W.H.M.M. 5/6/31

J. S. Foote, A. B., M. D., LL. D.

BONE AS A MEASURE OF DEVELOPMENT

WHEN AND HOW WE ACQUIRED OUR TEETH

BY

J. S. FOOTE, A. M., M. D., LL. D.

—1928—

PRESS DOUGLAS PRINTING COMPANY

OMAHA, NEBRASKA

Published by the
SCIENTIFIC FOUNDATION AND RESEARCH COMMISSION
of the
AMERICAN DENTAL ASSOCIATION
Headquarters: 58 East Washington Street
Chicago, Illinois

BOOK I

Bone as a Measure of Development

Pages 1-94

BOOK II

When and How We Acquired Our Teeth

Part One—Fishes

Pages 1-88

BOOK III

Part Two—Amphibians

Pages 89-159

BOOK IV

Part Three—Reptiles

Pages 162-182

Introduction

Laboratory research in this volume will be found to be a basis for a philosophy of life, the study of which should eventually have a bearing on the betterment of our human race. The interesting description of the changes which have taken place in the development of bone must certainly make a deep impression on the student as he pores over the various phases covered in this work.

Surely few men have the breadth of vision to relate or correlate the microscopic studies of the bones of the lowest forms of animal life with the highest development of man. The stupendous work of Dr. J. S. Foote, over a period of thirty-four years, has resulted in relating, step by step, the gradual elevation of the levels of development over a period of many thousands of years. With the vast amount of material spread out before him on his laboratory benches he could look into the far distant past and understand the how and why of man's femur of today, and perhaps envision the man that is to be.

One can think of no more fascinating study. And in these days of so much frivolity, of such great speed, and of the multitude of seekers for riches, there is a satisfaction in knowing an occasional rare individual who is not actuated by the movement of the crowd, but is contented to plod along the slow and difficult road to the revelation of a new truth, a truth which has to do with the welfare of the human race and which has in it no promise of financial reward.

It was the writer's good fortune to have visited Dr. Foote in his laboratory, to have seen something of his work and to have recognized in him the man that he was—a devoted, painstaking, tireless worker, whose brain was ever active in analyzing and arranging in logical sequence the facts that were before him in his microscope.

This book is the man. One may come to know him rather intimately by reading it, for it tells in a simple straight-forward way his life work and thoughts. It is his autobiography.

It is very unfortunate that he should be taken from his work at the time he was ready to take up the study of that part of the reptile group where he had noted the first important change in bone structure. Here he expected to find changes in the development of teeth and by following this study through all the various levels, find a possible biologic reason for the most common of man's diseases which is due to oral defects. I sincerely hope some man of Dr. Foote's qualities will soon take up the study where he was compelled to leave it. This man will find records most carefully and scientifically compiled and will have no difficulty in verifying all herein contained.

All honor to this man who was born to research and who has earned the everlasting gratitude of all professions dealing with the basic sciences pertaining to man.

ARTHUR D. BLACK,
Dean Northwestern University Dental School,
Ward Memorial Building, Chicago.

BONE AS A MEASURE OF DEVELOPMENT

BY

J. S. Foote, A. B., M. D., LL. D.

Research Professor in the

Dental Department of Creighton University,

Omaha, Nebraska.

PREFACE

The chief value of research in the biological field is measured by the applicability of knowledge acquired to the problems of human life. While these problems are many and complex, the first and most fundamental of them all is the problem of "making a living." Man must eat to live and therein obeys the same physiological laws which are common to all other animals. Around this central problem are grouped his later social distinction with which we are familiar in the course of human history.

The foundation of men's social distinctions were laid during the whole period of vertebrate life and he is simply finding his place by his acquired ability to recognize harmonious groups which are satisfying to him by virtue of their common origin. As the various bone types of man did not arise with the advent of man; but were extensions from the vertebrates preceding him, so his characters or attributes did not arise when he first appeared, but had their origin in the preceding vertebrates and were extended along a bone stem or bond of union which makes man a part of the vertebrate series.

In the First Part of the following investigation is considered the histological variations and bone types as they were found in bone sections of a large number of vertebrates and also the probable significations of those variations and types in developmental bone history. In the Second Part the application of bone type significations of the various social distinctions of man is made, the office of sex is considered and the value of bone type control as a eugenic measure in the progress of man. Bone, taken as a measure of development, offers a satisfactory explanation of the progressive changes observed in vertebrate history which finally terminate in man.

Index

A

B

C

D

E

F

G

H

I

L

M

S

T

U

PART I

PART I

BONE AS A MEASURE OF DEVELOPMENT

We are all more or less familiar with the various economic values of the animals of the vertebrate series. They are not all alike; some are better than others as they are measured by their own or human standards. Observation leads to preferences or to a conscious selection. Perhaps if we were asked why we think that one animal is better than another we could not give any good reason and yet we would make a selection as though there was a very good reason. The standards by which we choose the better animals vary according to the individual who makes the selection. Generally speaking, the animal which can take care of itself the most successfully in competition with others, can satisfy the most effectually the requirements of man and possesses the most teachable nature, we select as a better animal than one which exhibits opposite characteristics. As a vertebrate, man is not an exception to other animals; there is no doubt that some men are better than others. In the experiences of life, some succeed, while others fail, some occupy a low plane of mediocrity from which they cannot rise, while others occupy a high plane of superiority from which they do not fall. Their levels are recognizable in their characteristics and abilities. Nature has classified them just as though she had measured them all carefully and placed similars with high values in one group, those with low values in another and those with uncertain values in still a different group.

As we think of these classifications, the questions naturally arise: what were their causes? By what measure were vertebrates divided into groups? What are low and high values in animal life? Have we a measure of such values? Can we explain why some vertebrates are better than others? Can we identify, by any visible means at our disposal, the different stages of development and give a proper estimate of their values? If we have affirmative answers to these questions, as it seems to the writer we have, it will greatly help us to understand the various characters of the whole vertebrate series, in their similarities and differences.

As we look over this great series, it is quite obvious that we would have no trouble with such extreme developments as are recognized in the fish and man; but as we advance from the fish and recede from man, the meeting place would be beyond identification as the union of the ways shows no line of approach or departure from which comparisons can be made. It is evident that if there is a visable measure of the stage of development of an animal, it must be in the form of a permanent structure which measures degrees of differentiation in some tangible manner, and which estimates degrees of differentiation in terms of stages of development. Such a measure can be found in the histological variations in bone. If we make a microscopical examination of the bones of vertebrates, beginning with the fish and ending with man and keep a record of the structural variations found; if, then, we make a comparative study of these variations, we will be able to note the similars and differences in each class, group them and arrive at their significations by giving the same interpretation to each variation wherever it occurs and then estimate the values of those interpretations in terms of developments. By this method we may be able to determine the basis on which classifications rest, and arrive at a means of the identification of the stages of development and possibly of species.

Planes of development are vantage points in the life histories of animals. They are all dependent upon variations in structure. One is built upon another and each one makes possible a wider range of vision than the one below it. While the materials of construction are the same the architecture is so modified that the view is more comprehensive. The fish cannot see what man sees, although it has eyes and is a part of the vertebrate series, as he is, but the difference in elevation gives the latter a vantage point which the former does not possess. In the study of ourselves, it is impossible to understand how we advance from one comprehension to another and by what means our limitations are extended. There seems to be in man an intuitive sense that there exists in the universe some irresistible force which bursts at intervals into new and different degrees of consciousness within him, and entirely independent of his reason or prophecy. He does not know whence it comes, how it comes or why it comes. It is as though his old self had suddenly been released from an inexorable law of limitations and the sum total of all of the impresses of the ages had taken form and lifted him to a higher level, where he had expanded into a consciousness of a new order of things. His lines of vision are lengthened and he sees farther; his comprehensions are greater than ever before and a knowledge of the supposed secret and hidden things of the world seems to be within his reach. The universe is not smaller but he is larger; the mystery of life is no clearer than it ever was but he is nearer to it, thinks of it in clearer terms and has access to a greater number of unobstructed avenues of approach leading to it. He is born again and again, and each time into a world in which he has never lived before. The x, y, z of his past has, somehow, become the a, b, c, of his present. He examines nature much more carefully and questions her methods of producing results. He may not yet know how an acorn produces an oak tree, nor how a germ and sperm cell union produces a man, but the principles of biology, chemistry and physics have removed so many apparently insurmountable obstacles that he can think of these problems more clearly and satisfactorily and even outline a plan of investigation which promises much in the direction of a solution. In the light of his new consciousness he wonders why he has not understood these things before, and looks upon them as new discoveries, when, as a matter of fact, his old self, with its narrow limitations, was not able to understand them.

THE ANIMAL BODY AS A MECHANISM AND A PSYCHISM.

The animal body is composed of twelve or fourteen of the most common chemical elements, combined in such a manner as to form a very complex mass protoplasm. It is a marvelous, co-operating community of primordial elements known as the physical basis of life. By the innate principle of variation which characterizes the chemical changes necessarily in operation in such a complex mass, undifferentiated protoplasm becomes differentiated protoplasm or cells, cells become tissues, tissues become organs, organs become systems and systems make up the body. These are all arranged according to a definite plan which exhibits a perfect correlation of all of its parts. In a physical sense the animal body is a mechanism operated by power which is subject to direction. In a psychic sense it is an individual consciousness or self, which is the director of the mechanism and indicates its value by the peculiarities of its phenomena. We may consider the physical and psychical departments of the body as essential interdependencies of the most peculiar of all brown substances, protoplasm.

Primitive protoplasm, by the multiplicity of minute variations within it, exhibited energy and in the course of time became sufficiently differentiated to establish a division of physiological labor. There was, then, one protoplasm, operated by one common force (called vital for convenience) pervading the entire body and producing harmonious activities of all parts for the benefit of the individual. The fuctional value of a mechanical construction operated by power depends upon the character of the terminal to which power is applied.

The animal body, with all of its organs in operation, is analogous to a mill equipped with many machines and operated by power: as for example, a woolen mill making a cloth fabric. The different machines may be operated by a stream of water which is derived from many sources. There are machines for scouring, dyeing, picking, carding, spinning, weaving and finishing the wool, and in addition to all these operations, the same power may be used to light the mill. The different results depend upon the machines or terminals and not upon the kind of power applied. So it is with the animal body: the power applied produces different results according to the character of the various organs or terminals, as, for example, motion, secretion, excretion, cerebration, etc.

From the fact that the results are found in all vertebrates, it follows that they are necessary to vertebrate life, and that terminals by which they are produced will be fundamentally the same in structure in all cases. While this is generally true, yet there is some reason for thinking that the microscopical structure of these terminals is not always precisely the same in all animals, but shows more or less variation which has a definite influence upon the results of their activities. The continued supply of power to the different forms of life depends upon the constant supply of food adapted to their class, and upon the character of their environment. When these are greatly changed, as they may be by the introduction of unusual conditions, such as geological upheavals and depressions, by glacial and inter-glacial epochs, many animals suffer extinction, and leave their skeletal remains as monuments of vertebrate history.

Bone as a Permanent Record of Histological Variations by Means of Which Vertebrate Developments May Be Identified:

Bone is more changeable before than after death; in fact, it is the site of great activity during life. On account of its permanent character after death, it is the most satisfactory tissue of the body for the study of the developmental history of vertebrates.

Since the classes of animals in which bone is found as a fundamental structure are fishes, amphibians, reptiles, birds and mammals, and these occurred historically in the order mentioned, a microscopial examination of the bones of the series may be expected to show vertebrate developments, or, as they may be called, evolutionary levels in bone, if there are any. The chemical changes of decomposition, which begins in the soft tissues as soon as metabolism ceases or death ensues, render them unfit for study, unless they are subjected to the various forms of laboratory technique employed in microscopical work, when they are no longer the tissues of the body, in reality, but artefacts, which are useful in themselves but do not present pictures of living tissues. One never feels quite certain that what he sees under the microscope is what actually exists in the living body. There are no visible structural evidences by means of which chemical changes may be identified and therefore the comparative study of epithelial, muscular, nervous and connective tissues, (bone excepted) is unsatisfactory and levels of development are very difficult to establish.

We may now ask, what is understood by vertebrate developments and by evolutionary levels in bone, and what are their significations?

Vertebrate developments are successive stages of advancement in vertebrate history. Evolutionary levels in bone are histological variations accompanying stages of development.

If we compare the stage of development of the fish with that of man, we are conscious of the extreme stages of vertebrate life. If we compare the stages of development of the vertebrates, fish, reptile, bird and mammal, we are conscious of a series of developments. Furthermore, if we examine microscopically the bones of the series we will find that these different stages of development have different histological structures. Structures, therefore, may be taken as indices of the stages of development, if structures and development advance with equal step, as seems to be the case. These different stages, with their structural variations, may be considered evolutionary levels, since each one is transfused into another which succeeds it by the agency of some operating force equivalent in projecting power to the level reached. For example a fountain reaching a level of two feet may be transformed into a fountain reaching a level of ten feet by using the same material in larger quantity and increasing the projecting force; so in evolutionary levels, the projecting force is proportional to an objective elevation. This force did not begin with the first visible form of bone which occurs in the fish, but with the first form of life. As the projecting force of the fountain is the sum total of the projecting forces of many waters from different sources, so the force of development is the sum total of many forces which were derived from many sources and were in operation when bone appeared. With this understanding, we may speak of earlier and later, lower and higher developments or levels in bone. The projecting or evolutionary force has a directive character about it which always tends toward higher developments or levels and it is impossible to think of it independently of the Creative Fiat.

Bone developments or levels are identified by histological evidences and we may look for those evidences with the expectation of finding them if the directive power of tranformism has been effectual.

Following a prolonged study of bone sections under the microscope, the general statement can be made that there are conclusive histological evidences of a succession of developments or levels, extending from fish to man. (1) These evidences are found in the structural variations called "Types of Bone" and the developments or levels recognized by these Types are the expressions of advancements from the first undifferentiated bone substance to the most highly organized bone unit, or Haversian System. If the structure of bone were exactly the same in all cases, or if it presented no more definite variations in the bone series than can be recognized in the soft tissues, there would be no reason for thinking of different development or levels or of any indications of advancement which could be distinguished, and bone would occupy a mechanical position only in the vertebrate kingdom. But this is by no means the case. In advancing from unorganized bone substance to organized bone units, the animal is going from his lowest to his highest stage of development, and the class to which the animal belongs is proceeding along the line of the projecting force of Creation, which is always upward.

Let us now examine the bones of the vertebrate series in their historical order and see what those structural variations are which lead to evolutionary developments of levels.

(1) The study embraces a period of fourteen years and the examination of thirteen hundred cross, longitudinal and tangential sections of long, flat and irregular bones of fishes, amphibians, reptiles, birds, mammals and man.

The first bone type appeared in the fish during the Devonian Age and, therefore, has a history of great antiquity: Its microscopical structure shows how bone began. In these bone sections-cross, longitudinal and tangential—the two most essential parts are the circulatory system and bone substance; these essential parts will also be found in all bones from fish to man. During the long period of bone history, both the circulatory systems and bone substance have not remained unchanged, but have undergone very important variations as may be seen from the following descriptive account of the examinations made. It may be thought that as these bones belong to the fish of the present day and not to the fish of the Devonian Age, their structures might not be the same as those of the bones of that remote period, but the fundamental structures of bone today are the circulatory system and bone substance and must have been in the Devonian Age as nothing less than these structures could be called bone, no matter when it existed or in what form of life it appeared.

THE CIRCULATORY SYSTEM IN ITS PRIMITIVE FORM.

The circulatory system in the bones of these early fish, for example, the Muscalonge, represents a primitive form. It is composed of very minute, parallel clefts or channels, enclosing between them narrow discs, or thin plates of undifferentiated bone substance. At short intervals in these clefts are seen slight enlargements of the clefts produced by cells. These cells have very fine branches which occupy minute canaliculi extending across the discs, from one cleft to another. The clefts communicate by small, parallel blood vessels which are adjacent to the clefts. The blood vessels are composed of thin connective tissue walls, striated longitudinally, transversely and spirally, and have fine plexuses of nerves along the external surfaces of their walls. The branching cells of the clefts, which seem to be endothelial cells endowed with the power of secreting bone substance, present the first evidence of differentiating osteoblasts. The familiar lacunae, with their canaliculi containing the osteoblasts and their branches, and found in later bone differentiations, were not found in the bone differentiation of the early fish. While the Muscalonge is not a descendant of the oldest Triassic ganoid fishes, as the Gar-pike is, yet it is a descendant of the upper Cretaceous group, and represents a stage of development between the early Gancids and late Teleosts. For this reason it shows the bone differentiation of the earliest type of vertebrates, and may serve as a standard with which other bones may be compared. Judging from the character of the circulation in this early type of bone, it is quite obvious that nothing less could exist and be recognized as circulation. It is a cleft or channel circulation. The bone substance of the discs between the clefts is homogenous in structure and presents no visible evidence of any degree of differentiation. Nothing less than this could be recognized as bone substance. Moreover, in grinding down the sections, the subjective feeling of hardness is experienced, as it is in the grinding of all bone sections. Thus, the earliest bone was composed of bone substance, with a circulatory system, and we shall see later that this has not changed in its fundamental characters throughout the whole period of subsequent bone history. Bone substance was produced by cells in the circulatory clefts in the beginning and is now produced by cells in the lacunae, which are enlargements of minute circulatory canals or canaliculi. So, in either case, bone producing cells belong to the circulatory system.

The circulatory system, simple in arrangement, as seen in the early differentiation of bone, was potentially capable of extensions and architectural arrangements in later differentiations which then produced the more complex designs seen in the several bone types and type-combinations forming the bone of the later vertebrates.

Bone substance as produced by osteoblasts is a compound of protoplasm and inorganic salts, of such an unstable character that the salts may be delivered to the blood for general metabolic purposes, in proportion to the requirements of the tissues of the body, thus giving to bone the very important function of a calcium exchange. As a Banking Institution receives money from depositors and holds it subject to check, so bone receives deposits of calcium salts from the different foods and pays them out on demand.

In this respect bone has not changed during its whole history, and its purpose is the same in all forms of vertebrate life; but what has changed is the extent and arrangement of the circulatory system, giving new bone types and type combinations which appear in different vertebrates, and thereby indicate different levels of advancement in the bone series. Again referring to the bone histology of the Muscalonge, there were found, in sections of the lower jaw, which is more advanced than the cranial bones from which the above description was taken, certain areas where the bone substance was marked off in narrow parallel rows or layers, which remind one of an architectural design or plan, in that they are merely representations of something to be constructed. These layers, here seen in outline, later become lamellae, or the first differentiation of bone substance, or as it may be called the First Type Bone. In other areas there were found groups of these layers which were more complex and more prominent than layers, and which indicated the plans of a second differentiation of bone substance, later known as laminae, or the Second Type Bone. Finally, there were found, in still other areas, cross sections of small vascular canals, surrounded by clear circular regions in the bone substance, which were the plans of the third and most complex differentiation of bone substance, later known as the Haversian System, or the Third Type Bone. These vascular canals, with their surrounding clear bone areas, were later found in the bones of all classes of vertebrates, from fish to and including man. Thus we see the bone of the fish the laying out of the types of bone which are found throughout bone history, and are able to recognize in the different plans a constructive power in operation. The bone of the fish is the bone in the making. The architectural plans of all structural types of bone have been drawn and can be recognized. It remains only to construct the types according to the plans. When completed, these types represent bone levels, that is, a bone level is any one of the structural types, First, Second or Third. By a degree of differentiation is understood the smallest visible structural change occurring in a bone substance.

In bone history, undifferentiated bone substance was the first form of bone to appear as was seen in the fish, and therefore it may be taken as a standard with which all bone variations may be compared. Undifferentiated bone substance represents the simplest product of bone cell metabolism differentiation indicates organization as undifferentiated bone substance is differentiated into lamellae, the first bone level is produced, or into laminae, the second is produced, or into Haversian System, the third and last level is established.

Bone substance, then, introduces vertebrate life and may be considered a subtype. Differentiations of this bone substance introduce the structural bone units which may occur alone and form types, or they may occur in association and form type combinations. For example, a bone may be composed of undifferentiated bone substance alone forming a sub-type, or of lamellae forming a First type bone, or of laminae forming a Second type bone, or of Haversian Systems, forming a third type bone. Furthermore, a bone may be composed of lamellae and laminae forming a first and second type bone or, of laminae and Haversian Systems forming a second and third type bone, or finally of lamellae, laminae and Haversian Systems forming a first, second or third type bone. The appearance of bone substance marks a distinct advance in the progress of animal life, since the cells which produce it have acquired the power of forming calcium compounds of protoplasm, of storing the product and of using it for mechanical purposes and tissue metabolism.

Having found bone composed of a sub-type, of types and type combinations, we may now ask, what are their significations?

Signification of the Sub-type: Bone substance first appeared in the fish and, as we might expect, in its simplest and lowest form. If we attempt to give it a signification we will be obliged to keep in mind the fact that it is the bone of the first and lowest form of vertebrate life, and must represent the attributes of that life. It is bone unorganized by differentiation—the substance of which types are made. If, therefore, this first substance means anything in one vertebrate it must mean the same thing in another, no matter where it may be found, and if it should be found in the bone of an animal of a late degree of differentiation and stage of development, it would lower the grade of that animal in proportion to its extent. The signification of undifferentiated bone substance, then, is this: It represents the lowest bone level and the attributes which belong to it. Whenever it is found in association with higher types it signifies the existence of some restraining power operating against the phylogenetic force of evolution and the persistence of an unorganized bone substance which ought to be eliminated. It has quite a wide distribution in the vertebrate kingdom, since it is found in the bones of early vertebrates as the primitive fish and amphibians, in the early periods of embryonic life; in the bone of repair and certain pathological conditions. This associates phylogenetic ontogenetic, physiological and pathological conditions, with an important relationship between them, the last two depending upon the first two remotely and immediately. Let us now examine the bones of the different classes of vertebrates and determine, if possible, what structural variations are found which indicate levels of advancement.

