, Honorary Fellowship was conferred upon Col. James Earle Ash, Washington, D. C., for his interest and contribution to the profession of Dentistry.

Vice-President H. S. Thomson presided while President Hodgkin presented his address. Besides pointing out some of the opportunities that lie ahead, President Hodgkin took the occasion to review the significance of the Mace and Torch, to the interest of all.
Secretary Brandhorst followed with a paper on the “American College of Dentists: Its Objectives and How It Functions.”

In the executive session which followed, the secretary presented an ad-interim report calling for the ratification of several mail ballots submitted during the war emergency.

The vote of the members sustained the decision by mail ballot, so that the amended articles now read as follows:

“Section A. Members:

1. Nomination and Election. Any member of the College may nominate candidates for membership. Nominations must be presented on copies of the official nomination form, to the Secretary at least four months before the date of the annual meeting at which action on the nominations may be desired, to enable the Secretary to forward them to the Board of Censors in accord with the rules of the Regents. The Board of Regents shall develop plans for safeguarding the interests of the College whereby, after a nomination has been received, such name shall be submitted by the Secretary to selected Fellows in the state, division or area in which nominee resides, that they may interpose possible valid objections or furnish desired information, before action by the Board of Censors and final action by the Board of Regents. Knowledge of the nomination shall be kept inviolate by the nominators, the Secretary, the Board of Censors and the Board of Regents, as well as the local committees, until action is formally announced.”

“Section C. Board of Editors. The Board of Regents shall elect an Editor and such assistants and business manager, as they deem necessary, as well as a maximum of ten Contributing Editors. No one shall be eligible to serve in the same position for a term or terms exceeding a total of five years, save by unanimous vote of the Board of Regents in instances and under conditions wherein the services of any such person for an additional period may be deemed desirable for the continued conduct of the JOURNAL. The persons so elected plus the Board of Regents shall constitute the Board of Editors.”

Dual Membership:

At the Atlantic City convocation, July 11, 1937, the American College of Dentists adopted the following resolution:

“Resolved, that the American College of Dentists will not admit to membership any person holding membership in any similar honorary dental
organization. Fellows of the American College of Dentists, who are also members of a similar honorary dental organization are requested to consider the propriety of early withdrawal from one or the other."

On December 9, 1944, by order of the Board of Regents, the Secretary submitted a ballot to the membership by mail, giving the membership an opportunity to rescind the resolution. The mail ballot showed 386 favoring rescinding with 307 opposed.

This was presented to the session for ratification, with the result that the rescinding of the resolution was sustained.

**Student Recruitment:**

Dr. Stephen P. Mallett presented the report of the Committee on Dental Student Recruitment, outlining plans for the coming years.

**Necrology Committee:**

The secretary read the report of the Necrology Committee, indicating that 20 Fellows had gone to their reward.

**By-Laws Committee:**

The By-laws Committee, H. Otis Lineberger, Chairman, presented the following report, which is to be presented for further consideration and possible action at the next convocation:

"The special committee appointed to study the need for revision of the Constitution and By-laws of the American College of Dentists, studied the suggestions which have been submitted from time to time and have attended the meeting of the Regents at Chicago, February, 1947, at which time the advocates of proposed changes were heard. It is the opinion of the Committee that the future welfare of the College requires several changes which are to follow:

"*Article II. Section 5.* Forfeiture of membership; Sub-Section A, item (b), gives courses of instruction in dentistry in a privately owned undergraduate or post-graduate dental school; or, in a school that is associated with an independent hospital or dispensary but is not an organic part of it;

"The Committee believes that this item is implied in the preceding item (a) which confines the activities of members to approved professional schools or agencies, also that privately owned schools, etc., are fast disappearing."
Therefore, it recommends, the deletion of Article II, Section 5, sub-section A (b) from the Constitution.

"Article III. Officials, Section 2, Regents. A Board of Regents consisting of the President, the President-elect, the Vice-President, the Secretary, the Treasurer, the Editor, (Art. IV) and five additional members shall conduct the business of the College, excepting as otherwise provided.

"The Committee recommends the following additions to this Section. Following the words, The Editor (Art. IV) insert the words an Historian and eight additional members.

"An Historian is recommended as a member of the official family because the History of the College and other historical documents relating to dentistry should be prepared by one who has official status and sanction in the College. This officer should be elected for a stated period of one to three years, not in perpetuity.

"The Committee recommends three (3) additional members to the Board of Regents to meet the growing need for a more wide-spread geographical distribution of Regents. This suggestion would make it possible to elect Regents not as Section Representatives, but some consideration of geographical areas or regions, thus preserving a broad outlook and universal interests among the Board of Regents.

"The Committee recommends that the President serve as Counsellor of the College. In this capacity he shall maintain contact with the chairman of each Section, who in addition to serving as Chairman, shall serve as Counsellor of the Section. The President shall in ways to be determined, promote the integration of Section activities with the work and objectives of the College. He shall, by means yet to be determined, maintain active contacts with unorganized areas of the College membership.

"Changes in Article III of the Constitution will require modification of the by-laws to include the duties of the Historian and the election of the eight members of the Board of Regents.

"The Committee recommends that the nominating Committee be appointed annually, by the President, and shall consist of two most recent past-presidents, and three other members of the College.

"Finally, the Committee suggests that these recommendations be prepared with suitable explanation and mailed to the Sections for their study and
MINUTES OF THE CONVOCATION

suggestions, after which a final draft of desirable changes will be prepared by the Committee for presentation to the membership for action.

(Signed) WALTER H. WRIGHT,
GERALD D. TIMMONS,
H. O. LINEBERGER, Chairman."

In the absence of the members of the Nominating Committee, the secretary read the report of the Committee in which the following persons were nominated for the respective offices:

For President-elect ............... Earl W. Swinehart, Baltimore, Md.
For Vice-President ............... Paul C. Kitchin, Columbus, Ohio
For Secretary ...................... Otto W. Brandhorst, St. Louis, Mo.
For Treasurer ...................... Harold S. Smith, Chicago, Ill.
For Regent (3 years) ............... John E. Tyler, Worcester, Mass.
For Regent (5 years) ............... B. G. DeVries, Minneapolis, Minn.

There being no further nominations from the floor, it was moved, seconded and carried that the report be accepted and the secretary cast one vote for each of the persons nominated.

Adjourned, 4:30 p.m.

EVENING SESSION

Following a reception to the new members in the Assembly Room, 270 persons had dinner in the ballroom.

Following the dinner and entertainment by a chorus of young people, President Hodgkin introduced Vice-President Thomson, who introduced Rev. H. J. Cody, L.L.D., President emeritus and Chancellor of the University of Toronto, Toronto, Can., who spoke on "The Utmost for the Highest."

Following this, President Hodgkin installed the new officers and called upon the new President, Dr. Lee Roy Main of St. Louis, to present his inaugural address. Dr. Main spoke on plans for next year, announcing the theme as "Professionalism vs. Commercialism."

President Main then accepted the gavel and, after the reading of several telegrams by the Secretary, the meeting was adjourned at 10:45 p.m.
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SYMPOSIUM ON DENTAL CARIES

To be presented by the subsection on Dentistry of the American Association for the Advancement of Science


All Sessions and Dinner in Grey Room of Hotel Sherman

PROGRAM

On the basis of our present knowledge, it is evident that the three main avenues of research toward the solution of the problem of dental caries are:

1. Bacteriological and Biochemical Aspects.

One Session, therefore, will be devoted to each of these fields.

SUNDAY A.M. SESSION—9:00 TO 12:00

BACTERIOLOGICAL AND BIOCHEMICAL ASPECTS

9:15 a.m. 1. Is Caries of Enamel a Process of Decalcification Resulting from Bacterial Action? Dr. Robert G. Kesel, University of Illinois.

10:00 a.m. 2. The Role of Lactobacilli Versus Streptococci in Dental Caries. Dr. R. W. Harrison, University of Chicago.

10:45 a.m. 3. Immunological Reactions of Lactobacilli. Dr. Ned B. Williams, University of Pennsylvania.

11:20 a.m. 4. The Relation of Oral and Intestinal Strains of Lactobacilli. Dr. Elizabeth Hemmens, University of Illinois.

SUNDAY P.M. SESSION—1:00 TO 5:00

NUTRITION AND SUBSTRATA

1:30 p.m. 5. Nutritionist's View of the Caries Problem. Dr. C. A. Elvejhem, University of Wisconsin.

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2:15 p.m. 6. How Do Substrates Affect the Action of the Oral Flora? Dr. Philip Jay, University of Michigan.