Fish: In the representatives of the primitive fish, as the shark, gar-pike, bowfin, muscalonge and lake trout, bone substance predominates. It has a cleft circulatory system with primitive bone cells, in the cranial bones, multipolar bone cells and the outlines of lamellae, leminae, and Haversiàn Systems in the mandibles and vertebrae. With such an ill-defined bone as this, it is not difficult to recognize in the early fish, bone in the making. This is about what we would expect in these primitive animals, if there is a continuous connecting bond extending from the beginning to the end of the vertebrate series. Such a primitive structure is also in harmony with the quality of the attributes which the developmental stage of the fish presents.

Amphibians: The architectural plan of bone types was completed in the fish and it remained to construct the types according to the plan, which required time and the continued application of the Directive Power of organization. The great volume of vertebrate life has been aquatic in character and, perhaps, still is; but there has been a successful attempt to leave the water and quicken the life by the more available oxygen of the atmosphere. But why abandon the water which has been the principal abode of life, since life began, and adopt the lesser abode of earth with its more tenuous atmosphere and difficult environmental conditions? It was because of the presence of a Directive Power operating toward an objective which it was not possible to reach in an aquatic existence and which was necessary to the higher planes of life. It was necessary for life to leave the water, in order to advance as the forthcoming evidences will show. Evidently the change could not occur suddenly, but very gradually, as such a marked change would imply, and vertebrates both aquatic and atmospheric, (or the amphibians) appeared, and introduced a new order of things. The transition from aquatic to atmospheric life could not have taken place if the structure of the fish had remained unchanged; but it did not remain unchanged. There was outlined the plan of construction, and then followed the construction according to the plan. As was seen in the bone of the fish, there was a gradual change in plan, which necessitated a change in construction. The structural units, lamellae, laminae and Haversian Systems, were drawn in outline and if they had remained in outline, it is inconceivable how the same structural units could become adapted to and sufficient for both the aquatic and atmospheric forms of life. But the structural plans did not remain in outline. There are distinct evidences of the fulfillment of the purpose for which the plans were drawn, and these were found in the variations which appeared in bone structure.

Again, if there had been a transformation of aquatic to atmospheric life by an extension of the same structures as those which characterized the aquatic life, and this had been accomplished by the same Directive Power, the completeness of the transformation might not, and probably would not, be made at any one time but at different times, and there would be extensions of the lower levels of differentiation into the higher; that is, the differentiations of the fish might be extended into the amphibians and made it possible for them to live in water or on land, and this seems to have been the case.

APPEARANCE AND INSTALLATION OF THE FIRST TYPE BONE

Unit-the Lamella: In the bone of the Muscalonge we saw a channelled bone substance, without lacunae and the canaliculi, and the lamella, lamina and Haversian Systems in outline only. In the vertebrae of certain other fish, the lamella was more distinctly marked than is indicated by an outline. Bone substance has been extended from the fish into Amblystoma Tigrinum, a primitive amphibian, and as far as can be determined, it has the same structure. In other and later amphibians bone substance shows distinct evidence of a change in differentiation. Instead of clefts or channels in the bone substance there are now minute canals. Instead of bone cells being found in the clefts, or channels, they are now present in lacunae in the bone substance and the lacunae communicate with each other and with the vascular canals by canaliculi. Here is indicated an advance in the circulation, as it shows an increased distribution and organization. Furthermore, there is observed an orderly arrangement of the lacunae and bone substance enclosing them in very narrow parallel rows, or layers. Extending between the layers are seen granular, parallel lines, which are lines of union between the layers. One of these layers, with its lacunae and canaliculi, is known as a Lamella. Here is seen a new evolutionary level in bone differentiation, and having been once established it was found to remain as a possible bone unit in the structure of all bone. This Lamella, or First Type Bone, characterizes the classes of fishes, amphibians, and the lizards and snakes of the reptilian class, and may be understood to represent a definite level of advancement wherever it may be found. (2) As a matter of fact, it is found extending through all classes of vertebrates, from fish to and including man, and carries with it the signification of its degree of differentiation in bone history. It is the highest established type of bone in the class of amphibians and the lowest type of bone differentiation. It is in a comparative sense that, among amphibians for example, the bone of the frog may be considered a higher type of bone than that of the amblystona tigrinum. The former is represented by an organized, lamellated bone and the latter by an undifferentiated bone substance. As the degree of differentiation is, so is the stage of development of vertebrate. Thus, the classification of vertebrates had its beginning in the fishes, the classification, in each case, resting upon an evolutionary basis as revealed by the visible evidence of the bone differentiations or levels.

While we are unable to divide force into forms or kinds, yet we have become accustomed to certain names more or less descriptive of the substance upon which it acts, as, for example, vital force. While this can not be distinguished from any other force, probably because it is not distinguishable, yet it is in common use to indicate the force which is supposed to be peculiar to living things, and, perhaps, synonymous with life itself. Its principal quality or attribute is one of direction toward a definite end. An undirected or misdirected force is not in harmony with intelligence. If there is any such force in the universe it is beyond our conception.

A natural flowing stream is a visible evidence of gravitation, a force we know little about. We recognize it in the flow of the stream, the fall of a grain or the fall of a ton, as the same force, the difference being in the mass moved. It would be senseless to speak of stream force, grain force or ton force. So it is with the so-called vital force, or animal force. There is a stream of this operating force

(2) Foote, J. S. A contribution to the Comparative Histology of the Femur, Smithsonian Institute, "Contributions to Knowledge," Vol. 35, No. 3, 1916.

surface at intervals, are seen the different phyla, genera and species of animals which are the visible evidence of successive stages of development. It would mean the same in the amoeba as in the fish, and the same in the fish as in the mammal, and the same in the mammal as in man; but its perceptible evidences would vary according to the stage of development. It matters little what this flowing through the vertebrate series, from beginning to end, and, rising to the form of energy is called which is manifested in the phenomena of life, as every one has in mind the same thought whenever the term "vital force" is used. We can not think of amoebic force, fish force, reptilian, bird, mammal or human force, but we think of one force appearing in the different forms of life which we classify by the association of resemblances. As life leaves the water we naturally expect to find certain changes in structure adapting it to its new and different atmospheric environment. A long time must have elapsed while going from water to air, and the required structural changes must have been slow to appear. If, now, we examine the class of animals occupying this intermediate position and known as the class of amphibians we find that some very important variations in bone structure have occurred. (In this and all succeeding classes of vertebrates, the particular bones examined were the femora, for the reason that on account of their position and uses they are the most representative bones of the body.)

Internal and External Circumferential Lamellae: The lamellae having been outlined in the fish, we find it established as the principal differentiation in the amphibian. The next variation to be noticed was the separation of the wall of the femur into two concentric divisions, viz., a narrow band of lamellae surrounding the medullary canal and called the internal circumferential lamellae, and a wide band of lamellae surrounding the bone and called the external circumferential lamellae. This division may be seen in the femur of the amphibian,—Hyla femoralis. It was also found to extend throughout the vertebrate series indicating its developmental importance. Furthermore, in other femora, the wide band of external circumferential lamellae was divided into two concentric portions—a narrow external and a wide internal band, making now three concentric division in the wall of the bone, external, middle and internal divisions, which also remain throughout the bone series.

This three-fold division may be seen in the amphibians, Pipa Americana, Bufo Agua, Necturus Maculatus and others.

In other instances there was no division in the wall of the bone, there being a band of undivided lamellae enclosing the medullary canal. This may be seen in the amphibians, Hyla Versicolor, Rata Catesbeina, Spelerpes Ruber and others. It is interesting to notice that these divisions did not appear together in all amphibians, but separately, collectively or not at all. It is not in the nature of bone substance to separate into lamellae or to group themselves together in laminae; if it were, all lamellar bones would be so divided and show a uniform structure, but this is not the case. There must, therefore, have been in operation some organized plan whereby bone was assuming a form which would be adequate for the whole vertebrate series. In this variable manner appeared the divisions of the wall of the femur. While these main divisions remain the same, there may be found a diversity of variations in them and more especially in the central division. The wall of the femur, therefore, may be undivided and composed of one type of structure or it may be divided into two or three concentric layers and be composed of one, two or three types of bone units.

Very significant variations of an early character were seen in the femora of three frogs. One was a large bull frog, Rana Catesbeina, one a medium sized and one a small bull frog, and all belonged to the same species. The bone of the large frog showed, in cross section, numerous bush-like radiating canals extending from the medullary canal to the external circumferential lamellae. Many small branches came off from these canals, increasing in number from the medullary canal outward. The branches terminated in lacunae in the bone substance between the bush-like canals. The picture resembled bushes with branches and leaves. The stems and branches were the vascular canals and the leaves were the lucanae. In this bone the circulation was very extensive.

In the medium-sized frog the bush-like canals have disappeared from the outer half of the bone, and in their places were seen lamellae with their lacunae and canaliculi. In the small frog the bush-like canals have all disappeared, and the entire wall of the bone is composed of concentric lamellae, with their lacunae and canaliculi. In this series there were three diminishing variations in the vascular system, with the final installment of the lamellar type of bone in the small frog. This was found to be the case with other series of frogs of different sizes. Any large bull frog of this species will show the bush-like circulation and any small frog the lamellae without that circulation. These vascular variations must have appeared before those of the bone substance, for the reason that the bone substance is produced by the vascular system and the product could not precede its cause. The bone of the large frog had the more extensive circulation and this would be expected if its purpose was the production of bone substance, while the bone of the small frog had the less extensive circulation, and this would be expected because the bone substance had been made and the circulation had been reduced by developmental pressure.

Thus we see in the bones of the amphibians important variations in the circulation, the prevailing differentiation of bone substance into permanent lamellae, and the separation of the lamellae into external, central and internal divisions. None of these variations can be satisfactorily explained on the basis of function or environment, since these remain practically the same. It is much more reasonable to suppose that they represent the first evolutionary biological level, and the first type of bone which belongs to it. The transition from fish to amphibian, from water to air, is, therefore, accompanied by variations in structure which have no perceptible bearing upon the transition excepting they represent the evolutionary means to an end.

The Second Type Bone Unit, or Lamina: While the lamella represents the highest established level of advancement in amphibian life, yet a larger and more highly organized bone unit appears and is known as the Lamina. It is composed of undifferentiated bone substance, or of the several parallel lamellae, grouped together between parallel vascular canals. Of the thirty-six amphibian femora of different species examined, the lamina was found in only one, the femur, of the American Toad, Bufo Americana, where it occupied a very irregular position in the central division of the wall of the bone. The unexpected appearance of a single lamina in the bone of an animal characterized by a lamellar level of advancement indicates that a change is in progress and foretells the existence of another and different possibility in bone differentiation. There is no satisfactory explanation of the occurrence of the lamina in this situation on a functional or environmental basis. As far as can be determined, there is no reason why it should be found in the bone of the Bufo Americana and absent from the bones of all the other amphibians, unless it is a variation caused by those biological divergencies which are common to the evolution of living substance. While living substance is obedient to a law, yet it is sometimes disobedient to the method of observing it. The lamina is the logical sequence of the lamella, if a continuous power—of development—is in operation. It is bone substance molded into another form. It represents, in a larger way, the unifying influence of community interests and indicates it by the association of similars. It can not be said to characterize, in any way, the amphibian, but it may be said to occupy a position of advantage in bone history, from which other levels of advancement are visible. In the formation of the lamina, the circulation is primarily increased, and this increase is followed by the adjustment of the bone substance to the new vascular plan. It is for this reason that it is a higher form of bone unit than the lamella. It suggests a condition or state subsequent to that of the amphibians in which it has an exceptional occurrence. Having once appeared, it remained as a structural unit in all succeeding classes of vertebrate, thereby showing its importance in bone history. The lamina was the introduction to a new level.

The Third Type Bone Unit, or Haversian System: We have seen the lamella established as the structural unit in the bone of the amphibians; the lamina introduced as a more complex unit, and now we find that the early form of the Haversian System,—the most complex bone unit,—is extended from the fish into the amphibian, without apparent change. The term "Haversian System" is really applied to the completed bone unit composed of a central vascular canal surrounded by a variable number of lamellae, the lacunae of which communicate with each other and with the central canal by their canaliculi. It began as a vascular canal in the bone substance. The completed Haversian System does not appear in either the fish or the amphibian, as might be expected if there is a correspondence of the developmental level of vertebrates with their bone levels. Instead of the completed Haversian System, there are found vascular canals, surrounded by clear areas in the bone substance and extended lengthwise of the bone. These vascular canals are very numerous in some of the toads.—Pipa Americana,—and are very infrequent in other amphibians. As bone substance and lamellae extend from fish to man, so do the Vascular canals of the early Haversian System; in fact, they may be followed from the beginning of the vertebrate series to the end. They are not found in all bones of the series, but in some bones of all classes of animals which make up the series. They are the hour hands of development.

The Circulatory System in Bone: The circulatory system has been studied in a large number of bones of each class of vertebrates, (including all bones of the human skeleton) and shows by its variations an important relationship between the type of circulation and the type of bone structure.

The circulatory system is situated between the periosteum and the medullary canal in long bones, and between the pericranial membrane and diploe, and dura mater and diploe in the cranial bones. (3)

It can be seen only in tangential sections. As the bones of amphibians are small and round, they do not admit of satisfactory tangential sections. The circulation in the femur of the large bull frog is simple and quite in harmony with the type of bone structure. It is composed of several M shaped loops of vascular canals converging from the two ends of the bone toward the center of the shaft. They pass through the wall from the periostal surface to the medullary lamellae. From these loops are sent off the small branches which terminate in the lacunae, and are enclosed in bone substance. In the medium-sized frog, the circulation has the same arrangement, except that it is found only in the inner wall; while in the bones of the small frog it is not found at all. There is no explanation of this peculiar fact on the basis of function. There might be on the basis of evolution. If we compare the circulation and bone substance of two frogs, large and small, and attempt to place one before the other in the stage of development, the bone of the large frog would represent a lower stage than that of the small frog, for the reason that bone substance is the product of the circulation and there is less of it proportionally in the bone of the large than in the small

(3) The Circulatory System in Bones—Foote, J. S. Smithsonian Miscellaneous Collections, Vol. 72, No. 10, 1921.

frog, and the more finished product the bone has the later its stage of development.

It is not difficult to understand that the structure of the small bone could follow that of the large by re-arranging the circulatory system, by increasing the amount of bone produced by the blood vessels and by organizing it by differentiation into lamellae.

In early embryonic bone of mammals and man there are wide vascular canals which gradually decrease in size as the organization of bone substance progresses, until they have been completely replaced by a new circulatory organization and bone differentiation.

Reviewing the bone sections of the amphibians, the fundamental fact is established that the microscopic structure of bone is not the same in them all, although in some instances, as in the three bull frogs, the functions are the same. There are variations in the circulatory system, in the bone substance, in the internal, central and external lamellae, in the rise of the lamina and in the differentiation of the Haversian System. These variations are of such a character as to suggest a progressive movement toward an objective in bone history. There are more indications of advance in structural type in the toads than in the frogs, since the longitudinal vascular canals—early developments of Haversian Systems—are much more in evidence in the toad than in the frog, in fact, they were very infrequent in the frogs. The bush-like radiating vascular canals were not observed in the toads, and were very numerous in the large frogs. These, however, do not give rise to Haversian Systems, as Haversian Systems do not extend radially but longitudinally of the bone. The bush-like radiating canals, by the general concentric arrangement of their branches, forecast the formation of lamellae, while the longitudinal vascular canals forecast the formation of the Haversian Systems. Furthermore, there is no apparent reason why the known differences in the functions of the femora of the toads and frogs should demand such differences in structure as are observed. On the whole, therefore, we may think of the amphibian level of advancement as the lamellar level of bone differentiation, and give to it the signification of the first organized bone.

With this observation, we may extend the investigation to the reptiles.

Reptiles: The vertebrate series is divided into the warm and cold-blooded groups. The cold-blooded group comprises the fishes, amphibians and reptiles; the warm-blooded group, birds, mammals and man. Man is here considered separately, for convenience. It was extended, without much change, through the fishes and amphibians into the reptiles, where an important change occurred. The line of difference in bone type between the amphibians and the reptilian lizards is not well-defined. It is not a simple matter to decide just where the amphibian life terminates and reptilian life begins. The same lemallar bone type prevails in the lizards as in the amphibians, with a possible slight advance in the differentiation of the lamellae. The first evidence of a distinct change in bone structure is seen in the alligator, that is, the amphibians. The lizards and snakes may be arranged in one group, with one type of structure, and the alligators and turtles in another group, with another and different type of structure. From amphibian to alligator, no new bone level was indicated, as the lamella was the highest and most advanced established bone unit of structure. This does not suppose that no change was in progress, but that the visible evidence of it was slight and insufficient to indicate a new level. In the alligator, however, there appeared a new evidence of a change in structure, indicated by a rise of the lamina to a prominent place in bone construction. There was also a noticeable change in the degree of differentiation of the Haversian System, and in its proportionate increase. The femur of the preceding Python is interesting because it is the femur of a snake and rudimentary. It is not an outgrowth from a femur but the entire bone, produced in a vertebrate which does not require such an organ to serve any purpose whatsoever, and the testimony of such an organ would be free from functional influences. There were femora in the lizard ancestry of the snake, but just when they disappeared, or why they disappeared, when they reappeared or why they reappeared are questions which are unanswerable at present. This particular femur was taken from a Python twelve feet long. It was situated beneath the skin and was about 1 mm. in diameter. A cross section of the bone at the middle of the shaft was composed of incompletely differentiated lamellae, arranged in an irregular manner around a very small medullary canal. The lacunae in the bone substance was round or oval, indicating an early differentiation, and the bone substance was not distinctly separated into lamellae. The bone had the appearance of incompleteness. The particular interest in the bone centers about the fact that although it was rudimentary and functionless, yet it had a true bone structure. Camparing this structure with that of the amphibian and lizard on the one hand, and with the bone of the alligator and turtle on the other, the bone of the snake was found to be the same in type as that of the amphibian and lizard, and not at all like that of the alligator or turtle. The femur of the snake was true to the lizard type of structure, although it had lost the lizard function and was a purposeless bone. From such evidence as this it may be supposed that it is not function that decides what a bone type of structure shall be, but the level of advancement which an animal occupies in the vertebrate series. It the bone of the lizard had been a second or third type bone instead of a first, the bone of the snake would likewise be a second or third type bone; or if there had been a second or third type bone in the history of bone, before the lizard or amphibian, the bone of the snake might be first, second or third in type. It may also be supposed that the snake followed the lizard in point of time and not the alligator, as it has the bone structure of the lizard and not of the alligator. Between the lizards, snakes and alligators an important rise in bone level occurred, as is shown by the structure of the femur of the alligator. This rise may be seen in the structural prominence which the second type bone units, or laminae, have assumed, and also in the advanced variations presented by the Haversian Systems. The first type reptilian bone terminated with the lizards, which seemed to divide the reptiles into two parts, viz., lizards and snakes, alligators and turtles.

A cross section of the femur of the alligator, Alligator Mississippianis, is composed of alternating, concentric rings of incomplete laminae and the early differentiation of Haversan Systems. This marks an advancing change in bone structure. The alligator has emerged from the first type level and declared a second and third type differentiation on its way to a higher level.

Three histological changes are in evidence: The disappearance of the lamella, the installation of the lamina, as the prominent bone unit, and an advancement in the differentiation of the Haversian System. Of these three changes, the rise of the lamina is the most important, because it is the most complete in its differentiation. The Haversian Systems have greatly increased in number, and show important changes in structure. They are composed of central (Haversian) canals, surrounded by clear areas in undifferentiated bone substance, as was seen in the fish and amphibians; but in the alligator, the lacunae adjacent to the clear areas have assumed a concentric arrangement, which was absent in the fish and amphibian and some of the lacunae can be seen communicating with the Haversian canals by canaliculi. While none of the bone units are completed and established, as permanent levels, the laminar and Haversian System levels are distinctly forecasted in the bone of the alligator. This femur can be distinguished microscopically by its bone units and their arrangement. In a cross-section of the femur, mounted on a slide, and held up to the light, the concentric rings may be seen with the naked eye, reminding one of the rings of the trunk of a tree, in cross-section.

In the turtles there are indications of an additional advance in the Haversian Systems, while the laminae are not prominent. The central canals of the fish and amphibian type are surrounded by fairly distinct concentric lamellae, the lacunae of which communicate more freely with the central canals. The systems can now be recognized as Haversian Systems, although still far removed from the completed systems of the later mammals. Another interesting change is seen which appears for the first time, and that is filling of the medullary canal with a dense, heavy, cancellous bone, giving the section the appearance of solid bone, as seen by the naked eye. While this solid feature characterizes the femora of the whole turtle group, it is nevertheless, exceptional in occurrence, taking the bone series as a whole. It was thought, at first, that it might be caused by some functional requirement of the femur of the turtle, but when it was also found in the femora of some birds, a similarity of function could not be recognized, and it became necessary to fall back upon an evolutionary bond of union existing between the reptiles and their successors, the birds. The turtle is the most advanced reptile, by bone structure. It may be recognized microscopically.

Comparing the bone structure of the alligator with that of the turtle, it may be seen that the lamina, or second type bone unit, is rising to a position of prominence in the former and the early differentiation of the Haversian Systems, or third-type bone unit, in the latter.