3:00 p.m. 7. What Is the Relative Importance of the Polysaccharides, Disaccharides, and Monosaccharides in Caries Production? Dr. R. M. Stephan, U.S.P.H. Service, Bethesda, Md.

3:45 p.m. 8. What Factors Appear to Contribute to Natural Immunity to Dental Decay? Dr. Leonard Fosdick, Northwestern University.

Dinner—6:30 P.M.

Evening Session—8:00 to 10:00
Prevention and Control

9. The Public Health Aspects of Caries Control:

8:00 p.m. A. An Analysis of the Problem. Dr. Allan Gruebbel, American Dental Association.


9:00 p.m. C. Fluorine Therapy. Dr. Francis A. Arnold, U.S. P.H. Service, Bethesda, Md.
   1. Fluorination of Water.
   2. Topical Application.

9:30 p.m. D. Roles of Dental Clinics in Caries Control. Dr. John T. Fulton, Dental Service Advisor, Research and Child Development, Children’s Bureau, Washington, D.C.

Isaac, Schour, Secretary,
Univ. of Illinois College of Dentistry,
808 S. Wood Street, Chicago, Illinois.
BOOK REVIEWS

Collected Lectures, a Study of the Fundamental Pathology of Periodontal Disease: This is the title of a compilation completed originally in 1946, published in 1947, as a text on Periodontology, by James Nuckolls, D.D.S., Professor of Operative Dentistry and Robert W. Rule, Jr., D.D.S., Associate Clinical Professor of Operative Dentistry, College of Dentistry, University of California. This book deals with the fundamental pathology of the periodontal lesion and is intended for undergraduate students as well as general practitioners. It is designed to bring about an understanding of tissue reactions in health and disease as applied to clinical practice. Treatment planning is thoroughly discussed. The book has no index but does have a detailed table of contents. Biochemical processes are fully considered. It is published by the Lithotype Process Co., 523 Folsom St., San Francisco, California, price $3.50.


This dictionary represents an improvement over the last volume, just as succeeding volumes of the past have over preceding volumes. It is a standard dictionary for medical and dental use; of equal value to each of the profession.
Strong-Carter Dental Clinic: This is the 26th Annual Report, being for the year 1946 of the Palama Settlement at Honolulu. It is a very clear picture of what has been accomplished and points the way to future possibilities. Copies may be had by addressing Palama Settlement, 810 N. Vineyard St., Honolulu 10, T. H.

Accepted Dental Remedies: This is the little book on dental remedies published by the Council on Dental Therapeutics of the American Dental Association. It is now familiar to all dentists, its value being thoroughly established. The 13th Edition came from the press August 15th and is now available at the price of $1.50. It may be secured through the A.D.A., 222 E. Superior St., Chicago, Ill.

Applied Nutrition, Journal of the American Academy: Volume 1, Number 1, Spring 1947, has just made its appearance, being the initial bow of this new magazine. It is as the title indicates, a journal devoted to the subject of food and nutrition. It is owned by and is the official organ of the American Academy of Applied Nutrition, Los Angeles, California. The editor is Dr. J. C. A. Harding of San Diego. The editor, the editorial board, are all connected with the journal including the officers of the Academy are well-known physicians and dentists. This first number appears quite pleasing and contains much of value. The art work on the outside front cover is truly a work of art in which a well-known muralist tells the story of the relation between man and food. It is published quarterly at $4.00 per year, the office of publication being located at 409 North Camden Drive, Beverly Hills, California.

Dental Rays: This is the annual publication of the College of Dentistry, University of Pittsburgh. It is well arranged, well printed, and a very presentable copy of such and similar publications.

The Rockefeller Foundation, a Review of 1946: This is a report which makes its appearance annually being the stories of accomplish-
ment made by the Rockefeller Foundation in its various contributions and individuals. While this Foundation does not support directly any undertakings of dental interest, yet they do contribute among others to medicine and the life sciences. Pages 46 to 50 include the report of their efforts in behalf of social science, medicine, research councils, etc. under the title "Investing in Men." On page 50 we find figures as follows: medical sciences, $99,835,792; social sciences, $1,714,061; humanities, $6,823,986; libraries, $4,746,452; science of education, $25,784,792.

Upwards of 25 per cent of these figures were allocated to negro schools and colleges.

While dentistry has no direct benefit accruing from this yet indirectly there is a benefit to be gained in these particular items. The total expenditure for all purposes under this heading "Investing in Men" was $287,649,529.
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