It cannot be said that another and distinctly higher bone level has been established in the reptile; it is more like finding the degrees of differentiation representing transitional stages of development, or like tracing an evolutionary bone level in the making, since there are two rising structural bone units in the early laminae and Haversian Systems.

The Circulatory System in Reptiles: The circulatory system in bone is the key to the structural variations which are found. Bone is an extremely vascular organ and in order to understand why it should have such an extensive circulation, and this regardless of its location or the species of animal to which it belongs, it is necessary to know what its functions are. These are mechanical, calcium exchange and hematopoietic. The function of bone is generally supposed to be largely mechanical, as it forms the framework of the body to which the muscles, blood vessels and viscera are attached, and makes locomotion possible by a system of bone levers. It is, however, quite obvious that a very extensive circulatory system would not be required for these mechanical purposes; in fact, too extensive a circulatory system would reduce the mechanical value of bone by the substitution of blood vessels for bone substance.

The circulatory system is not the same in all types of bone. There are two types, viz., the branching and plexiform. (4) The branching is found in bones of connective tissue origin, like the cranial and the plexiform, in bones of cartilaginous origin, like the femur and other long bones. The plexiform is the more extensive type because it has a greater number of blood vessels in a given sectional area. Within physiological limits, the more extensive the circulation the greater the function. It is in a tangential section of bone that the circulation can be satisfactorily seen. If we look at such a section of the femur of an alligator, a very surprising circulatory system is brought into view which is plexiform in type. Evidently the function indicated by this extensive blood supply could not be chiefly mechanical. It would be impossible to conceive of a mechanical function

(4) "The Circulatory System in Bone." Foote, J. S., Smithsonian Institute, Miscellaneous Collections, Vol. 72, No. 10, 1921.

being greatly increased by such a vascular picture as was presented in this section of the femur of the alligator.

Furthermore, such a rich blood supply as is usually found in bone could not be required for the nutrition of bone unless bone requires as great a blood supply as a liver or other gland. But there are two functions of bone which would necessarily demand a very extensive circulatory system in order to maintain a standard of value in the economy of vertebrate life. These are calcium exchange and the formation of red and white blood cells. Bone is a storehouse of calcium salts which can be drawn upon by the tissues of the body for the purpose of general metabolism. Obviously, the more extensive the blood supply within physiological limits in the bone, the more readily the exchange is made. Again, the enormous number of red and a great many of the white blood cells are produced by bone marrow, and this would also require a very extensive circulation. Now, as calcium salts, red and white blood cells are constantly being used up and as constantly replaced during the wear and tear of a life-time, an exceedingly active and profuse blood supply would be required to meet such demands. As there is no other adequate sorce of calcium salts, red and certain forms of white blood cells, (and these are absolutely necessary to the continuation of life) it follows that any particular disturbance in the anatomical or physiological characters of the circulation would change calcium metabolism of the body and the respiratory capacity of all of the tissues, thereby initiating a general pathological condition of grave importance.

Again, the two types of the circulatory system are found in association with the three types of bone; the branching circulation is found with the first bone type, and the plexiform with the second and third bone types. The branching circulation is simplest; its sectional area is not as great as that of the plexiform and therefore the type of bone produced by it would naturally be the simplest or first, while the plexiform, being much greater in extent of distribution, and more complex in its organization, would produce the more complex bone type, or the second—or third.

As a matter of fact, we do not find the branching circulation in second or third type bones, nor the plexiform in the first; hence the more extensive the circulation, the higher the level of advancement or, in other words, the level of advancement depends upon the circulatory systems. As the plexiform circulation began to rise in importance, as may be seen in the bone of the alligator, the second and third types of bone also assumed a rising importance.

Comparing the bone structure of the reptiles with that of the amphibians, it is not difficult to recognize a marked change in both the circulatory system and type of bone. The operating force of a progressive development must have received some special impulse in the alligator which forecasted a higher level of advancement. As far as type of structure is concerned the amphibians could be extended to the alligators. It is not difficult to distinguish between the bone of the amphibian or turtle, or between the alligator and turtle, while it is extremely difficult to distinguish between the bone of the lizard and amphibian.

It is in the reptile that we are able to recognize a distinctive evidence of a departure from the first-type bone and of the formation of the second and third types, which introduces the thought of further changes and their possible relation to progressive developments. We must look to the reptile for the first appearance of our Haversian System.

BIRDS.

The birds are linked to the reptiles in three ways: by the Pterodactyl, which was a flying reptilian vertebrate with teeth and with vertebrae extending to the end of a feathered tail; by the elliptical red blood cell and by bone. A physiological change of great importance also appeared in the birds and that was a change in temperature. The cold blooded vetebrates terminated with the reptile, and the warm-blooded vertebrates began with the birds. Some very important change must have taken place between these groups. In the former cold-blooded group the temperature varies with the environment, while in the latter warm-blooded group a thermostat has been installed and set to operate around 100-F. The elliptical red blood cell was the first red blood cell and has been extended from the fish through the whole vertebrate series. From fish to mammal, it is elliptical and nucleated. But some peculiar disturbance in the biological history of the red blood cells is evident in the mammal. This seems to be indicated by the behavior of the nucleus, and the change in the shape of the cell. The changes in the nucleus are those which result in its final disappearance in the higher mammalian levels, while the change in shape from elliptical to round accompanies the nuclear changes. The existence of the nucleated round cell in the Petromyzon (a variety of fish) and in the human embryo is significant. But it is in the variations in bone structure that we are especially interested. We saw two bone units in different degrees of differentiation in the reptiles, viz., the lamina and Haversian System, and we would expect to find them extended into birds, if the reptiles and birds are linked together. In this we are not disappointed. It is in birds that the lamina reaches the most advanced and dominant type, while the Haversian System makes considerable progress toward a similar end. Very different degrees of differentiation of the laminae are found, depending upon the changes in the circulation. In some instances short curved segments of blood vessels, having a general concentric arrangement within the wall of the bone, are found dividing the bone substance into crude laminae. This is the earliest form of laminae in birds. In other instances, the segments of the blood vessels are lengthened and the laminae are more distinctly marked, while in still other instances the blood vessels have assumed the form of parallel, concentric circles, which are crossed radially by blood vessels extending from the medullary canal to the periphery of the bone. By this arrangement the wall of the bone is completely divided into laminae which then establish a second type bone. The laminae, as seen in birds, therefore, are concentric sheathes of bone substance, with oval or round lacunae and short canaliculi, separated by plexuses of blood vessels arising from radiating vessels from the medullary canal. A marked change has taken place, since the lamina has now become established for the first time in the history of bone as a dominant bone unit. The same may be said of the Haversian System. In one group of birds we see the lamina and in another smaller group the Haversian System assuming the most important place. We may have, therefore, second and third type birds. The femora of some birds are composed entirely of laminae, while those of other birds are composed almost entirely of Haversian Systems. The medullary canals of the laminar bones are full of marrow, while those of the Haversian System bones contain no marrow. The Haversian System in birds is unlike that of any other vertebrate in its structure. It is composed of a small, central vascular canal, surrounded by a very close network of blood capillaries embedded in undifferentiated bone substance. Around this central portion is a peripheral portion, composed of concentric lamellae, with long lacunae and straight canaliculi. The central portion is early and the peripheral late in differentiation. It is a transitorial form.

As the birds followed the reptiles, and the mammals followed the birds in vertebrate history, if there were a connecting bone link between the reptiles and mammals, it might be expected to appear in the birds and possibly in a transitional form. Such a form is seen in the Haversian Systems of the ostrich described above. The basis of advancement in the Haversian System of birds is indicated in the character of their circulatory arrangement. This is not like that of the Haversian Systems of the foregoing reptiles, nor like that of the following mammals, but has a greater circulation than either, indicating a greater physiological activity than either. It can not be said to establish a new evolutionary level in bone history, but a specific level peculiar to birds. It can be recognized microscopically.

There is an important relationship between the extent and activity of the blood supply and general metabolism; that is, the functional evidence of this activity, would be proportional to the blood supply, and as this is greater in the Haversian System group than in the laminar group of birds, there would be birds of high and low types respectively represented by the third and second types of bone structure. These types can be recognized in the Turkey Buzzard (Cathartes Aura Septentrionalis) and the Domestic Turkey (Meleagris Gallipavo). The bone structure of these birds is quite different. The bone of the turkey buzzard is an early differentiation of the third type, while that of the domestic turkey is an incomplete second type. The femora of the turkey buzzard group have no marrow in their medullary canals, while those of the domestic turkey are full of marrow. The functions of the femora of these two groups of birds are practically the same and yet there is a fundamental structural difference between them which function does not account for. Just why the two types of bone should appear in these birds is difficult to explain. There is no apparent reason why two birds as nearly alike in general appearances as the domestic turkey and the turkey buzzard should have a bone structure so far apart in the degree of differentiation as the Haversian System and lamina, unless it is one of the evolution of a higher from a lower type by the biological principle of variation, which gradually produces new and diverging forms of living things. The Haversian System birds form a smaller group than the laminar birds.

When we say that the lamina is a lower type of bone than the Haversian System, we mean that it has not reached the limit of bone differentiation while the Haversian System has. It is also true that each bone unit shows different degrees of differentiation, depending upon its distance from its origin. The lamina begins as a dominant type in the birds, and terminates in mammals, while the Haversian System in its early form, begins in the birds as a dominant type, and terminates in a complete type in man. A bone unit of short duration in life represents a lower level of advancement than one of long duration, so that the lamina would represent a lower level than the Haversian System. The lamella has existed in bone history as long as the Haversian System and longer than the lamina, but it reached its culmination before either one of them. If the bone units are arranged in the order of their appearance, duration and culmination, the result would be about as follows:

Lamella,—first outline in the fish: duration from fish to man; culmination in the reptiles.

Lamina,—first appearance in the amphibian: duration from amphibian to man: culmination in the ungulates.

Haversian System,—incomplete first appearance in the fish: duration from fish to man: culmination in man.

As may be seen this is an ascending series of evolutionary bone levels, each one carrying with it the signification or biological value of its development. Each unit has its own signification or value, which is always the same since it is always produced by the same type of circulation and therefore must have a constant value. While a bone unit is passing through its various degrees of differentiation it represents the working value of a biological force in operation toward a definite end, and when completed it remains as a visible evidence of the work done and the experiences acquired by the class of vertebrates to which it belongs; therefore it could not represent one value in one case and a different value in another. It is for this reason that it must represent the same value wherever it may be found.

These values are impresses made upon the animal by developing bone units, and are capable of extension whenever the unit is extended; that is, a lamellar impress may be extended from amphibian or reptile to man and modify his character, because the lamella extends from amphibian and reptile to man. On account of the fact that the lamella is the simplest organized bone unit, and reaches its culmination first, the lamina next and the Haversian System last, the lamella would not represent the same degree of developing power as the more highly organized units, which reach their culmination later. Like a flowing stream an impress gathers force as it proceeds, by virtue of the additional impresses received during its period of transition. There is a cumulative dynamic value acquired in the duration of living bone which continues until its operating limits are reached, when it remains stationary, or nearly so until that value has been exhausted, and then falls into a senile state, in which it loses its power to maintain itself. The value of a bone unit depends upon its method of differentiation and degree of organization. In these respects the Haversian System is the most important. There are three methods of Haversian System differentiation, with different significations: the first, by the gradual transformation of a simpler vascular canal, as seen in the fish, into a complete Haversian System, by the addition of concentric lamellae with their lacunae and canaliculi, as seen in man: the second, by a local circular widening of a concentric vascular canal, situated between two laminae and the bending of bone substance, or lamellae, around it, as may be seen in the second type bone, like that of the pig or deer: the third, by the partial filling of a mesh of a coarse cancellous bone, with lamellae as seen in the bone of repair. Of these three methods, the first is the most fundamental, because it shows the organization of the most complex from the simplest unit; occupies the longest time in its development, and extends from one end of bone history to the other. Haversian Systems of the same period of dvelopment will have the same differentiation, and can be recognized as such in whatever animal it may be found. A correspondence in type developments may be seen in the bone of man. For example, the first form of Haversian System, the simple vascular canal, is found in the lamellar portion of a first and third type bone, and as far as can be determined, is the same in development as the vascular canal of the fish. The extremes of Haversian System development are found in adult men, whenever the bone is a first and third type combination:

The Circulatory System in the Bones of Birds: The circulation in the bones of birds is very extensive and largely plexiform in type, which means that the bone type is largely second. In the second-type bone of the domestic turkey group, there is a dense plexus of blood capillaries between each two laminae, thereby providing a supply of blood out of all proportion to the nutritive needs of the bone, but quite in harmony with the general metabolic requirements of the animal. With such a circulation as is here shown, the bone must be a laboratory of great activity, the output of which is expressed by tissue values. In the Haversian System group of birds, the circulation is a less dense plexiform arrangement of blood capillaries. The meshes of the plexus are longer and wider and the circulation, at first sight, seems to be less extensive than it is in a second-type bone, or bone composed of laminae. But Haversian Systems are hollow cylinders, the walls of which are composed of a number of concentric lamellae, with their lacunae and canaliculi, so that there is greater vascular distribution in the Haversian System bone per unit of volume than there is in the laminar bone, and it therefore represents a higher bone level.

Reviewing the evidence of structural variations in the bones of birds, we find that the principal change is taking place in the circulation, and in the formation of the laminae which accompany the change. The lamina is established as the bone unit of the bird period of development, and appears in various stages. None of them, however, are completed. The lamellae show no special change from the reptilian lamellae, excepting that they show a tendency to conform to the changing circulation. The Haversian Systems present a unique form, transitional in character. A progressive movement is more evident in the many laminar differentiations than in the Haversian System differentiations, which are less noticeable. The laminar is a simpler organization than the Haversian System and the simpler the organization the sooner it is completed. Comparing the bone of the bird with that of the reptile, there is an evident advance in evolutionary level to be seen in the lamina, which rises to a prominent place in the structure of bone. This is accounted for by the developmental force of the circulation and the differentiation of bone substance which accompanies it.

There is further evidence of advance to be seen in the Haversian System bones. The Haversian Systems are transitional in structure and reflect a transitional character to the Haversian System birds.

On the whole, then, the reptiles and birds present unmistakeable evidences of different developments in the bone variations which are found.

MAMMALS.

As a flowing stream brings down waters from many sources and merges into the ocean, so the moving stream of life, coming down through the ages, brings down the elements and impresses from many sources, as the fish, amphibian, reptile and bird, and merges into the mammal. As the ocean is a compound of the waters of the land, so the mammal is a compound of the impresses of the vertebrate kingdom. The attributes of an animal are so dependent upon the histological structures of the animal that they may be considered as the peculiar properties of the structures. It is, therefore, difficult to understand how attributes could ever disappear unless the structures disappear first, and even then the influences or impresses of those attributes might be extended by kindred structures, by virtue of their correlation. If there is organic extension from reptile to bird and from bird to mammal, we would then expect to find some attributes extended from reptile to bird and to mammal, and in this we are not disappointed. Such an extension is seen in bone.

Now if we follow the known attributes from one class of vertebrates to another we find the egg-laying attributes of the reptiles and birds in the monotremes (lowest order of mammals) and the flying attributes of the bird in the mammalian bat. There are two classes and one order of egg-laying vertebrates, viz., the reptiles, birds and mammalian monotremes and two classes of flying vertebrates, viz., the birds and bats. The bird is supposed to be the connecting link between the reptiles and mammals, but if such a connection is required, the transition from reptile to mammal by way of the bird was somewhat irregular, as indicated by the bone structures of the animals forming the borders of the gap between them. There were upheavals in vertebrate life during the changes which occurred between the egg-laying method of reproduction, which began in the fish and the placental method which began in the mammal.

The power of flight began with the reptilian Pterodactyl and disappeared in the mammalian bat and neither of them are birds. These changes did not take place suddenly but gradually, as the monotremes, marsupials and bats indicate. We would expect to find then some upheaval in structural bone types corresponding to those physiological disturbances which are involved in the transitional period. This seems to be true in the bones of birds. Bone may be produced in the egg outside of the body or in the uterus inside of the body. As a rule, the early bone types belong to the egg-laying or flying groups, and the late bone types to the placential group. The types of bone which are found in the egg-laying group are early first, second and third, and in the flying group the early first, later second and early third. The elimination of flight and the appearance of the placental method of reproduction mark the beginning of a most important change in vertebrate history, since it was followed by the elevation of bone types to the highest level and the rise of development to its highest stage. Interesting relations are displayed by the organs of reproduction in those animals along the boundaries of reptilian and mammalian life. The monotremes have the prototypes of mammary glands in their sweat glands and no placenta; the marsupials have a mammary gland, incomplete placenta and immature foetal development; the bats have a mammary gland, incomplete placenta and immature foetal development. The egg-laying attribute was extended into the mammal and was continued after the sweat gland was first used as a mammary gland, as may be seen in the monotremes. The sweat glands of the monotremes were employed to feed the young mammal before the mammary glands of the later mammal appeared. The flying attribute continued after the appearance of the placenta, as may be seen in bats.

Thus we see that changes of an important character were in operation during the early mammelian history and especially during reptilian and bird histories of bones. If the classification of vertebrates was based upon bone structure the monotremes could very well be classed with the reptiles and the bats with the reptilian lizards. The bone of the monotreme is a first and early third type bone; resembling in the degree of differentiation the bone of the later reptiles; or if classed as a mammal it would represent the lowest type. The marsupial has a first, crude second and early third type bone, somewhat reptilian and not at all bird-like in character, but more advanced than the monotreme. The edentate has a first and early third type bone, the first predominating and the third more advanced than that of the marsupials. The whole order of bats has a first type bone like the lizards. Physiologically the monotremes have attributes of the reptiles and mammals; that is, they lay eggs and nurse their young and histologically their bones have the structure of the reptiles. The bats have the attributes of the birds and mammals, that is they fly and nurse their young, but histologically their bones resemble the lizards and not the birds. The bat does not have the wing or the flight of the bird; does not have the histology of the bone of the bird and does not resemble the bird in its method of reproduction. On the contrary, it does have the histology of the bone of the lizard, the power of flight of the bird and the method of reproduction of the mammal, therefore it exhibits impresses extending from the reptile, through the bird, into the mammal and displays some of the attributes of each, as might be expected. In vertebrate history egg-laying appeared first, flight second and placental reproduction third. Egg-laying continued while flight, which was not perfected, lagged behind to reappear in a perfected form in the bird only to fall behind again in the bat, where it disappeared. The rise, culmination and decline of the egg-laying attribute were completed before the placental method of reproduction was established, while flight was extended beyond this method of reproduction. There have been, then, flying reptiles, birds and mammals, egg-laying fishes, reptiles, birds and mammals, and oviparous, ovoviviparous and placental methods of reproduction in vertebrate history.

The method of reproduction is the most important factor in the elevation of the types. Of the three methods mentioned, the placental holds the highest place in bone advancement. The change from the first and second to the third type bone occurred after the egg-laying and flying attributes had disappeared and the placental method of reproduction had been established. Placental life, therefore, introduced the higher levels of advancement and may be generally recognized in the structural variation of bone. We have seen in the fishes, amphibians, reptiles and birds three unfinished types of bones, viz., the first, second and third. These three are now carried forward into the mammals, where they are completed and appear either as pure types or as combinations of types, each one writing its own biography in the characters of bone. These types, however, did not all appear in the same degree of differentiation at the same time, but one followed the other, as it did in the early vertebrates. It is, perhaps, a question which type of vertebrate really belongs at the threshold of mammals, the bats or monotremes. The bats are all true to the lamellar type of bone, with the exception of the pteropus group, in which the early vascular canals,—forerunners of Haversian Systems—are found. The lamellas, which formed the entire bone structure of the order, present about the same degree of differentiation which may be taken as the bone level of this vertebrate. Inasmuch as practically the same bone level is also established in the amphibians and lizards, we may suppose that the amphibians, lizards and bats are not far apart in the degree of advancement. In the monotremes a slight advance is seen in the Haversian Systems, while the lamellae are about the same or are perhaps a little lower in degree of differentiation. However, as far as structure is concerned, the Haversian System is the indicator to the stage of advancement. In the method of reproduction, the bat is placental, while the monotreme is egg-laying. In the method of nutrition the bat feeds its young by a mammary gland, and the monotreme by an earlier form of mammary gland, as the sweat or sebaceous gland. From monotreme to primate, or from ornithorychus to orang-outang bone structure shows a series of variations progressive in character. Of the two existing monotremes—ornithorynchus and echidna—the former has a slightly higher bone differentiation than the latter.

The marsupials, represented by a large group have the first and early third-type bone, both structural units being somewhat more advanced than they are in the monotremes. This is more especially true of the Haversian Systems, as may be seen in the opossum, Didelphia Virginiana. On the other hand, however, in the bone of the wombat, Phascolomys Ursinus, the Haversian Systems are simple, vascular canals, enclosed by lamellae.

The endentates have a first and early third-type bone, the third type predominating, as in the ant-eaters; while the sloths have a later third-type bone almost exclusively, but the Haversian Systems are nearly all senile.

The insectivores have a first and early third-type bone, as in the three-shrew, Tupaia, or a first and later third, as in the hedgehog, Erinaceus Europaeus. The ungulates or hoofed mammals, have a second or second and late third-type bone, both bone units of late differentiation, as in the deer, Cariacus Macrotus, or the horse, Equus Caballus; while the second type bone is usually associated with the third in these vertebrates, the second type predominates and gives the second-type valuation to these animals. The animals having this bone are herbivorous.

The rodents are first and early third in type, as in Hydrochoerus Capybara, or first and later third in type, as in the squirrel—Sciurus, or beaver—Castor Canadensis.

The carnivores have a first and third-type bone, as in the tiger,—Felis Tigris—or the first, second and third as in the lion—Felis Leo. In these vertebrates there is a proportionate increase in Haversian Systems units. These animals are flesh-eaters. Generally speaking, carnivorous animals have a first and third-type bone, herbivorous animals second and third, and omnivorous first and third or third. An exception is seen in the herbivorous African elephant, which has a complete third-type bone. The Asiatic elephant conforms to the rule, that is, has a second and third type bone and is herbivorous.

The primates—monkeys, apes and man, have a first and third, first, second and third or third-type bone. The bone units may have a complete or partial degree of differentiation. We may arrange the mammals according to their bone types as follows:

Bats—first type.
Monotremes—first and early third.
Marsupials—first and later third type.
Edentates—first and early third type or complete third type, senile.
Insectivores—first, second and early third type.
Ungulates—late second and third, or third type.
Rodents—first and early or late third type.
Carnivores—first and late third, or first, second and late third type.
Primates—first and late third, or first, second and late third, or late third type.

As may be seen from the above arrangement, the first and early third type bone prevailed from monotreme to ungulate, with here and there an exception: for example, the two-toed sloth among the edentates has a complete third-type bone, which is unexpected in the edentates, but the Haversian Systems are mostly senile, that is, have lost much of their bone substance. This does not often happen in the lower vertebrates, but is common in man. The most marked evidence of advancement in type is observed to begin in the ungulates, where the lamina has reached its culmination and the Haversian System is not far behind in differentiation.

Thus we see a gradual rise in bone type, from one end of the mammal series to the other. As the second-type bone is the most representative type of bone in mammals—exclusive of the primates—it may be considered as the second-type bone level.

CIRCULATORY SYSTEM IN THE BONES OF MAMMALS.

The circulatory system, as seen in tangential sections of second-type bones in mammals, is very extensive and is plexiform in type. Plexuses of capillaries alternate with the laminae as we saw in second-type birds. The meshes of the plexuses vary in size and shape and the vascular expansions mentioned above may or may not be prominent. The blood supply of the second-type bone is surprisingly great, indicating an inorganic exchange and haemapoietic activity, proportional to the development of the animal. As a rule, we expect to find the bone type of a mammal true to the representative bone type of the class to which it belongs, and in this we are not disappointed. The type of bone is mapped out before birth, according to an ancestral plan, as a first, second, third, or some combination of these types, and nothing can change the types excepting cross-breeding. Ancestral strains are transmitted by extended bone types. Bone may be destroyed by senility, faulty development, or some pathological process, but not transformed to another type. Hypertrophies, atrophies, hyperplasias, may follow marked changes in diet, or infections, but the type still remains the same. A flesh diet represents a higher dynamic value than a vegetable diet; the Haversian System a more highly organized bone unit than the lamella or lamina, and the plexiform a more extensive circulation than the branching; so that a mixed flesh and vegetable diet, Haversian System type of bone and plexiform circulation represent the highest form of vertebrate development. There is always to be considered, in this connection, the strong probability that there are two types of bone differentiation low and high—in each species of vertebrate. This has been noticed in some of the lower vertebrates, and has been demonstrated in each one of the three races of man, Black, Yellow-brown and White, as will be seen later. There is no great change in the degree of differentiation of the Haversian System from ungulate to man. There is, however, a marked increase in the proportion of Haversian Systems to the other bone units, the lamella and lamina. If we compare the bone type of the herbivorous ungulate sheep with that of the carnivorous tiger, we find that the percentage of Haversian Systems is much greater in the bone of the tiger than it is in the sheep, or, if we make a similar comparison of the bone type of the ungulates, carnivores, and primates, we find gradually increasing percentages of Haversian Systems, from one end to the other of this series. Again, the proportion of Haversian Systems to other bone units varies greatly in the ungulates: for example, the bone of the African elephant—Elephas Africanus—is pure third type, while the bone of the Asiatic elephant—Elephas Indicus—is second and third and, furthermore, the bone of the deer family is almost entirely second type. Why there are such wide difference in the bone structure of these animals is difficult to explain on the ground of habit, size, food or environment, as, for instance, in the two elephants. The pure third-type bone is found infrequently in the class of mammals and not at all in other classes. There were only three mammals found in a list of over 300 which had a pure third-type bone, viz., African elephant, orang-outang and man. They were practically all type combinations. The finding of the three pure Haversian System type bone was probably accidental; while Haversian Systems are found in varying proportions in the class of mammals, they are not uniformly present or extensive enough to characterize the class and, therefore, the Haversian System, or third type bone level is not established below man. A long series of progressive variations has brought the Haversian System, in the course of time, nearly to completion as the Primates appear, where it is finished. Its biological history is interesting, as it may be followed from beginning to end, showing the ascending line of vertebrate progression. Thus we saw it as a simple vascular canal, surrounded by clear circular areas of bone substance in the fish, amphibian, lizards and alligators; as a vascular canal surrounded by more or less concentrically lamellated bone substance in the turtles; by a dense plexus of blood capillaries in the bone substance of birds; by clear homogenous areas in the bone substance of bats; by concentric, incompletely differentiated lamellae in the monotremes, marsupials and edentates; by much more completely differentiated lamellae in the rodents; by completely differentiated lamellae and laminae in the ungulates and carnivores; by completely differentiated lamellae and Haversian Systems in the primates (apes and monkeys); by completely differentiated lamellae and a much larger percentage of completely differentiated Haversian Systems in man. These progressive variations give to the Haversian System the role of Indicator which measures and records stages of development. This conclusion derives further importance from the character of the type of bone in which vascular canals (lowest differentiation of the Haversian System) are always found, viz., the First; so that a First and Third type combination bone (the First enclosing Vascular canals) would represent the low type bone, while the single Third type would represent the high type bone. This is especially interesting in the bone of man. Looking over the microscopical sections of the femora of man, we find that 76% of the Black, 65% of the Yellow-brown and 44% of the White races have type combination in which lamellae, enclosing many vascular canals, are prominent and are therefore low in type.

Arranged in the order of their high percentages, we have the White race first, 56%, Yellow-brown second, 35%, and the Black race third, 24%.

This means that in order to reach the complete Third type bone differentiation and the highest stage of development, these races must lose, by elimination, their low type bone units, which are respectively 44% in the White, 65% in the Yellow-brown and 76% in the Black race.

RELATION OF DIET TO TYPE.

If we divide the mammals according to the character of their diet, we find the completely differentiated Haversian Systems in the carnivora and omnivora and Haversian Systems of about the same degree of differentiation in the herbivora, but there is a greater percentage of Haversian Systems in the bones of the carnivora and omnivora than in the herbivora, and if the bone is a type combination bone there is greater percentage of second and third type combinations in the herbivora than in the carnivora and omnivora. This does not mean, however, that diet governs the bone type. This is fixed during embryonic life by the remote and immediate ancestral forces of the family to which an individual belongs.

We somehow expect to find the completely differentiated Haversian System representing the bone level in the primates—monkeys and apes—but in this we are disappointed. It does not represent a bone level. The prevailing type is the first and third type combination; this type may serve as a prophecy of that which is expected in the remaining primate,—man. There is no regularity in the proportions of the single types in the bones of primates. In some monkeys the first type, enclosing vascular canals, greatly predominates, while in others the third type is markedly increased, the type combination remaining the same. This variation in the proportion of single types in a bone makes a low and high type monkey, or, in general, a low and high type vertebrate. For example, the bone of the monkey,—Macaca Rhesus—is a first and third type bone, the first greatly predominating; while the bone of the monkey—Ateles Tehauntepec—is a first and third type bone, the third predominating. The former would be low and the latter high in type. The bones of the monkeys show a wide range in the proportions of their single types; thus, the bone of the monkey "Presbytis Rubicunda" is first and third in type, the first greatly predominating. The few Haversian Systems present in the bone show an advanced differentiation. The bone of the monkey—Lasiopyga Centralis Johnstoni—is first and third, the first predominating and the third much increased; of the monkey—Midas Rufoniger—is first and third in about equal proportions; of the monkey—Colobus Abyssinicus Caudatus—is first and third, the first forming nearly the whole bone; of the monkey—Callicebus Torquatus—is first and third, the third predominating.

A similar range is found in the bones of the apes, although the bone units are carried to a greater degree of differentiation than those observed in the monkeys. Thus, the bone of the baboon—Cyanocephalus—is first and third, the first enclosing the very many vascular canals and the third showing incomplete differentiation; of the mandrill—Cyanocephalus Maimon—is first and third, the first predominating and showing a low degree of differentiation of both units; of the gorilla (Gorilla) is first and third, the first predominating, and the third much increased; of the gibbon (Hylobates) is first and third, the first predominating and both units showing an advanced degree of differentiation; of the chimpanzee (Anthropopithecus) is first and third in about equal proportions, the Haversian Systems showing a high degree of differentiation; of the orang-utan (Simia-Satyrus) is practically a third type bone in a high degree of differentiation.

Thus we see a low and high type monkey and a low and high type ape, the type of bone being further advanced in the ape than in the monkey. The same is also true of all classes of vertebrates. There are low and high types in each, as may be seen from the following list:

Smaller Type Amphibians—Low Type

Amblystoma tigrinum
Hyla versicolor
Hyla arenicolor
Hyla femoralis
Hyla evittata
Hyla cinerea
Hyla regilla
Hyla squirella
Hyla gratiosa
Dendrobates tinctorius
Leptodactylus albilabris
Chorophilus feriarum
Acris gryllus
Rana catesbeiana
Rana palustris
Rana aerolata circulosa
Rana pretiosa
Rana draytonii
Spelerpes ruber
Cryptobranchus allegheniensis
Necturus maculatus
Scaphiosus holbrookii
Scaphiosus couchii
Scaphiosus hammondii

Amphibians—High Type

Pipa americana
Bufo agua
Bufo halophilus
Bufo columbiensis
Bufo lentiginosus woodhousii
Bufo americana
Bufo lentiginosus cognatus
Bufo valliceps

Reptiles—Low Type

Sphenedon punctatus
Phrynosoma cornutum
Chameleo vulgaris
Phrynosoma douglassii
Ptychozoon homalocephalum
Iguana tuberculata
Veranus arenarius
Heloderma suspectum
Sceloporus clarkii
Cyclura carinata
Arnolis cristata
Crytaphytus collaris
Eumeces fasciatus
Gerrhonotus grandis
Python regius

Reptiles—High Type

Alligator mississippiensis
Chelydra serpentina
Trionyx spinifer
Cheloups guttatus
Chrysemys picta
Teṣtudo (gopgerus) polyphemus

Birds—Low Type

Typanuchus americanus
Pterohlossus torquatus
Aramus vociferus
Centrocerous urophasianus
Cyanocitta cristata
Cyanocitta stelleri
Ajaja ajaja
Charadrius pluvialis

Birds—High Type

Mergus serrater
Numida meleagris
Amazona oratrix
Turdus migratorius
Rhea americana
Chauna cristata
Cygnus Clor sp. (Swan)
Haliaetus leucocephalus
Cathartes aura septentrionalis

Mammals—Low Type	*Mammals—High Type*
Bats	Ungulates
Monotreme	Rodents
Marsupials	Carnivores
Edentates	Primates
Insectivores	Man

The above arrangement is interesting as it shows that there are low and high bone types in each class of vertebrates; that there are more low than high types, with the exception of the mammals; that the most important rise in the percentage of high types followed the reptiles, that is, occurred in the birds and mammals. There are, furthermore, low and high type bones in the different orders, families, genera and species by the extension of similars along a common bond of union as might be expected.

It is in the class of mammals that we are most interested, since man belongs to that class and has been placed in competition with the monkeys and apes in the race for supremacy.

As far as the monkeys are concerned in their relation to man, there is nothing in their type of bone structure to indicate a higher level than that of the rodents, ungulates or carnivores; in fact there are bone levels among the ungulates or carnivores which indicate a higher level than is shown by the monkeys. No new bone level is established in the monkeys. The same can be said of the apes, with one exception. One ape, the orang-utan (Simia satyrus) has a third type bone differentiation. No other ape or monkey examined has shown this degree of differentiation, or reached this bone level. However, this would not be sufficient to establish an Haversian System bone level in the Primates, as it can not be said to characterize them. It is nearer to the truth to think of the Haversian System level as being established during the whole history of vertebrates, and here and there declares itself in some particular case, as the two-toed sloth, among edentates, the African elephant among ungulates, and the orang-utan among primates.

The circulatory system varies with the type of bone and governs it. It is very extensive in the later mammals. In the first bone type, like that of the bats, it consists of a few parallel blood vessels from which extend minute parallel channels as was seen in the amphibian. In type combinations the circulation is more complex. In the first and third type it is branching in the first type and plexiform in the third type; in the second or third, second and third it is plexiform and in the first, second and third it is branching in the first and plexiform in the second and third. The association of circulatory type and bone type is very close and they are to each other as cause and effect.

An Operating Force Toward Higher Levels in Bone Differentiations:

Although man is a mammal, we have placed him in a class by himself, because his acknowledged superior attributes have placed him there. He is the highest form of mammal endowed with a vision. This must have been accomplished by the increasing values of gradual differentiations in the fundamental tissues, or by a separate act of Creation. If we can assume the former, the latter is unnecessary. We have followed the differentiation of bone substance (perhaps the most fundamental of all tissues) from its first appearance in the fish to its completed state in man, and have been convinced that there is a force in operation advancing unceasingly toward higher levels. We have seen it as undifferentiated bone substance at the beginning of vertebrate life, then as differentiated lamellae, then as laminae and have also observed Haversian Systems on their way from vascular canals in the fish to completed Haversian Systems in man. We have observed, furthermore, these bone units have formed single bone types and type combinations. There would be no good reason for supposing that these single types and their type combinations, which had been so long in the making, should terminate with the so-called lower mammals, and a new and different type of bone should begin and become established in man, on account of his superior intellectual and soul attainments; but, on the contrary, we would expect an extension of those bone units, which have been gradually formed during the long period of bone history, tried out and proved to be satisfactory, into man and this is what we do find. Both the single types and type combinations of vertebrate history are found in great confusion. It reminds one of a stream which has overflowed its banks and spread the objects which it carried, in confusion, on the land. Comparing the first undifferentiated bone substance with the last bone differentiation of the Haversian System, we are justified in thinking that some constantly active force has been responsible for the changes which have occurred. This force has declared itself in a succession of bone levels which can be recognized. The types and type combinations as observed in over 1300 bone sections of vertebrates, from fish to and including man, may be arranged as follows:

Single Types			*Type Combinations*	
Fish	Bone substance	100%	None	
Bats	First Type	85%	First & early third	14%
Amphibians	First Type	77%	First & early third	23%
Reptiles	First Type	67%	First & later third	33%
Birds	First Type	88%	Second & later third	12%
Mammals	First Type	20%	First & late third	80%
Mammals	Second Type	7%	Second & late third	87%
Mammals	Third Type	75%	First, sec., late third	93%
Man, Black	Third Type	26%	First & late third	74%
Man, Yellow-brown	Third Type	35%	First & late third	65%
Man, White	Third Type	74%	First & late third	26%

This is a bone type arrangement and somewhat different from the usual arrangement of vertebrates. The bone of the fish is undifferentiated bone substance, with the outlines of differentiated bone units.

In the amphibian, reptile and bat we see the rise and culmination of lamella; in the birds and mammals the rise and culmination of the lamina, and in man the culmination of the Haversian System. These bone units are found as dominant units about as would be expected in an ascending series of bone differentiations or developmental levels. It may be further noticed that in the amphibian, lizards and snakes among reptiles, and in bats among mammals, the single bone type is dominant; in the alligators and turtles (among reptiles), in the birds and mammals, the type combination is dominant and in man, in the Black and Yellow-brown races, the type combination is dominant, while in the white race the Haversian System bone type is dominant. Again it may be seen that the completely differentiated Haversian System has made its appearance in the ungulates and primates, as was shown in the bones of the African elephant and orang-utan. The great majority of them, however, are first and third or second and third type combination. It is in the later mammals that the second type begins to disappear and the third to rise to a dominant place in bone structure. As we enter upon the study of the bone types of man, the last and highest form of mammal, with a long bone type history preceding him, we would naturally expect to find an extension of the same types and type combinations which had been successful in the mammals before him. In this we are not disappointed.

There are three races of men based on color, as far as name is concerned, viz., Black, Yellow-brown and White. A study of many bone sections of each one of these races shows that the same bone types and type combinations which were found in other vertebrates are found in man and that no new or different type has appeared. There are seen, however, many differentiations of the types pointing toward a higher bone level.

The bones of the Black race have 26% third type and 74% first and third combination; of the Yellow-brown 35% third type and 65% first and third type combination; of the White 74% third type and 26% first and third type combination; that is, there is a smaller percentage of third type bone in the Black and Yellow-brown than in the White race. The individual Haversian System is no more highly differentiated in the White race than it is in the Black, Yellow-brown race, or even in some of the apes, as, for example, the orang-outang, but there is a higher percentage of them in the White race; in fact, the Haversian System seems to have been practically completed in the ungulates. The greatest advance in third type percentage is found in the white race of man, and as there is no bone unit beyond the Haversian System in differentiation, it is evident that the latest mammal and latest bone type are found together and this is quite significant, since the earliest vertebrate and earliest bone type were also found together. There is no one completed bone type extending from one end of vertebrate history to the other, or from fish to man, but a series of bone differentiations rising to different levels of advancement and presenting successive stages of development. There are no apparent gaps which require connecting links, but there is an extension of bone substance reaching out into new variations, which are in harmony with different species. If we found completely differentiated Haversian Systems in the fish, frog, lizard or bat, and simple undifferentiated bone substance in man, as the characterizing bone units, then the whole plan of bone types as a measure of development would fail, but just the reverse is the case. The more complete the differentiation of bone units, the higher the stage of development. The differences in the percentage of the three bone types in the races of man may be seen in the following table:

Black race:		
	First type appears in	71%
	Second type appears in	56%
	Early third type appears in	89%
	Complete third type appears in	100%
	Pure third type appears only in	29%
Yellow-brown race:		
	First type appears in	65%
	Second type appears in	52%
	Early third type appears in	65%
	Complete third type appears in	100%
	Pure third type only appears in	17%
White race:		
	First type appears in	43%
	Second type appears in	15%
	Early third type appears in	28%
	Complete third type appears in	100%
	Pure third type only appears in	51%

In the light of bone history previously considered, the race having the highest percentage of completely differentiated third type bone must be acknowledged as the highest in the stage of development, while the others will be graded according to their relative percentages.

The comparison of bone types above shown, in percentages, is a convenient presentation of the facts as they were derived from the bone sections examined.

It does not assume either superiority or inferiority of race. Looking over the comparative percentages, we find that the first bone type is highest in the Black, the second bone type is highest in the Black and the early third bone type is highest in the Black. The first type bone is lowest in the White, the second type bone is lowest in the White and the early third type bone is lowest in the White. The complete third type bone is found to some extent in all human adult bones. Comparing the percentages of pure third type bone, we find the highest in the White, the next highest in the Black and the lowest in the Yellow-brown. The majority of the Yellow-brown bones were taken from the ancient Peruvian, Pueblo, Chicama and Pachacamac Indians and their high percentages of first and second bone types would reduce the value of the third type bone in the average estimate. As the lower types, first, second and early third, decrease in the percentage of occurrence, the complete or late third type increases. The highest type bone is composed of completely differentiated Haversian Systems only; the lowest type bone is composed of the first type (major part) and third type (minor part). There has not been found an adult, long, human bone composed of the single first or second types. They all have some percentage of the late Haversian Systems. It is evident, then, that there are low and high type human bones, the degree of elevation depending upon the percentages of first, second, early third and late third type units present. For example, of 142 human femora examined in which the type percentages have been averaged, 36.5% were found to have a late or complete third type bone, while 63.5% had a first and third type combination. The first group (36.5%) are high type and the second group (63.5%) are low type bones. This does not mean that the low types are all equally low or that the high types are all equally high, but that they are relatively low or high for a class of animal or race of man. We may have, therefore, a low and high type amphibian, reptile, bird, mammal or man. These types represent bone levels which have been reached by differentiation of bone substance.

Taking the type level in each case as the standard of differentiation, all the types and type combinations are compared with it. Thus, the high type amphibian, reptile, bird, mammal and man would by no means be represented by the same type level or bone unit, but by definite differentiations of that unit or type level. One could not be substituted for the other, but might be transformed into the other in the course of time, and under the guidance of a Directive Force.

Referring again to the type percentages of the three human races, it may be seen that there is a high type Black, a high type Yellow-brown and a high type White. All three races have bones composed entirely of completely differentiated Haversian Systems and it is impossible to distinguish the Haversian System of one from that of the other, as far as the individual is concerned; there is, however, a higher percentage of pure third type bones in the White (51%) than in the Black (29%) or Yellow-brown (17%). That is, the White race has advanced more rapidly toward the final differentiation of bone units than the other races.

The Circulatory System in the Bone of Man:

The circulatory system in the bone of man shows the same two types as are found in other vertebrates, viz., the branching and the plexiform, and governs the bone type. The pure third type bone is found with the plexiform, and the first and third-type combination with the branching and plexiform. In all long human bones composed of a type combination, the first bone type is found external to the third, and therefore the branching circulation is external to the plexiform. Variations are found in the meshwork of the blood capillaries and in some cases this is quite marked. The meshes are long, large and irregular in shape. Such extreme variations reduce the distribution of the blood capillaries from a plexiform to a branching type, thereby affecting inorganic values in general metabolism.

Medullary Index, or the Relation of Bone Volume to the Medullary Canal:

The medullary canals of the different femora show quite important variations in the characters of their contents. In the majority of femora the canals are occupied by marrow and blood vessels, as in mammals and man; in some cases the canals are occupied by cancellous bone, the meshes of which are filled with marrow and blood vessels, as in reptilian turtles and a few birds, as the yellow-hammer, or domestic pigeon; while in other cases the canals are perfectly empty, with the exception of slender bone trabeculae extending from wall to wall, as in some birds,—turkey buzzard or peacock.

It is evident that in a long bone the larger the medullary canal is, the smaller will be the volume of bone, and vice versa. The ratio of the former to the latter is determined by what is known as the Medullary Index, which is the ratio of the square of the mean diameter of the medullary canal to the surrounding bone, the calculation being made at the central cross line of the bone. The medullary index is given in percentages. An examination of the medullary indices of 440 femora of different vertebrates shows that the medullary canal does not bear a constant ratio to the surrounding bone, but presents many interesting variations.

The average percentages of the medullary indices found in the different classes of femoral vertebrates are given for the purpose of showing the relative bone volumes of the classes of vertebrates:

Average medullary index of Amphibians	36%
Average medullary index of Reptiles	26%
Average medullary index of Birds	159%
Average medullary index of Mammals	63%
Average medullary index of Man	38%

From the above percentages it may be seen that the proportions of the medullary canals to the bone volume varies greatly. It is understood that the larger the percentage, the smaller the volume of bone and the larger the medullary canal. The lowest medullary index is found in reptiles (26%), the highest in birds (159%); that is the reptile has, relatively, the greatest volume of bone and the bird the smallest. Perhaps this would be expected on account of the flying attribute of the bird, although it is not true in all birds.

The Index falls from amphibian to reptile, rises sharply from reptile to bird, falls from bird to mammal, and from mammal to man.

It is also found that the circulation in bone increases from amphibian to reptile, from reptile to bird, from bird to mammal, and remains about the same in man as in mammal. The circulation may be increased in two ways, viz., by increasing the medullary index or by changing the type of bone. If bone is the product of the circulation and the circulation increases from amphibian to man, we would expect that the volume of bone would also increase from amphibian to man. This seems to be the case (bird excepted) as may be seen if we follow the circulation in the bone types and type combinations. The smallest circulation is found in the first, the next increases in the second and the largest increase in the third bone type. Now, the amphibian is first, the reptile first and early third, or second and early third; the bird second and incomplete third; the mammal first and third, or second and third; and man first and third, first, second and third, or third. The bone units are the indicators of circulatory increases. The circulation is greater in the third type than it is in the second or first, for the reason that the Haversian System is a hollow cylinder composed of concentric lamellae and therefore the same volume of bone of the third type would have a greater circulation than of the first or second types although the medullary index may be lower. Again, the medullary index rises from amphibian to bird, falls from bird to mammal and from mammal to man. At first thought, this would seem to be due to the fact that more bone is required to support the weight of the body of a biped than of a quadruped, body weight being practically the same. This, however, does not hold in the large ostrich, for example, in the femur of which the medullary index is 240%. That is, mechanical function does not explain the variations in bone volume. In the three races of man, a considerable variation in Medullary Index is also observed, as may be seen from the following:

Medullary Index in the Black race	41.9%
Medullary Index in the Yellow-brown race	43.8%
Medullary Index in the White race	35.8%

From the above percentages it may be seen that the White race has the largest volume of bone and smallest medullary canal; the Yellow-brown race has the smallest volume of bone and largest medullary canal, while between the two is the Black race. The White and Black races are modern, while the Yellow-brown is, for the most part, ancient. How the total amount of inorganic salts available for metabolic purposes in the body varies in proportion to the volume of bone and blood, since these tissues are the mediums of inorganic exchange. The calcium salts are deposited chiefly in the bone, the sodium and potassium salts together with the carbon dioxide, in the blood plasma. The bone and blood are therefore very intimately associated in general metabolism. The value of inorganic salts in nervous and muscular metabolism is extremely important, since it standardizes the actions of two of the most important tissues—muscular and nervous—of the body. The White race has relatively a greater working capital stock of calcium salts than the Black or Yellow-brown race, because it has the most bone. The racial differences in the inorganic salts of the blood plasma are not known at present, if there are any. Variations in the carbon dioxide of the blood would change the availability of the calcium salts. The value of inorganic salts in bone, in general and special metabolism, depends upon their availability and this upon the extent and character of the circulation, which, in turn, depends upon the type of bone. The first type bone has a less extensive circulation than the third, for the reason that the first type has a branching while the third has a plexiform circulation, and this is greater in extent than the branching. There is a larger percentage of third type bones in the White than in the Black or Yellow-brown races, and therefore a more extensive circulation and accessible stock of calcium salts. The bone of the White race is a better bone than the bones of the Black or Yellow-brown races. For this reason, the Haversian System level, which is established in the White race to a greater degree than it is in other races, adds higher values to those phenomena which indicate racial distinctions. Of the other classes of vertebrates, the reptile has the most bone and the bird the least, but the circulation in the bone of the bird is greater in proportion to the unit of bone volume than it is in the reptile, and, hence, provides a better means of calcium exchange.

The Haversian System represents the highest degree of bone differentiation and the highest type of circulation. A bone composed entirely of Haversian Systems is the highest type of bone in the vertebrate kingdom. It is found very infrequently in the bone of vertebrates below man and not always in the bones of man. There are many type combinations in human bones, and some of them are on the same level as those of the apes. Notwithstanding this, it can be said that the Haversian System level is established in man. Now, as an exchange of bone salts is constantly going on during the whole life of the individual, and is largely dependent upon the carbon dioxide of the blood, upon the character of the food, of the digestive and absorptive functions of the alimentary canal, the Haversian Systems do not maintain their standard values for an indefinite period, and sooner or later there appears a precipitation of inorganic salts in the lamellae around the Haversian canals, and one lamella after another disintegrates, the canal becomes larger and larger until narrow, dark brown or black ring of disintegrated bone substance and inorganic salts remains. This is bone senility. The bone salts are no longer available for metabolic purposes; they are so much foreign matter to be removed by the blood. This is a frequent condition in adult man, but not in the lower vertebrates. The senile percentage in the bones of man may be seen below:

Senile bones in the Black race	35%
Seniel bones in the Yellow-brown race	22%
Senile bones in the White race	72%

Thus we see that the bones of the White race, which show the highest degree of differentiation, show the highest percentage of senility, and this regardless of age in years. Some bones were found to be senile at thirty years of age. This means that bone senility is inorganic salt deficiency. It usually begins around the medullary canal and extends outward, thereby increasing the medullary index. It is also possible for the index to be greatly increased by absorption of bone substance, without disintegration. There may be a decreased deposit of calcium salts in the bone, or a more unstable chemical combination of these salts with protoplasm. In such a bone, the Haversian Systems have simply disappeared. This was soon in the femur of a congenital epileptic (White) who died at 40 years of age. The medullary index was 277%. A mere shell of bone 2 mm. thick was all that remained, and this was composed of Haversian Systems, none of which were senile. The variations in Medullary Indices referred to above may be accounted for by senility, absorption, or chemical instability, and also may be the starting point of serious disturbances in general metabolism. Calcium promotes muscular contraction, and phosphorous nervous tissue activity; potassium of the blood and muscle promotes relaxation and sodium of the blood osmotic pressure. The equilibrium of the interaction of these chemical elements being disturbed results in muscular and nervous tissue dullness, which are symptoms of senility. The race of man which reaches its highest degree of bone differentiation first, reaches its highest degree of development first, and is first to decline by reason of the retrograde process of senility. The White race is nearer its culmination and decline on the basis of senile disintegration that the other races.

FUNCTION, FOOD AND ENVIRONMENT.

The variations which we constantly find in bone are too numerous and irregular in arrangement to be satisfactorily explained by function, food or environment. For example, there is no reason why the femur of one biped should be a first and third type bone, and that of another a third type bone (body weights being equal) on account of difference in function, food or environment, and especially when these differences do not exist, as may be seen in the femora of man; or why the femur of one quadruped should be a second and third type bone as in the Asiatic elephant (Elephas Indicus) while that of another similar quadruped should be a third type bone, as in the African elephant (Elephas Africanus) and especially since the weights, functions, food and environment of these animals do not greatly differ; or why there should be fan-shaped areas of second-type bone in some human femora and not in others; or why there should be vascular canals (first differentiation of Haversian Systems) in some and completely differentiated Haversian Systems in other femora; or why some femora should be composed of First, others of Second, others of Third type bone, and still others of different type combination; or why the bone type of the multiple offspring of parents should differ from the parents and from each other, as was seen in the femora of a litter of kittens, on the basis of function, food or environment.

There are many concrete examples of structural variations in the bones of vertebrates which are not in harmony with any known variation in function, food or environment as causes. Such variations are found in all classes of vertebrates. For example, the femur of the amphibian Hyla versicolor is uniformly composed of lamellae, while that of another amphibian, Hyla femoralis, is composed of two concentric divisions of lamellae. The femur of the amphibian Pipa Americana (Surinam toad) is composed of narrow internal and wide external lamellae, in which are numerous vascular or early Haversian canals; the femur of the amphibian Bufo americana (American toad) is composed of narrow external lamellae in which are many vascular canals of wider internal lamellae, with the same development of vascular canals and a single irregularly concentric lamina situated between the two groups of lamellae.

The femur of the reptile Sphenoden punctatus is composed of rather crude lamellae; of the reptile Veranus nuchalis, of crude lamellae in which are numerous vascular canals; of the reptile Alligator mississippiensis, of concentric rings of laminae (early differentiation) alternating with rings of early differentiations of Haversian Systems; of the reptile Chelydra serpentina, of external lamellae with numerous vascular canals, of narrow laminae alternating with wide central rings of early diffentiations of Haversian Systems and of narrow internal circumferential lamellae surrounding a heavy cancellous bone occupying the medullary canal.

The femur of the bird Ajaja ajaja (spoonbill) is composed of lamellae in which there are a few concentric segments of vascular canalas and a few transitional Haversian Systems in the posterior ridge; of the bird "Meleagris gallipavo" (domestic turkey) is composed of concentric laminae between which are vascular canals and posterior Haversian Systems (transitional) of the bird "Aramus vociferous" (courlan) composed of concentric laminae with a few Haversian Systems of the bird type; of the bird "Emberiza Citrinello" (yellow hammer) composed of narrow external lamellae with a few Haversian Systems of the bird type and of a central fine-meshed cancellous bone occupying the medullary canal; of the bird "Chauna cristate" (crester screamer) composed of narrow external and internal lamellae between which is a wide ring of Haversian Systems (transitional).

The femur of the mammal "Mormoops" (bat) is composed entirely of lamellae while the femur of the bat "Pteropus poliocephalus" is composed of external, middle and internal lamellae, with vascular Haversian canals in the middle portion.

The femur of the egg-laying mammal "Echidna" is composed of a wide external ring of very crude lamellae, in which are a few vascular canals and early differentiations of Haversian Systems, and a narrow ring of internal lamellae around the medullary canal. The structure resembles that of one of the primitive reptiles "sphenodon punctatus."

The femur of the marsupial opossum—Didelphis viginiana—is composed of a wide external ring of lamellae and laminae, enclosing short, radiating and oblique vascular canals, of a middle ring of early Haversian Systems and of an internal ring of lamellae surrounding the medullary canal. It is more advanced in differentiation of all bone units than the bone of the echidna. The femur of the edentate armadillo—Tatu novemcinctus—is composed of external and internal lamellae with many short, oblique vascular canals and a middle portion of early Haversian Systems. An advancement in differentiation is seen in the lamellae and Haversian Systems.

The femur of the insectivore hedgehog—Erinaceous europoeus—is composed of external and internal lamellae and laminae enclosing early differentiations of Haversian Systems.

The femur of the ungulate deer—Cariacus nacrotis—is composed of completely differentiated laminae with groups of late Haversian Systems in the posterior wall. The ungulates form a very large group of mammals in which the laminae culminate and the Haversian Systems reach a complete diffentiation. The femur of the rodent squirrel—Sciurus—is composed of external lamellae, a central ring of late Haversian Systems and wide internal circumferential lamellae. The bone is very much advanced in differentiation as indicated by the late Haversian Systems. The rodents form a very large and important group of mammals in which the fully differentiated first and third type combination is established.

The femur of the carnivorous tiger—Felis tigris—is composed of narrow external and internal lamellae between which is a wide ring of completely differentiated Haversian Systems. The bone shows a high degree of advancement.

The femur of the primate ape—Orang-utan—'Simis satyrus"—is composed of completely differentiated Haversian Systems, and shows a high degree of advancement. It is possible that other apes of this species may show a first and third type combination.

The femur of man—homo sapiens—is composed entirely of completely differentiated Haversian Systems or of the first and third type combinations. The bone has reached the limit of differentiation.

Thus we are able to follow an orderly advancement in the differentiation of bone units from fish to man.

Now, if these advancing differentiations are due to function, food or environment, these bones would imply the interaction of a greater range of such causes than actually exists. At least we might reasonably expect that the functions of similar bones of the same species would remain the same and therefore the structures would remain the same. For example, we would expect that the functions and structures of the femora of a litter of kittens of one mother would be the same, but this is not the case. The structure of the femora of such a litter were found to be quite different and as variable, in fact, as the color of their fur. There is no explantion of this fact unless it is that remote and immediate ancestral strains are transmissible in bone and the differentiations found are the evidences of those transmitted strains. Pure bloods breed true, cross bloods breed according to the impresses made by remote or immediate ancestral strains. Again, there is no good reason why the structures of the femora of man should vary on account of function, food or environment, as these are practically the same, but they do vary greatly. It is true that different circumstances may cause variations in the size or shape of bones, but they can not change a bone from one to another type of structure.

Having seen the variations above mentioned in a large number of bone sections, the question arises: Why do such variations exist?

It is natural to think of bone as a mechanical organ, on account of its positions in the body and its hardness, and there is really no apparent reason why any variations should be necessary. The thought that bone is bone, wherever it is found, has delayed investigation.

It is the comparative study of bone of all classes of vertebrates which reveals the variations and establishes types of structure. These types are three in number, each one rising in an incomplete and culminating in a complete differentiation. This makes bone a living organ. No bone type appeared in a complete form. Its biography was written in its structural differentiations. Having reached a culmination, bone remained for an indefinite time as a useful type of structure, bearing at all times and in all places, the same signification.

The culmination of types established three bone levels, which have already been mentioned. Understood in this way, each level is an index of the degree of bone differentiation and stage of development of the animal from which the bone was taken. That is, these types are the visible results of imperceptible, progressive transformations which time and a directive force toward an objective, accomplished.

If we think of three times two we can hardly avoid thinking of six; but if we think three times two and a fraction we can not avoid thinking of some variation of six, the fraction being the variable factor. So, if we think of a bone cell and a directive force applied to it, we can hardly avoid thinking of bone substance; but the directive force is the variable factor depending upon ancestral impresses, remote and immediate, and hence the product of these factors is some variation of bone substance, or a type.

The product of osteoblastic activity is bone substance without differentiation. It it the mother substance from which all succeeding variations are derived. The existence of variations, therefore, is the inevitable result of living bone substance under the direction of an operating force which received its first impulse at the beginning of life.

When and how did these variations make their appearance?

The variations did not all appear at the same time nor in the same degree of differentiation, but at different times and under varying degrees of the directive force. Incomplete, at first, they established, sooner or later, three bone levels, each one in advance of and at a later date than the other; that is, from the bone substance there came first the lamellae, second the lamina and third the Haversian System. When this had been accomplished, bone differentiation rested and consequently bone, instead of presenting one and the same structure in all vertebrates, presents a number of structures or types which become indicators of progressive stages of development.

Bone substance appeared in the lanceolate fish during the Upper Silurian period and exists at the present time chiefly in embryological or in pathological conditions. Vertebrate life is bone life, bone life is the life of the association of protoplasm with calcium compounds, and marks the beginning of the most important group of animals on earth.

From the Upper Silurian to the present age, this calcium compound has been undergoing transformations from the simple to the complex forms of life. This phylogenetic history of bone is corroborated by a recapitulation or ortogenetic history of the stages of development of the human embryo. In the formation of the femur of the human embryo of different ages, we find bone substance first, lamellae and laminae second and early differentiations of Haversian Systems third. The bone is very far from a complete differentiation at birth. It is, however, during this short intra-uterine period that the bone type is decided. Whether or not it is going to be a first and third, first, second and third or a pure third will depend upon the degree of differentiation of the dominant ancestral type unit. There is a type race toward an objective bone level which has been forecasted by ancestral impresses. In man the race is toward an Haversian System level, and whether or not it reaches this level will depend upon some competitor in the race, which is most frequently the lamella. If the race is evenly matched, as it often is, the result will be the first and third bone type, a very common type in man. It is thought by the writer that a dominant type strain of a class of vertebrates may be transferred to man by bone extension, and become a controlling influence in shaping his characteristics; thus, man has always had within him an innate desire to swim, fly, hunt, kill and possess, because his dominant type impresses have been extended from the fish, bird, reptile or mammal which preceded him. Bone variations appeared at the dawn of vertebrate history, gradually assumed recognizable forms known as types, and displayed certain qualities known as characters.

What is their relation to each other?

The intimate association of variations suggests relationship—a common origin. There is no certain gap in bone type history. The nearest approach to it, perhaps, is seen in the peculiar Haversian System of the bird, which does not seem to have had an antecedent in the reptiles and does not seem to have been extended into mammals. Variations appear in regular order; one follows another and reveals such gradual differences from it that it is impossible to say when one becomes the other, although it is possible to say that one *has* become the other. This means the evolution of one from another.

If undifferentiated bone substance is produced by the osteoblasts of the fish, it may remain undifferentiated, but if it is produced by the osteoblasts of the reptile, bird, mammal or man, it will show, sooner or later, that some definite variation is being established and this is always along an ascending line through the lamellae and lamina to the Haversian System; that is, the same bone substance with which we started in the fish, modified in its inorganic association with protoplasm as it progresses, is arranged in new ways, for new reasons, by the guiding power which resides within the circulation. This new arrangement enlarges the scope of the physiological division of labor, which was the first evidence of progression in protoplasm. There is an optimum circulation for each level of progress. It operates the terminal to which it is applied and produces certain phenomena which are recognized as belonging to one particular level, and not to one before or after it. The circulatory advance by which these levels are produced leaves an impress upon each level so that the last variation feels the influence of all foregoing variations. It is very difficult to understand how one variation can lose the impress of the one from which it is evolved, so that the last one produced would become a composite of all preceding variations with their influences. It is hardly possible now to think of a completed Haversian System without including in the thought its differentiating history, and if the Haversian System has a signification it must be that of a sum or product, rather than that of a unit or factor. It represents a long period of time and a vast number of successive differentiations. The relation of these variations to each other is, therefore, one of competition for the supremacy of the dominant strain.

What do these variations mean?

From the various material evidences which are unmistakeably recognizable in bone as variations, we conclude that they have established certain levels with definite significations and represent low and high stages of development in vertebrate life. This conclusion is the more convincing when we know that there are many histological degrees of differentiation in bone, and are able to recognize many physiological stages of development in the individual. The association of differentiation with development is unavoidable in the study of bone sections. It would certainly be illogical to conclude that the lowest degree of differentiation would represent the highest stage of development, or that the highest degree of differentiation would represent the lowest stage of development, but we would suppose from their persistent associations, that as the degree of differentiation is, so is the stage of development. This means that each variation, which is the sum total of an indefinite number of degrees of differentiation, and which is known as lamella, lamina and Haversian System,—has its own individuality or signification wherever it may be found, and becomes the basis of the classification of low and high type vertebrates. The replacement of bone substance by lamellae, of lamellae by lamina and of lamina by Haversian Systems means advancement in type and development; combinations of types means the extensions of variations from unlike ancestors and the visualization of transmitted strains.

Looking over the whole series of bone sections, from fish to man, there are found more combinations of types than single types, and more combinations of types in the bones of the later than in the earlier vertebrates, as would be expected, since pure bloods project their own type, which is single and which is early, and mixed bloods project the types from which they sprang, which is a type combination. If we group together those vertebrates which have a common type of bone we will have a strange collection of animals. For example, amphibians, lizards, snakes, bats, monotremes,—are represented by the first, or lamellar, type level; many birds and mammalian ungulates, by the second, or laminar level; reptilian alligators and turtles, marsupials, some edentates and insectivores, by the early third or Haversian Systems level; some ungulates, carnivores, rodents and primates, by the late third or Haversian System level; some members of the human race—not all—by the late third or Haversian System level. This type irregularity and conformity to definite levels in bone indicates both unequal and equal extensions of bone connections between unlike groups of vertebrates. We can not separate one of these groups from another, but are obliged to consider them all united by a bone stem, with outcropping variations which imply the continuous extension of the original stem from which they sprang, since they could not come into existence by themselves. Fundamental bone substance, therefore, extends from one end of the vertebrate kingdom to the other, and upon this has been grafted similar and unlike forms of bone substance with similar and different endowments, all declaring themselves distinctly or confusedly in types and type combinations, the result being the appearance of new forms representing new departures from the old, raised to new levels which are established by constructive dominant forces received from ancestral sources. Although the variations produced by such a mixed ancestry are many, as they are found singly and in combination, yet they can be considered here as forming two large physiological types, viz., the low and high. These are inevitable as we proceed from undifferentiated bone substance to the completely differentiated Haversian System, and we find that while we are making our observations we are really following an ascending line and looking along the way for stations of progress. The separation of vertebrates into low and high types, on the basis of structural variations seems to be a natural one, and is especially the more striking since it harmonizes with an equivalent separation into low and high types, on the basis of physiological variations, as they are observed in animals. The differentiation of bone substance in the fish has been slight, and yet it may be detected, in some situations. For example, the cranial bones have a channel circulation, enclosing simple bone substance; the lawer jaw has vascular canals enclosing bone substance, with plan of lamellar and laminar differentiation, and the vertebrae have lamellae concentrically arranged around a central canal. From this it may be seen bone differentiation is in progress in the fish and is most pronounced in the vertebrae. However, the circulation in the fish is the simplest in character, the bone simpliest in type, and both are in harmony with the attributes of life with which the animal is endowed. This simple bone substance and circulation do not occur elsewhere in the adult, excepting in some pathological conditions which are the results of faulty bone differentiation. If the bone substance of the fish could be changed to the complete Haversian System, we would also expect to find that the attributes of the fish had been changed to those of the late mammal. Bone substance which begins as an undifferentiated bone substance in the embryo and terminates in the adult as bone substance, as as a slight differentiation of it, represents the fish; bone substance which begins as undifferentiated bone substance in the embryo and terminates in the adult as completely differentiated Haversian System, represents man. Undifferentiated bone substance is a sub-type, having but one signification, viz., the lowest form and simplest attributes of vertebrate life. It may be thought that the occurrence of undifferentiated bone, as it is found in the fish with the simple attributes of the fish, is a coincidence, but it is a fact that such a bone substance does not occur in the bones of vertebrates endowed with higher attributes than those of the fish. As we have already seen, there is no explanation of the confusion of the bone types which are present in the bones of the different vertebrates on the basis of function. On the contrary bone types and attributes advance together; so that if we find bone substance, and this only, in the bone of an animal, we can be sure to the attributes of that animal are as simple in character as the type is in differentiation. In mixed types, where one is bone substance and the other, or others, are type differentiations, the character of the attributes will depend upon the predominating type of structure. One multiplied by itself any number of times will not make two or anything but one. The fish has not risen above its own level, because bone substance alone has been multiplied and not bone differentiations. The attributes which we are able to distinguish as higher in quality than others are those which are associated with the intelligence and these have not been found in those vertebrates in which bone substance was present as the predominating bone structure. The imminent action of a bone cell is its prerogative and can not be estimated as low or high any more than a creative act can be qualified by such adjectives; but the endowment of a cell of imminent action with a directive power forward, implies the possibility of qualitative values of variable characters which sooner or later appear, and may be classified as low or high in comparative values. The fish is sufficient unto itself and its environment, but not unto the amphibian and its environment. Some structural variation is necessary, otherwise it must remain a fish and live in the water. The first differentiation which occurred in bone and gave it an impetus forward was from bone substance, without lacunae and their canaliculi, as found in some bones of the fish, to bone substance with lacunae and their canaliculi, arranged in parallel layers, or lamellae, as found in the amphibian, reptilian lizard, snake and in the mammalian bat. This is, after all, merely establishing bone cells with their dendrites, in lacunae and canaliculi, in bone substance outside of the blood vessels instead of within them, by changing the circulatory plan of distribution. It advances undifferentiated bone substance to the first differentiation or first bone type, known as the lamellar. Such a slight change as this seems, at first sight, to be unimportant and with little or no signification, but to attempt to think of the cause of this little change which could not take place by itself, magnifies the importance of the change and gives to it the signification of a forecast of future possible transformation in vertebrate life. Such a change has no power within itself to begin or terminate. There is no power of choice about it any more than there is in the flowing stream, which is strictly obedient to the inexorable law of gravitation. The stream can not help flowing, and as it flows it receives many waters from many sources and now and then displays new forms of life along its banks. In some such manner undifferentiated bone substance behaves. It changes in obedience to a biological law. It can not help it. Its own peculiar transformations are set forth in the original plan of vertebrate life and must go on in regular order, unless prevented by death or held in check by the limitations of that law which have been greatly modified by some external force. It follows the law of vertebrate being, and whenever variations in bone substance are represented in visible form, they follow the same course, that is, lamellae, laminae and Haversian Systems. It is quite evident to an observer that the undifferentiated bone substance of the fish and the completely differentiated Haversian Systems of man, are situated at the extremes of bone differentiation. There is nothing less than the former that is bone, and nothing more than the latter that is bone; therefore, we may suppose that those extremes represent the lowest and highest types of bone, and that the means of these extremes—lamellae or laminae—represent intermediate types, the character of the type depending upon the predominating bone unit. The order of elevation of differentiation may be written as follows:

Undifferentiated bone substance—Lowest, or sub-type.

Lamellae—Next higher, or first type.

Lamellae and laminae—Next higher, or first and second type.

Laminae—Next higher, or second type.

Lamellae, laminae and Haversian Systems—Next higher, or first, second and third type.

Laminae and Haversian Systems—Next higher, or second and third type.

Haversian Systems—Highest, or third type.

As may be seen from the above type arrangement, type elevation is based upon the signification of the structural unit.

Now in order to use the signification of structural units as a basis of type elevation, it is necessary to understand why we attribute different meanings to bone units. Why does one unit have one meaning and another unit a different meaning? For instance, why do we give to undifferentiated bone substance the lowest type value, and to the completely differentiated Haversian System the highest type value? If this can be determined, then, it is easy to arrange the intermediate types in an ascending series, from the lowest to the highest type, and give the proper values to each.

THE DETERMINATION OF TYPE VALUES.

The value of a type unit can not be determined by statement; there must be some good reason for thinking that it is low or high in value as a type of unit. Undifferentiated bone substance, lamellae, laminae and Haversian Systems, occurring in the order mentioned, mark the steps of advancement in bone history, and their values are known by the different times of their first appearance, the structural forms which they presented at those times, their genetic relation to each other, and their association with recognizable attributes revealed by different vertebrates. As we have already seen, we find undifferentiated bone substance in the fish and the completely differentiated Haversian System in the later mammals and man. The order is never reversed. There is little doubt or uncertainty about the rise of the fish in the Silurian or Devonian Age, and therefore, of the first appearance of undifferentiated bone substance. It is equally certain that the later mammals and man made their appearance at a much later period,—Miocene or Pleistocene Age—and it is in these vertebrates that the Haversian Systems reach their highest degree of differentiation. We know that bone substance became lamellae, laminae or Haversian Systems by changing the circulation. We know that the Haversian Canal appeared in the fish and was extended throughout the vertebrate series into man. We know by observation that as the attributes of vertebrates rise in quality, the evidences of intelligence become more and more pronounced. If we found, after an extended examination, that the Haversian System, or any other single bone unit, constituted the sole structure of all bone of the vertebrate series, then, there would be no reason for thinking that there was any important relation between the bone units and the increasing complexity of attributes which we know characterizes the different classes of vertebrates; but this is not the fact. There is no type of bone unit common to the bones of classes of vertebrates as the sole constructive unit, but there is a number of types and type combinations which enter into their construction and these admit of no satisfactory explanation, unless we consider them as the representative of biological forces in operation in the developmental history of vertebrates. It so happens that we find just about what we expect to find, if a type of bone unit represents a quality or attribute.

If, now, we compare the attributes of the fish with those of man and attach any meaning whatsoever to the types and type variations which are found in those animals, we will be obliged to give the lowest attribute to the undifferentiated bone substance of the fish, and the highest attribute to the Haversian System of man. We will also be obliged to give intermediate attributes to intermediate variations and especially if there is a logical sequence of types which we have reason to think there is. It is a peculiar fact that the individuals of a class, order, family, genus, or even species, are not equal either in type of structure or quality of attribute. In the study of bone, the mixed character of the variations observed forces upon us the conclusion that bone types are visible evidences of the transmission of ancestral type strains and the attributes which belong to them.

For instance, the ass has a second type bone, and the mare a second and third type bone, with the third predominating; the offspring, or mule, has a second type bone and resembles the ass in its general character more than it does the mare. The bone of the mule is the bone of the ass; the attributes of the mule are the attributes of the ass; the shape of the mule, and the second type bone level which the ass occupies, is the bone level which the mule occupies. In another instance, a litter of kittens presented as many bone type combinations as there were kittens, and were as diversified in the degrees of differentiation as the color of the fur. Such examples are convincing testimonies that types of bone are the results of transmitted strains, and that attributes are transmissible with the strains. This has an important bearing upon the crossing of vertebrates and raising of types. Evidently, single types will transmit single types and their attributes, and there is no gain or advance made by the crossing. This, however, is not true crossing,—it is merely an extension. In order to advance the type and attributes, single types or type combinations must be crossed with higher types, and higher type combinations, for the higher type is a predominating type, by virtue of its higher organization. There will, then, be a gain in type value, and if it is continued long enough, remarkable elevations will be reached. As we look over the bone types of the different classes of vertebrates, there is doubtless a class level represented by the prevailing bone type, and this may be taken as the class standard with which individuals and other classes may be compared. The high type in one class is higher in value than the high type in the class before it, in point of time. While it is, perhaps, impossible to state in words just what is understood by the highest type amphibian, reptile, bird, mammal or man, yet it is possible to say and to think that one has a higher class value than another.

It is not difficult to realize that the class value of mammals has a higher standard than that of the amphibians, reptiles or birds, and for the reason that the Haversian System of mammals has a higher standard of organization than the lamella, lamina or Haversian Systems of those animals. The unequal class values explain quite readily the natural division of vertebrates into leaders and followers, or of man into king and subject, or master and slave. Such divisions prevail throughout the kingdom of animal life. Simple observation is enough to show that some individuals lead and others follow. There is no kingdom of neutrals. The leaders are comparatively few while the followers are many. The power to lead is an attribute of the high organization, and the willingness to follow of the low organization of bone type. They are unequal in organization, but equally essential to the purposes of life. One is just as necessary to the genus or species as the other. The unequal step with which type variations have been advanced not only makes this division possible, but actual. The physical value of a leader has some influence in his leadership, although as a rule leaders become leaders by the common consent of their followers. They want to be led. They love a master and find enjoyment in obedience. It is the conquest of type strains. In the amphibian class there is a high and low bone type, but the difference between the two is very little. They are all practically of the lamellar or first type and operate upon the lamellar level. The leader and follower are not as distinctly indicated here as in the later and more highly organized vertebrates. The simpler the type, the lower the organization. The simple type and low organization extends into the reptiles as far as the alligators, where a change is apparent. While the reptilian alligators and turtles show an advance in type, they are not closely enough united by bone type to be associated in one community group. The thought of leadership does not easily arise between an alligator and a turtle, but between individual alligators or turtles it is a matter of physical value. In biological administrations, leadership is recognized as a necessity for the good of the community. Protoplasm feels the impress of its superiority during its embryological experiences, and exercises its prerogative by the peculiarities of its birth.

In the class of birds, there is a greater variation in bone type, and a more apparent evidence of leader and follower. Leadership advances with the advance in type.

In the class of mammals, there are a great many type combinations of a higher organization and consequently more evidence of a struggle for leadership.

In man, the type variations and combinations are advanced, and numerous, and the leader and follower, king and subject, master and slave, are as much, if not more, in evidence than they are in any other class of vertebrates. Wherever we look in human history, there we find the leader and follower, the master and slave, although they may not be called by these names. By the mysterious nature of protplasm, the slave likes to the be driven just as much as the master likes to drive. It is the love of the inferior for the superior or the love of complements.

INTERPRETATION OF BONE TYPES.

Established bone types are bone levels, and since they have been a long time in reaching their levels, they would be expected to have some individual signification. As we follow the study of bone, from fish to man, we discover many surprising variations in histological structure appearing in orderly succession, which raise such questions as these: Why do such variations exist? When and how did they make their appearance? What is their relation to each other? What do they mean? The two thoughts of an answering character which naturally follow such questions are: first, that the variations may be caused by a different function, food or environment, and second, that they may be the visible evidences of a progressive tranformism by which one type of bone gradually becomes another. We may consider these thoughts in order as we try to answer the above questions according to our findings in bone sections.

PART II

PART II.

THE APPLICATION OF BONE TYPE SIGNIFICATIONS TO THE PROGRESS OF MAN.

Man is a bone animal as much as any other animal. He has the same bone types and type combinations as many other vertebrates, and it is reasonable to conclude that they have the same signification, wherever they are found, as long as they have the same degree of differentiation. A very noticeable fact in connection with the bone types and type combinations of man is that they vary greatly in the three races, Black, Yellow-brown and White, and also in the individuals of any one race. Man has no constant bone structure and therefore could not be expected to have a constant, unvariable character. If bone types have constant significations, it is unjust to consider all men equal. They could not be equal on a basis of structural inequalities, and are not equal by observation. Man has a high and low type bone as widely separated as the Haversian System and lamella. He is a master or slave, leader or follower, and that, too, without his volition. He is born into an estate for which he has been prepared by a long course of ancestral tuition. The differences in structural type establish different degrees of organization. The high type, or Haversian System bone, represents a high degree of organization, a leader or master; while the low type, or lamellar bone, represents a low degree of organization, or the follower or slave. The reverse of this is neither logical nor possible on the basis of organized valuations. The higher the bone type, the nearer it is to its culmination; and the lower the bone type, the nearer it is to its beginning. The particular quality which makes a leader or master is one of a superior intelligence, and this belongs to the high type bone. The question may arise, at this point, how do we know that the high type bone represents the high degree of intelligence and the low type bone the low degree of intelligence? We cannot examine the bone of a living individual for for the purpose of answering such a question. In the first place, we do not know who has the lowest or the highest degree of intelligence, or who is greatest or least among men. It is very difficult, if not impossible, to compare one man with another without making use of ourselves as standards. Human history abounds in philosophers, religionists, poets, artists, writers, scientists, thinkers, generals, leaders, masters, and their followers. Who is greatest or least among them? No one knows. If one should decide today, he would very likely change his mind tomorrow. The civilization of the world has been accomplished by the combined energies of both groups. The first group formulated the plans, the second executed them. The first group represents the higher, the second the lower intelligence. One acknowledges the other as indispensable. They are hardly comparable. The advances in civilization are evidences of the increasing intelligence of both groups. They are not interchangeable, and they both know it. A master may be made a slave by force of circumstances, but not by nature, A third type of bone can not be made a first or second; nor a first or second a third, except by a selected crossing. The limitations are set before birth, and can not be changed after birth in any one individual. As the sowing is, so will the harvest be. If a third type is sown, a third type will be matured. There is always to be acknowledged, in this connection, the modifying influence of the Mendelian law. Now, we are willing to grant, from the foregoing account of bone variations, that bone types and intelligence have advanced together, and as the structural type advanced, the intelligence followed and announced it. As long as bone types are known to have reached their structural limitations in man, and as long as we acknowledge, with common consent, that the highest intelligence known belongs to man, we are justified in the conclusion that the highest type of bone represents the highest intelligence. Another evidence of advancing bone type and degree of intelligence may be seen in the development of the human embryo. The observation was made during a study of the femur. At 2 to 2½ months it has undifferentiated bone substance and no intelligence; at 3 to 3½ months has a crude first and second type bone and no intelligence; at 4 to 5 months it has an early second type bone and no intelligence; at 6 to 7 months it has a second and early third type bone and no intelligence; at 9 months, or birth, it has a second and later third type bone and no intelligence; at one year it has a second and later third type bone, and perhaps a very slight intelligence; and with this as a measure we are able to understand why the highest degree of intelligence is found where the highest degree of bone differentiation is found, viz., in adult man. This ante-natal biography of bone is interesting. While it does not allow the possibility of gross intelligence on the part of the fetus, it does not disallow the possibility of intelligence on the part of the cell. The embryo is a cell formation in which the cells are so true to the law of their being that they produce a definite result which can not be understood without the superintendence of cell intelligence. We are not able to account for an embryo by an external force operating upon blind, neutral masses of protoplasm called cells, if there are any such cells. On the contrary, we are obliged to assume the presence of an internal force, or intelligence, operating upon each cell and directing the course of events. We do not know when intelligence of the individual is first recognizable. It does not manifest itself in a sudden burst of evidence, but announces itself more after the manner of an opening flower. It is the sum of cell intelligences, its recognition would depend upon the degree of cell development and it would show a gradually increasing evidence from a mere suggestion to an indisputable fact, which is about the evidence it does show.

As the bone of the human fetus recapitulates, in a way, the phylogenetic history of bone is the vertebrates antecedent to man, and we know something of the bone types and attributes of that history, we conclude that man is no exception to the rule, and that the grade of human intelligence increases in value as bone advances in differentiation. Furthermore, in those cases in which the grade of intelligence was known, the writer found that the individual of low intelligence had a low type bone, and the individual of high intelligence had a high type bone. In this it resembles adolescent and adult life. The former has a lower type bone and lower degree of intelligence than the latter.

This investigation was begun on the hypothesis that the structural type of the most useful bone of the body would represent the structural type of all similar bones of the body, or, in other words, that the osseous system of an animal has a representative bone type which characterizes the animal. It remained, then, to show that the above assumptions are facts, or near enough to facts to justify the investigation.

Since, with the exception of the bones of the fish, the bones from which the above data were derived were the femora of different vertebrates—the section being taken in each case from the mid-line; it may be well to state why the femur was selected, why it was thought that the structural type which was present at the mid-line was the structural type of the whole bone, and not of one particular section, and also, why the type of bone of the mid-line section might be expected to represent the types of bone of all the long bones of the body. If these were not facts, the whole foundation of our purpose in this investigation would be destroyed and the work would be in vain.

The femur was selected for the following reasons:

First, because it is a convenient size in the majority of vertebrates; *second,* because it is in constant use, and, therefore, not subject to the atrophy of disuse;

third, because it is a single bone, engaged in bearing the weight of the body, and in taking an active part in its movements; *fourth,* because it has an extensive circulation; *fifth,* because its general usefulness implies a physiological importance in calcium exchange.

It was thought, therefore, to be the most representative bone of the body, and the one best adapted to an investigation of this nature.

In order to show that the structural type of the mid-section was the structural type of the whole bone, a human femur was cut into segments one inch long, and a section from each segment was examined microscopically. In this particular case it was found that the mid-section was first and third in type combination, and that all sections of the different segments had the same structure. Carrying the examination further, it was also found that all of the long bones of the whole skeleton had the same structure as the femur. From this examination it was concluded that the structural type of the femur was the bone type of the whole skeleton, and consequently might be taken as a reasonable basis upon which to form a theory relating to the development of an animal from a universal type. Furthermore, in connection with the above facts, it is assumed that a comprehensive study of the bone types of the whole vertebrate series—combined with an observation of the comparative grades of intelligence, will lead to additional evidence that a bone type represents a stage of development.

Generally speaking, our judgments of men are very circumscribed, since our standards are our very narrow selves. We pass judgment upon him during a brief association with him, and do not take into account the many and varied impresses which have been made upon him during his long vertebrate history. The glamour of appearances conceals him; he looks like a man. If we can think of him as a part of the vertebrate kingdom of life, modified by the innumerable impresses of that life; if we can think of him as an individual of the genus Homo, in all of its higher characterizations; if we can think of him as the embodiment of mind and matter, protoplasm and spirit, we can understand his virtues, contradictions, duplicities, successes, failures and incomprehensibilities, or the real nature of his being, and in no other way. He is the best animal on earth and the worst. As a form of life walking the earth today, burdened with his own conceit and potency, he is beyond our comprehension. It is the looking backward that helps us to understand his present, and the looking forward that gives us hope of a better future. We simply see him now at one point in his journey from antiquity to futurity. Cycles of life pass before a changing world, and each one contributes its impress to its immediate successor. Man is born under a crushing burden of indebtednesss (called legacy) to his antecedents which he can never pay off. The lower types of vertebrate life form the foundations upon which are erected the higher types, and the impress of the lower is not entirely eliminated as it merges into the higher. From our level, human history is long. From geological levels, it is short. In accordance with the present geological knowledge, the first man lived 500,000 years ago. He was called Pithecanthropus, or the Trinil Man, because discovered on the banks of the Trinil River of Java. From that time to the present he has been slowly advancing, through the following: Piltdown, Heidelberg, Neanderthal and Cro-Magnon races, to a higher level. Beginning as an animal, with pronounced animal instincts, man is still an animal, with animal instincts, but has added to his psychological armamentarium a superior intelligence and a soul, and this without his volition. He could not create any of these attributes, he could merely discover them. They appeared gradually as he rose from one level to another. If we can understand the Pithecanthropus, the Piltdown man, the Heidelburg man, the Neanderthal man and the Cro-Magnon man (a line of prehistoric races of man covering an immense stretch of time) we can understand the animal, industry, religion, art and science in modern man;

we can understand Adam and Eve, the first characters of man's written history and man's first recorded disobedience or consciousness of a moral obligation; we can understand Cain and Abel and man's first recorded murder; we can understand war, peace, the criminal, the supremacy of the animal impress and the unequal conflict of the animal and the spiritual, the gradual rise of conscience, the moral conception, the very slow and gradual submergence of the animal and the equally slow and gradual rise of the spiritual concept. The conflict of impresses is too great a conflict for man to adjust or settle within and by himself, as many of them were made during the formative age of the vertebrates and are so indelibly fixed that they can not be erased or disposed of.

He realizes that he must have a higher power than himself to make the adjustment or settlement. No matter how strongly one argues against the spiritual within himself, he is conscious of a dual nature, and his very argument is proof of it. He may be dominated more by the animal than by the spiritual nature, as might be expected, since he has lived ages in association with the animal, and comparatively a few years with the spiritual being and the transition from one to the other or the displacement of one by the other, or the replacement of one with the other, is attended by great disturbances. The extinction of life has been necessary to the advancement of life. Occurring at intervals, it has solved the very difficult problems as they appeared during the origin, rise and culmination of an exceedingly complex living world. The glacial and interglacial period of the earth's history, with their exterminating and transferring agencies, have been the most powerful means of adjustment. The world may wait 30,000 years for another glacial epoch, the result of which may be the elimination of the old and the rise of a new and more advanced order of things. We do not know that man is the final objective of vertebrate life, but we think that he is, on the basis of bone differentiation. He is ever changing in structural type and character, and the power that changes him is the power that projects him from one age to another along an ascending line. The changes are slow, perceptibly slow, but nevertheless, real. Our judgments are too hasty, we expect too much in a short time. A period of 20,000 years is only long enough to effect the transformation of Cro-Magnon man to modern man, and the principal difference between the two is not to be found now, in the total elimination of the lower attributes, but in their modification and in the cultivation of the higher attributes. An empty skull may speak as clearly as a full one, and more truthfully. With all of his advancements, man is still, most of all, an animal. He displays the characteristics of the animal; he delights in conquest, in the possession of property of others, in the accumulation of great wealth which he does not need and which he can hold for a few years only, in power, which he assumes by virtue of physical strength, wealth or position,—and what are these but the dominant characters of those vertebrates which preceded him.

As we have already seen, there is a low and a high type bone structure in the three races, of man, viz., Black, Yellow-brown and White. The low type was the first and third and the high type was the third. Between these were many intermediate variations. As a matter of fact, there were no two bones of precisely the same structure or same differentiation. As we look at these variations, the thought of a logical succession of types becomes more prominent than ever. We know that the First Type could not have been derived from the Third Type bone; this would have required a reversion from a higher to a lower type, or a reversion from a higher to a lower organization, which is fatal to the existence of any type. We know that the Third Type could have been derived from the First by differentiation, and the higher organization from the lower by development which follows differentiation, which has been the rule in bone history. If the First Type bone appeared first in bone history we can account for the other types, but if the Third Type appeared first we can not account for the other types. Now, as far as has been determined in this investigation, both the First and Third Types appeared in combination in man at the same time. This is a very frequent type combination in the later mammals, as well as in man, and must have preceded the Third Type, as we have seen above. If we take the types and type combinations as we find them in the vertebrates series, exclusive of man, and compare them with the types and type combinations as we find them in the bones of the three races of man, it is more reasonable and satisfying to think that the bone types of man are extensions from the preceding vertebrates, with the unequal type strains which characterized those animals, than it is to think of them as coming from an immediate, ancestral group of Primates. The bone types of man do not resemble the bone types of the monkeys and apes (orang-utan excepted) any more than they resemble the bone types of the rodents or carnivores. Man has a much wider bone history than any class of vertebrate would indicate. Now if bone can be considered as the one recognizable tissue which extends from fish to man, disclosing visible evidences of its differentiations as they appear in the different classes, orders, genera and species of vertebrates, and if the attributes of these animals seem to adjust themselves to the differentiations, then man can be considered best from the whole vertebrate level, instead of from one small part of it, as the Primates. Were it not for the general resemblance of the ape form to the human form, man might as well be a descendant from the rodent or carnivore as from the ape or monkey.

SOCIAL DISTINCTION BASED UPON BONE TYPE VARIATIONS.

If man, as a vertebrate, has received the impresses of the different classes of vertebrates which have preceded him in bone history, and this by virtue of bone extensions, these impresses might reasonably be expected to declare themselves in some such recognizable form as his personality. From the necessarily mixed character of these impresses, derived from such a variety of sources as the fish, reptile, bird and mammal, his personality would vary and exhibit the dominant character of that particular impress with which he was the most intimately associated by bone extension. For example, if a man has a first and third type bone, the first predominating, the character of his personality would be modified, even to the point of recognition, by the impress of the first or lamellar type in vertebrates history; if the third type predominates, his personality will be influenced by the impress of the third or Haversian System type in vertebrate history; if the third type prevails, with no combination with other types, he would exhibit the personality of the highest bone organization in vertebrate history, so that the human race would naturally be divided into different personalities, or classes of social distinctions with which we are familiar, and which may be designated as the unlaboring, laboring, criminal, intelligent, ignorant, poor and wealthy classes. These classes are race wide in their distribution, and are founded upon biological differences in origin. Similars are gregarious. The old saying, "Birds of a feather flock together," is based upon biological grounds. The lower levels of differentiation and development seek their own level in other animals, because they are in harmony with them, understand them, and seem to have the ability to know it. For instance, a first and third type bone level is not in harmony with a third type level and does not understand it. If there was only one degree of differentiation and one stage of development, all men would be in harmony, would understand each other and be equal. But this is not the case. On the other hand, if there are extensions of different bone types from one vertebrate to another, and transmissions of different impresses from one vertebrate to another, the various personalities of the races of man which can not be explained on basis of equality would be about as we find them at the present time.

Let us now examine these social differences, or classes, in the light of these impresses.

As we look over the range of vertebrate life, we are impressed with certain inerrant social distinctions which are history-wide in their application, and are forced to believe that they had a part in the original plan of the living kingdom of animals. Two of the most important and wide-spread of these distinctions are those of leader and follower, master and slave. Such an almost universal division of animals, whether in the lower classes or in man, must have had some fundamental basis. It can hardly be thought of as accidental. It implies inequality in physical strength, intelligence, or both. If the degree of intelligence of the animal is proportionate to the type of bone which the animal possesses, we would expect to find just about the classification of leader and follower, master and slave that we really do have; that is, if we have a high type bone and low type bone, so we conclude that the former represents the master, or leader, and the latter the slave or follower. The master and slave do not make themselves but are made by the variable forces of differentiation, which are beyond their control or even their knowledge. Each one feels the impress of the family of vertebrates from which he sprang, and responds to it with a self expression. In some instances, the family is remote, in others not so far removed. As it is possible for the bone type to be extended throughout the vertebrate series, so it is for the characters which belong to those types.

The principal characters of the bone types of the five great groups or classes of vertebrates preceding man, viz., fishes, amphibians, reptiles, birds, mammals, can be recognized in man, if one observes him closely, as, for example, swimming, flying, acquiring by duplicity, which began as far back as the reptilian age, possessing by force, which began as far back as life itself, hunting, tormenting, conquering, killing, love of offspring, of home, feeding and protecting the young, love of conflict, victory, love of peace, of change, etc.

There is, for instance, the amphibian man, a land and water animal, cold blooded, impassive, indifferent to the welfare of others, a moral negation, a low grade or no grade intelligence, gregarious habits, a selfish, loveless unattractive creature, living on a low level.

There is the reptilian man; cold, subtle, noiseless, creeping, saying one thing and meaning another, enticing, devilish, succeeds by duplicity, wrecks human character with delight, accomplishes his object without the knowledge of his victim, a despicable, slimy creature, generally shunned and living on a low level.

There is the bird man; warm blooded, restless, a lover of the air and water, fearless of altitude, active and swift in movements, an intensive lover, a happy rover, a good observer, living on a higher level.

There is the mammalian man; warm blooded, a citizen of the land, a lover of the forest or plain; a child of Nature, honorable, dignified, affectionate, trustful, stable, stolid, selfish, lovable intelligent, unemotional, persistent; accomplishes his object by physical strength, a resident of a higher level.

There is the primate man; cunning, mischievous, active, imitative, distrustful, treacherous, selfish, intelligent, teachable, fickle, interesting, and living on a high level.

There is, then, the Super-Man; warm blooded, lovable, unselfish, altruistic, just, conscious of the universe of God, of a future life, a living conscience, a lover of right, beauty, truth, goodness, grandeur, a spiritual being, a citizen of the universe, possessing the highest degree of intelligence and living on the highest level. It is strange that so many of these characters which are found in man should also be found in the lower classes of vertebrates if there is no structural bond of union or means of transmission between them. We can not believe that such is the case, but prefer to think that man is a composite of all classes of vertebrates, both in structure and in character, to which has been added a spiritual life by virtue of his superior development. He is an animal with a soul. He is the glorification of protoplasm, a transcendentalism by a power that can not fail, the supreme association of two great extremes, Earth and Heaven, the crowning point of time, the herald of Eternity, a great promise fulfilled, an apothesis of matter.

A suggestive evidence of vertebrate impress on man was presented by two human femora which were taken from the same tomb of the period of the twelfth dynasty of Egypt, 4000 years ago. One was larger than the other; the larger bone was a completely differentiated third, or Haversian System type bone, while the smaller was a first and third, or lamellar and Haversian System type combination. It was over one-half lamellae. These two bones could not represent the same degree of differentiation or the same stage of development. The larger bone was the high and the smaller was the low type bone. The larger declared its superiority by the total absence of all evidences of the lower type structures, while the smaller bore the impress of a lower class of vertebrate. The larger suggested the leader, or master, the smaller the follower, or slave. The larger was a superior differentiation and development, the smaller an inferior; otherwise type differentiations are meaningless. This, in the light of the foregoing investigation is hardly reasonable. It is more satisfying to think that one served the other and was entombed with him with the possible expectation of a continued service in the next world, as was a custom with some of the primitive types of man.

We can not reconcile the wide extremes of the development of man on any common ground. If we contrast a head hunter of Borneo with Sir Isaac Newton, we know that there is an irreconcilable difference between them. As we have no doubt about the inferior character of the former, so we have no doubt about the superior character of the latter. Such widely divergent characters could not have arisen from an immediate, common source. There is a great gulf between them. They are on different levels. As well might Sir Isaac Newton attempt to descend to the level of the head hunter, as the head hunter to ascend to the level of Sir Isaac Newton. They may have lived at the same time, but they did not start from the same point.

The race was a biological race; they did not have the same environment and could not have had it and survived. Their places in life were not interchangeable. The differences in their environment could not account for the differences in their intelligences. There must have been some great difference in their biological foundations, by reason of which the one outstripped the other in the rapidity of his departure from his original source—unequal race from unequal starting points toward a common objective.

As we have already seen, there is low and high type bone in all classes of vertebrates, man being no exception to the rule; and it would surely follow, that, if the bone type of man was an extension from the bone type of a lower class of vertebrates, the lower type would be an extension of the lower and the higher type, an extension from the higher type animal. The reverse of this would be impossible. Neither could it be true that both came from the same type of animal; furthermore, it is not probable that one was created a head hunter and the other Sir Isaac Newton, but that both represent different levels of advancement in vertebrate history. Such an unequal race serves a very important purpose in human affairs. If the people of the world had all been head hunters, the laws of gravitation would be unknown, and man would still be on the level of the lower vertebrates; if, on the other hand, they had all been Sir Isaac Newtons, the race of men would have become extinct by the slow process of starvation, long before the present era. We do not like to think that God created the head hunter by preference, but we can understand that one Creative Fiat, expressed at the beginning of life on earth, is working its way through the lower forms of life, and the ungulates, rodents, carnivores and primates (including the head hunters) are some of the recent forms.

UNCONSCIOUS AND CONSCIOUS LABOR.

As we look over the whole range of life which we have the power to observe, perhaps the most noticeable result of the observation is that to live is to work. Life exhibits states of unconscious or conscious labor, depending upon the stage of advancement of the class of vertebrates to which it belongs. Unconscious labor appeared first, conscious labor last.

Unconscious labor is an original endowment of protoplasm, because protoplasm is a chemical compound which admits of oxidation, thereby associating it with a chemical universe in which oxidation plays a most important part. The vegetable kingdom is a world of unconscious labor. The animal kingdom, beginning with unconscious gradually merges into conscious labor, in the course of time. Growth is the evident result of the expenditure of energy, either in the plant or animal world. The beauty and fragrance of a flower are the results of unconscious labor. In the animal kingdom, a remarkable example of unconscious labor may be seen in the life of the working bee, as it forms the intricately constructed honeycomb. The architecture and construction of the comb are worked out by the bee, which outlines the geometrical figures and constructs these figures in the dark, a feat which conscious labor could not perform.

But such labor as this is not materially improved by experience. Its results are as perfect in the beginning as at the end of construction. It may be supposed that the mere existence of animal protoplasm, without the exercise of any of the properties which it possesses, excepting that particular one which accounts for the intake and output of chemical elements, with the release of just sufficient energy to keep it within the boundaries of life,—in brief, the more living of protoplasm—makes no progress. It is not even able to maintain itself for any length of time, but drops to lower levels until its extinction is threatened, and, perhaps, accomplished. The power to maintain itself resides in the relation of its chemical elements to each other. Unconscious labor is practically synonymous with life.

CONSCIOUS LABOR.

By conscious labor is understood the unconscious labor of life directed by an intelligent purpose toward a definite end, and intended for the preservation of life. It carries with it the thought of progress toward an objective which could not otherwise be accomplished. It is pre-eminently the labor of civilization and is displayed in the constructive achievements of man. It is wholly within his power of will; he can perform it or not as he chooses. His unconscious protoplasm produces the energy and it remains for his higher intelligence to apply it. Does not unconscious labor, extending over millions of years before man appeared and still in existence as an active force, throw some light upon the conscious labor of man and its results?

The differences in types, type combinations and characters which are so evident in man have been the causes of the division of the race into the social classes mentioned above, viz., the unlaboring, laboring, criminal, intellectual, ignorant, poor and wealthy classes. Let us examine them in their relation to the bone types of man.

THE UNLABORING CLASS.

The unlaboring class of man is the natural sequence of his legacy received from the unconscious labor of past ages. When man first appeared he was confronted with the problem of living. He was omnivorous by virtue of his protoplasm. He was unconcerned about his method of living by virtue of his legacy. As he looked about, his limited power of observation led him to think that the varied forms of life about him lived upon the natural resources of their environment, and, to a great extent, without the necessity of individual effort. Nature had, apparently, provided food for all, and he accepted the gift with all the other animals, and in the same spirit. It could not have been long, however, before he realized that some animals were better provided for than others, and as a result of competition. This gave him his first glimpse of living by labor. He may also have noticed that the birds built their nests and many animals constructed places in which to have their young, and this gave him the idea of home-building which required a special form of labor. He found a part of the animal world busy and a part doing nothing, when he emerged above the horizon of the later mammals. Which condition would he naturally prefer? For which condition was he best prepared by his long ancestral history? Would he or could he accept the new life at once?

It is a perplexing question even now, just what proportion of the human race belongs to the unlaboring class. Perhaps the existing savage, barbarian and some members of the civilized races are the best answers to the question. The fact that these races now exist after thousands of years of experience and observation, and the results of labor among them are as widely different as the savage and civilized races show, seems to have had little or no influence upon the savage. He is still a savage. His labor is, for the most part, the unconscious labor of protoplasm; like the animals below him, his labor in search of food is the labor of protoplasm. He has no power to change his metabolism and, therefore, is driven to the chase by the demands of an exhausted protoplasm.

After all the years of his experience with different human levels, he is still contented with his lot, prefers it—and if, by chance, he is separated from it and given the benefit of the higher civilized life, he chafes under it and anxiously returns to his beloved savage state whenever the opportunity offers. He does not and can not understand civilization. Its advantages are embarrassments to him which he is eager to avoid. We see a mild form of this condition in those whose lives are spent in an unfrequented island, in the forest or on the plain. If by structure and character man is an extension of the lower vertebrates, we would expect to find him endowed with the basic attribute of unconscious labor which would display itself in those who claim that the world owes them a living and they do not propose to work for it. It is surprising to what an extent this feeling exists in civilized man today. Even in his higher stage of development he thinks of the time when he will not be compelled to work for a living. He really dreams of a return to the savage state, although he is not willing to acknowledge it. If man ceased to labor and lost the educational value of it for a number of years, he would rapidly return to a lower level of indolence where he would suffer the disastrous results of degeneration and possibly extinction. Conscious labor is an educator. It has an elevating influence upon protoplasm whereby it accomplishes better results than a mere existence. It opens the way to a better condition in the future in which man's whole being finds satisfaction and pleasure. When the change from unconscious to conscious labor came, the dominant character of the former prevailed, and a struggle for supremacy ensued which was not settled for a long period of time. It is not surprising, then, that the unlaboring class of man in which the unconscious labor of protoplasm has been and is the ruling power, exists and exerts a powerful restraining influence upon human progress.

Is there not an explanation of this turbulent condition to be found in bone? As there are fundamental, structural variations in bone, pointing toward higher objectives extending throughout the vertebrate series below man, so there are similar variations in the bone of man indicating higher objectives by the elimination of the lower and the substitution of the higher structural types which establish a supremacy of control. If we find in the bone of man, as we do, over one half of the reptilian or lower mammal structural type, we are justified in thinking that some of his attributes also belong to that stage of development, that is, to the lower levels of human advancement, as seen in the unlaboring class. We have all seen the type of the unlaboring man. He is slow of movement, heavy, dull of comprehension, unresponsive to environmental changes. His world is a small one. His aspirations are few and simple. He is uninteresting and uninterested, selfish and stubborn. He requires the constant goading of a master whom he respects, to be at all effective. If he is excavating ground for a building, he does not know or care what the excavation is for, any more than the horses which haul away the dirt. The pickaxe and the shovel are the tools of his level of industry. He has the opposable thumb, erect posture, strong sex, thick speech, very limited vocabulary and passes for a man. If he is drafted into the army and is sent out to drill, he blunderingly responds to "Hay Foot, Straw Foot" while "Right, Left" are meaningless sounds to him. Aroused he is unmanageable and useless. He will follow but will not be driven, or if driven will accomplish nothing. Like an animal at bay, he growls and snarls. His physical powers are not subject to direction. He does not think because he can not. He is practically incapable of any recognizable degree of education, on account of his anchorage to the lower vertebrate life. He inhabits the civilized world, but is not a part of civilization. He is the animal unspiritualized, the barbarian out of place. He is true to his type of structures—a small part man and a large part lower vertebrate. He exhibits glimpses of the former and direct evidence of the latter. He obeys the simple laws of protoplasm, for these are his by inheritance. Man did not rise from a low to a high estate by leaps and bounds, but very gradually and through many intermediate stages of development. The unlaboring and laboring classes are the extremes of his development. In the type of man described above we would not expect to find a high type bone. On the other hand, if we find the bone of man, as we do, in which all the lower structural types are displaced by the highest structural types, we are justified in thinking that it belongs to the thinking or conscious laboring class; for it is the conscious thinking class that labors. When man began to think he began to work. When he began to think and work he began to progress. Man came out of the darkness into the light when his brains assumed control of his muscles. This was the dawn of civilization.

The unlaboring class is self-destructive because it can not see beyond its present needs. A mere existence is ruinous to his stage of development. As there are many structural bone types in man, extending from the lowest to the highest, so there are corresponding characters representing those types, as might be expected, if types of structure have any significance. It is not strange, then, that we have the unlaboring class of man, which is still feeling the impresses of the ages past and gone. But, it may be asked, is it wholly to blame for its attitude toward labor? It has no power within itself to change itself or to transform its protoplasmic self into the spiritualized being of the higher level. It is doing what it has been doing for millions of years. The unlaboring man is teachable, or unteachable, in proportion to his release from his lower vertebrate anchorage.

THE LABORING CLASS.

The laboring class is constructive and looks toward the future. It has learned the value of labor. Labor is an expenditure of energy, and may be unconsciously or consciously performed. With unconscious labor, the purpose and action are one; with conscious labor, the purpose is the cause of the action. The lower vertebrates are not conscious of labor, as man is. They can not realize that they must work to live. Labor, over and above a mere existence of maintenance, elevates protoplasm to higher levels by the acquired agency of purpose. There is some sort of experience of a supervising nature gained by the exercise of the inherent powers of protoplasm beyond the point of maintenance. This is an education resulting in the acquistion of some new power which it did not have before. The individuality of protplasm, which seems to be possible, experiences a sensation of satisfaction or well-being, whenever it has accomplished something by labor. It is not always the particular thing accomplished, but the resulting feeling of an ability to accomplish more, better and different things in the future. The confidence which it now has in being able to do what it has not done before is the exciting cause of further action. Success strengthens the powers of protoplasm and leads to the repetition of its acts. It increases the rate of living by increasing oxidation.

The laboring class has the power of observation and in this differs most essentially from the unlaboring class. It has received instruction from the study of the results of unconscious labor which are everywhere visible in Nature. If man had appeared first on earth, with no models to observe, it is doubtful if he could have worked out his present civilization. Unconscious labor was the first labor. It obeyed the laws of geometry and mechanics in the construction of countless objects and with no knowledge whatever of those laws. It revealed those laws, however, in its works to a mind that was far enough advanced to recognize them. The designs in Nature were innumerable, and everywhere to be seen. The fitness of things was self-evident. A world of synthesis was awaiting analysis, and when the laboring man appeared he began to analyze and copy the objects before him. The copies were crude enough at first, but they stimulated a thinking mind to repeat them and improve them. The intelligence that drew the first plans gave man enough intelligence and desire to copy them. The power to see and the desire to reproduce what he saw separated the laboring man from his less fortunate brother. Whence came that power to see and that desire to reproduce what he saw? Why did it come to some and not to all? Is there any answer to these questions excepting one, viz., unequal advancement in the stage of development? A thinking man had come into a world of embodied thought. He was the laboring man.

It is doubtful if man, with all his opportunities, has ever constructed anything which was not its counterpart in form in the unconscious world. The lovely forms of vegetable life, the marvelous products of protozoan and insect life, the amazing architecture of the unconscious embryos, the wonderfully beautiful geometrical crystals of the inorganic world, which have furnished man with so many designs, the spherical, starlit heavens, the circular horizon, all are the works of unconscious labor, and have furnished the patterns and models which the later intelligence of the laboring man imitates very poorly in his architectural constructions. The great work of the world has been and is now, the work of the unconscious world, while man receives the approbation of his kind for the crude copies which he produces. The laboring man found a busy world, and he soon began to use the materials of Nature, to copy the designs of Nature, to imitate the life of Nature, and now calls it civilization. He swells with pride as he surveys the works of his hand, apparently forgetful that the foundation of it all was laid millions of years before he came into existence.

If now we accept the type of bone as a measure of development, then we ought to find in bone of the laboring man, who is also a thinking man, evidences of a departure from the lower types which we have seen characterized the unconscious labor of the lower vertebrates. This is generally true. The completely differentiated Haversian System type of bone is the bone type of the highest stage of development, which is the stage of development of man. There is an analogy existing between the bone types and attributes of infancy and childhood and those of the lower vertebrates. Infancy and childhood have a first and third type bone and belong to the unlaboring, unthinking class. This type combination may be replaced by the complete third type in the adult, or may remain unchanged, depending upon the ancestral impress. The unlaboring, unthinking man is child-like and the laboring, thinking man is god-like in comprehension. The writer was impressed with the comparative values of young and adult types of bones, as he saw them displayed in the full time, foetal and adult pig and in the foetal and adult man. The bone type of the foetal pig was an incomplete second, of the adult pig a more nearly completed second, with a small proportion of incomplete third; the bone type of the human foetus was an incomplete second and third, of adult man a complete third; the second type had disappeared. In the pig, no change in bone type accompanied the growth of the animal from birth to maturity, while in man the bone type had changed from an incomplete second and third at birth to a complete third at maturity. This is very interesting and significant. The complete third type has not been found in the adult pig nor the complete first or second type in man. The child at birth is about as far advanced in bone differentiation as the pig ever is; while from birth to maturity the child shows a constantly increasing differentiation until bone limitations are reached.

THE CRIMINAL CLASS.

The criminal character in man is the legacy which he has received from the lower vertebrates. It is the natural outcome of the conflict between the unlaboring and laboring man. It is, perhaps, difficult to define clearly the word "criminal" inasmuch as the great majority of all mankind has a criminal character in some degree. Laws were instituted in the first place to control the animal nature of man. The violators of those laws gradually became known as criminals. But this is primarily a biological problem. The destruction of life by another life to maintain its own life is world-wide in the animal kingdom. It began with the Protozoa. There is a fundamental difference between the vegetable and animal cells in their methods of nutrition. The vegetable cells are able to build up their protoplasm from the chemical elements of water, carbon dioxide and certain salts, by the agency of sunlight. Animal cells can not. They must first tear down a complex protoplasm and then build up the chemical elements so obtained into their own protoplasm. They therefore became dependent upon some other form of life. In order to live, then, they must first kill living cells. Here was instituted the first biological command, "Thou shalt kill," by obedience to which the first animals were able to escape starvation and death. They lived by the destruction of other forms of life. This has been the law of protoplasm from the Protozoa to Man. It was a matter of indifference to the animal cells whether or not the life destroyed belonged to one cell or another. The killing violated no law, but obeyed the law of being. It is a fact, however, that later forms of life prefer certain definite cells as food, some vegetable, some animal, and others both. This may be a matter of elemental volume, or perhaps voltage, as the atomic character of the vegetable is simpler and less in voltage than animal protoplasm. It is possible that the protoplasm of a cell is tuned to the vibrations of a vegetable or an animal cell, and that on this account a condition of harmony or disharmony is established by the choice. In this case, the former would be destroyed and the latter escape destruction by the devouring cells. This preference of one cell for another particular cell as food established the carnivorous, herbiverous and omnivorous animals. As carnivorous and omnivorous animals appeared, the head of the criminal arose above the distant horizon. The survival of one by the death of another was now established as the law of protoplasm. For millions of years, this law has been operative in carnivorous and omnivorous animals. Man has been and is both. He has always been and still is obedient to his protoplasmic command,—Thou shalt kill. He has received this impress of the ages. He can not murder an animal. The law of his being is supreme. Unable to live on water, carbon dioxide and inorganic salts, he is forced to tear down protoplasm in order to obtain the chemical elements required, and in order to obtain these elements he was and is obliged to kill. The criminal did not take definite shape until the command "Thou shalt not kill" found him with a consciousness of right and wrong, and this at a comparatively recent date. What would be expected when such a command was given to man after millions of years of the former reign of law of protoplasm? He was still protoplasm and the very law under which he lived was suddenly annulled by its opposite. "Thou shalt not kill" was not spoken to protoplasm, but to the new-born conscience. Protoplasm had no ears which could hear the command, the conscience had. Men were not all in the same degree of differentiation or stage of development. Some were high, many were low, some could receive the new command, many could not. What was the result? The rise of the great disobedient or criminal class. Are those whose stages of development are low, who still have within them the unwritten law of protoplasm, who are still doing what the animal has been doing during its long vertebrate history, altogether to blame for the violence of their acts? If a man is over half lower animal in structural type, and has the characteristics of that type, can he be expected to eliminate all of those characteristics when a command is given? Can he understand the new command? Obviously, no. His record under the new reign of Thou shalt and Thou shalt not kill, shows that he did not understand the confusing opposite commands. Man is still struggling between these two opposites. It can be truthfully said that all men are murderously inclined at times. They only recognize the existence of certain conditions. For example, if a wife, daughter or sister has been raped, what are the impulses in the mind of the husband, father or brother? If one country is at war with another country, do not the people of both countries with one accord pray for victory and while they are praying they are willing to sacrifice thousands of lives. What an example of human weakness and inconsistency is shown, when two opposing factions meet in their respective churches and each faction prays fervently for victory in the dreadful battle which may at the time be raging, and then after a victory, thank God for it, unmindful of the thousands slain and the indifference to the poverty and distress which are sure to follow. Is this murder? The world replies, No. War is a law unto itself. Is this not the impress of age-old protoplasm not yet eradicated and not even controlled? There is a biological war of protoplasm in the world of life. A protoplasmic hatred exists which invites combat. As we have often observed, two animals meet and the very sight of each other starts a fight which may result fatally to one or the other. There is no apparent reason for the fight, as they may never have seen each other before. Man has something like the same feeling toward certain members of his race. How often have we said, "I hate the very sight of him," and yet the speaker could give no reason for such a hatred. We are attracted to or repelled from others and without any reason that we know of. It is a war of protoplasm. There seems to be a racial hatred in the world which gradually increases in volume with the population until it bursts into a war, after which it is relieved for a time, but not extinguished. Neither the conquerors nor the conquered change their minds. The war of protoplasm is inextinguishable. It only requires time for the accumulation of another surcharge of the battery, when another explosion follows. As long as man is an animal there will be war and the criminal class. It is the animal level. A war of souls is a contradictory expression.

There is also a harmony of protoplasm, by which animals and man are drawn towards each other. This is a protoplasmic state which can be appreciated by any one of the five senses. A battle between individuals in harmony is practically impossible, for harmony is love, and love does not fight itself.

Sex is a solvent of protoplasmic differences. How is it possible to explain the fundamental differences in protoplasm which have wrought such havoc and caused such happiness in the world, unless we assume that they are inherently component parts of protoplasm. The separation of the vegetable cell, which does not kill to eat, from the animal cell which does, or the protophyta from the Protozoa, seems to have been an important point of departure in the history of protoplasm. The conveyance of these elemental properties along the stream of life, one after another rising to the surface as a dominant power, where it is maintained for a brief period, helps us to understand the strange contradictions in man which suggest a dual existence. Protoplasm has no conscience; it can not murder. It kills only to live and thereby obeys the law of self-preservation. But why must it live? The answer is not to be found in the individual but in the aggregate. It lives that a successor may live which is not and can not be precisely like itself. It may be better, at least it will be different. Thou shalt kill, was the command of protoplasm; Thou shalt not kill, the command of the soul. Both could not be received. The ten commandments could not have been obeyed by unequal human developments at the time they were given, nor are they now, and for the same reason. How easily they may all be abolished in time of war, when man reverts to his animal self. The criminal is not any particular person distinguishable from every other person by distinctive marks, but is one in whom the lower vertebrate character traits are more pronounced than they are in others and not as easily controlled.

Now we may ask, can the criminal character be recognized in the bone type? As suggested above, there is no distinct, recognizable criminal class of man, but there is a recognizable criminal element in man which is under better control as he advances. If all of those whom we like to call "criminals" were in one group and all others were in another group, it would be useless to attempt to tell the difference since the difference is only one of degree and there would probably be found no one in whom the character was entirely absent. The criminals are by no means all in penal institutions, if they were there would be no one left outside but ourselves. The criminal nature in man is his animal nature extended from his vertebrate ancestors along a continuous bone stem. Therefore, the lower the type of human bone, which is a first and third, with the first predomianting, the more nearly it approaches the lower vertebrate type and the more pronounced are the characters that belong to that type which we call criminal.

THE INTELLECTUAL CLASS.

The intellectual class declares itself by comparison with the majority of the human race. It is recognized as representing a group of individuals with higher endowments than those expressed by the majority of people. They think more clearly, understand better, comprehend more and stand out from the masses by thought, word, conception, purpose, action and power. They speak from a higher level, and in a thought language which all do not understand. Such a class is relatively small. It has raised its anchor from the lower regions of life and reached out to the universe. It did not come into existence suddenly, but very gradually, as the purposes of conscious labor advanced, and as they advanced they became more and more radio-active, until they had introduced a new standard of a highly intellectual character. As a class, it considered industry, religion and art in terms of the Logos, and called it Science. It found itself in a universe of substance and laws relating to it, and set itself to work to account for them, as though impelled by some irrestistible power. As the work progressed by multitudinous experience, it expanded proportunately. The brevity of individual life and the inability of one to bestow his knowledge upon a successor delayed advancement and introduced the errors of misinterpretation. Even after many centuries it is still anchored to protoplasm and, therefore, subject to error; but as protoplasm has been trained by these centuries of experience, its judgments are increasing in accuracy. This augurs well for the future. It does not and can not forget or even ignore the more accurate results of unconscious labor, but endeavors to investigate them and determine the methods of action which produced them, in order that it may have a foundation upon which to establish its own methods of action; for if it was separated from the unconscious world, it would have nothing to rest upon. The results of unconscious labor are accurate, while the results of conscious labor are subject to error in proportion to the interpretations of man. The intellectual class is creative and differs from the intelligent class only by its creative power. It can not be said to have had a definitely distinct or recognizable beginning, any more than day or night. It is the sum total of instinct, which activates the unconscious world, intelligence and creative power. It employs industry, religion, art and science as words of a different vocabulary with which it expresses higher thoughts as a mathematician might employ addition, subtraction, multiplication and division while working out a problem in calculus. The intellect belongs to man and can not be defined in terms of protoplasm. It is one of those words which is understood without a definition. We do not know how a rose produces its fragrance, but we do know that without soil, water, atmosphere and sunlight there is no rose or fragrance. Chemical and microscopical analyses are equally powerless to explain where the fragrance is, nor have we any means of expression by which the fragrance can be described to another. All we know is that we have certain olfactory cells and certain brain cells which are able to appreciate it. Furthermore, we content ouselves with the thought that it is a property of the protoplasm of the rose, and dismiss it from any further attempt at explanation. We simply infer that there is some structural portion of the plant, chemical, histological, or both, which is responsible for the fragrance. We can not separate one from the other, or account for one without the other. So it is with the intellect of man. It introduces us to the supreme character of what is called "mind," which is the highest endowment of protoplasm. We can not describe it, locate it or explain it, any more than we can the fragance of the rose; but we know that if certain protoplasmic cells of the nervous system are destroyed, the intellect and mind are gone. Perhaps nothing is more disappointing to an observer than the microscopical examination of brain cells for the purpose of explaining how they operate or produce their wonderful results. It is just as easy to tell how a rose produces its fragrance. Cell protoplasm is not one and the same chemical or histological substance wherever it is found, any more than the diamond and the charcoal are the same substance, if it were, the results of its activities would always be the same and this is not strictly true. Its great variety of products depends upon its countless variations as they occur in plant or animal life, which are the only situations in which it is found. While we can not think without protoplasm, we can not think with it. We do not know to what extent thought is produced by brain cells alone. We can not separate the mind from the body as a whole, which we think of as the Ego. The highest thoughts which are possible to man are those which contemplate God, life beyond the grave and the Universe. It is impossible to understand how such thoughts could arise from an atomic activity of substance. Something more is required; something with which protoplasm is in tune; something which is always present, always conscious, always active and always playing upon the cells of the body which are tuned to different keys, and which respond to the player in a symphony or jazz. We can truly say that mankind has always recognized a higher power than itself, has had a conception of other worlds than the earth upon which it lives, and has had thoughts of a future life. There has also been a racial mind, which thinks in broader terms than the individual mind. Conceptions change from time to time, as experiences are multiplied. There was and is a wide difference between the God of the primitive man and of the late intellectual man, between the universe of the savage and of the intellectual man, and between the future life of the savage and of the intellectual man, although there would be no discernible difference in the chemistry or microscopical structure of the cells which made these thoughts possible. We can not find the thinking power, no matter what investigation we make. Comparison of identical types, as they are found in the bones of the lower vertebrates and man, leads to questions which are hard to answer. If we compare the third type bone of the African elephant with the third type bone of intellectual man we can find nothing in the type of the one that can not be found in the type of the other. They are both completely differentiated Haversian System bones. Of course the volume of bone is much greater in the elephant than it is in man. Now these types of bone represent the highest degree of bone differentiation in both individuals, and yet they do not express the same quality of attribute or character. In both cases we are dealing with high type Haversian System bones, but the Haversian Systems of the elephant represent the highest bone differentiation of the ungulate, while the Haversian Systems of man represent the highest bone differentiation of primate. The enormous stretch of time between these classes of vertebrates gave to the Haversian Systems of man the opportunity to complete their physiological development and to display the attributes and characters which the earlier Haversian Systems of the ungulates could not express. This can be understood if we grant that there is a vertebrate rise and culmination, or vertebrate cycle, and also that each class of vertebrate has its rise and culmination or class cycle. Structural as well as character units would vary at different times, and in different classes, according to the point in the cycle at which the observation was made. There is an old saying, "Quot homines, tot sententiae,"—so many men, so many minds. We can also add, —"as many minds, so many variations in protoplasm." Protoplasm is an undefinable chemical substance, variable in composition and properties or attributes. Each atomic variation modifies a property or attribute. We often make the mistake of taking it for granted that similars are identities, and arrive at wrong conclusions. We pass judgment upon others unfairly and thoughtlessly. No one can say what another man thinks; he does not know. One's life is a sealed book, which will not be opened in this world, but when it is opened, his thoughts and beliefs will be found to be fundamentally the same as those found in other sealed books which were written by the same type of differentiation, and the same stage of development. We can not conceive of the life-book of the infant as being the same as that of a philosopher or scientist. Experiences establish differences which are proportionate to the variation of those experiences. Released from the bondage of protoplasm, man is a part of the universal Spirit. The war of protoplasm does not cease until protoplasm comes to an end. Strange to stay, the most wicked battle ground of such a war is in man. Atheism, agnosticism, materialism, are missles hurled by one against another because the latter does not think as the former thinks, and he does not because by differentiation and development he can not. Such words ought to be eliminated from the vocabulary of man. They are obsolete, and their revival is an evidence of reversion to a lower level. They do not characterize the intellectual class, which is a class of higher purposes than calling names, reaching out beyond that which is known, into that which is unknown and striving to know it. The intellectual class employs the forces of the universe to explain its own mysteries.

Here again it may be asked how such an elevated state of man can be dependent upon or associated with types of bone; for such an association hardly seems possible. This elevated state appears to be more of the nature of a separate consciousness, acting independently and alone, but it may be possible to partially understand if it is remembered that this state did not spring into being by itself at any one time, but has been thousands or millions of years in arriving at its present condition, which is by no means perfect now. It has come down through the ages and along the stream of life. It is unknown and unknowable, excepting as an attribute of the highest form of protoplasm. Its gradual rise corresponds to the gradual rise of the highest bone type, which has been ages replacing the lower bone types. Their rise and progress have been contemporaneous and equal. It has been found throughout this investigation that the highest bone type has been found in those vertebrates which possessed and displayed the highest degree of intelligence. This has never been reversed. If we should find an Haversian System man with the intelligence of a lamellar frog or a lamellar frog with the intelligence of an Haversian System man, we would be fully convinced that bone types made no difference with the degree of intelligence, but this is not the case. There is a recognizable harmony in the correspondnce of bone types to the degree of intelligence which, as we have seen above, is indicated by the teachableness of the animal, for teachableness implies a consciousness of what is required. Some vertebrates seem to be practically unteachable, not so much on account of a stubborn character as an inability to understand what is wanted and a fear of the teacher. The lamellar bone type animals are not teachable at all, or only to a slight extent, as for example, the amphibians, reptiles, many birds, bats, monotremes, marsupials, edentates. The laminar bone type mammals are teachable to a higher degree, both in its pure type and type combinations, as may be seen in the ungulates, carnivores and primates. It is interesting to notice here that these animals are late differentiations in point of time and therefore the teachable character of vertebrates is correspondingly late. The Haversian System bone type animals are the most teachable of all vertebrates, as may be seen in man.

As the majority of human bones are type combinations, it is found that the degree of intelligence, and, therefore, of teachableness, depends upon the proportion of Haversion Systems to the other bone types present. From the ungulates onward to man, we notice that there are some animals which have the Haversian System bone type as well as man. This being the case, there will arise an apparent difficulty in an attempt to explain why the intelligence and teachableness of the Haversian System bone type African elephant, for example, are not equal to the same character in the Haversian System bone type man. As far as bone type is concerned, perhaps, no one could tell the difference between the bones of the two animals, excepting a difference in volume. In the foregoing pages, attention has been called to bone levels as they were represented by types of structure. These levels have been established in bone history at long intervals and by slow, gradual process of eliminating the lower types, which no longer represent advancing values and substituting the higher types, which do represent those values. The result of each substitution would be a gain in value. It would be like a small water wheel turned by a small stream of water, being replaced by a large water wheel turned by that stream which had been increased by the additional water from many tributaries along its course. In this case, there would be an increase in the dynamic value of the large wheel. There are only three types of bone—the lamellar, laminar and the Haversian System—which represent bone values after millions of years, and these stand out as dynamic stations with ever increasing values. These stations indicate developmental periods in bone history. In the lamellar period, there was the low lamellar value with the Haversian Canals just appearing; in the laminar period, there was the higher laminar value, with the early diffentiation of the Haversian System just appearing, and in the Haversian System period there was the high Haversian System value, with the latest differentiation of the Haversian System. This means that the Haversian System bone unit, beginning as an Haversian canal and terminating as a completely differentiated Haversian System, has an ascending value, from fish to man. This value is always changing, in regular order, and can be appreciated only at its different levels or stations, which are known as classes of vertebrates. The Haversian System value, in the amphibian, is insignificant; it is more important in the reptile, more in the bird, still more in the mammal, and most in man. The Haversian System, therefore, may be taken as an index of physical values.

Now while the Haversian System elephant may be compared with the Haversian System man, the comparison is one of volume. It is not the volume but the application of power that raises values. Niagara Falls represents a tremendous volume of power, but its value was not raised until it was applied to a new terminal. Numerically, the Haversian Systems of the bone of the elephant are many times more than they are in the bone of man. A large stream would turn a larger wheel and produce a greater power than a small one, but in both cases the power would be the same in kind, that is, physical. But if the wheel power is applied to a dynamo, electricity is produced, which is the wheel power transferred to new values by a different terminal.

Protoplasm is composed of a few chemical elements, with many atoms of each, arranged according to a variable formula, and represents a variety of terminals which are not recognizable by the microscope, but are known by the different phenomena which they produce. The larger the volume, the greater the protoplasmic power, but that power is physical. It is the large water wheel which is not applied to a dynamo. It is the Haversian System power of the elephant. There is power enough but it is not applied to the right terminal to produce the highest values. In Haversian System man, although the volume is less, the power of protoplasm is applied to the dynamo of consciousness, which is a different terminal, and brings into recognition the intellect and soul power. There would then be a great difference between the Haversian System development of the elephant and that of man; the former is physical with an early form of terminal, and the latter is physical with a late form of terminal and a high degree of consciousness, or a soul. As there is a universe of electricity, a small portion of which is brought into recognition by the proper terminal, so there is a universe of soul power, a small portion of which is revealed by certain high levels of protoplasmic development. This does not mean that protoplasm is the cause of the existence of the soul, but that the existence of the soul is made apparent by it as a controlling power, and it will vary in its application in proportion to the terminal or stage of development of protoplasm. We may compare physical values, but not physical with soul values.

There are five geological ages or periods of vertebrate life, viz., the age of fishes, the age of reptiles, the age of birds, the age of mammals, and the age of man; while these several ages appeared in succession, the one lapsing into another, and occupied millions of years, the respective vertebrates of these ages, in the meantime, reaching their culmination and extinction by processes of elimination and substitution, yet notwithstanding their long formative period and tremendous losses by extinction, they are all present as classes in this age of man, selected by the power of adaptation to new and different environments. Connecting them all, is still to be found the same bone stem which is all that remains to tell the story of vertebrate life of remote ages.

The comparative histology of fossil bones has not been worked out, but we are fairly certain that bone types were no more advanced in differentiation than they are at present, that nothing less than bone substance could have existed as bone, that the classes of vertebrates and the bone types which belong to them did not all appear at any one time, but at different times, and in different degrees of differentiation and became the basis of classes or levels which the geological ages have revealed. We may read the biographies of the present vertebrates in paleontology.

Now if bone types represent the developments of these different ages, then their various combinations in the bones of intellectual man are not difficult to understand. When man first began to bury his dead and to place in the grave utensils and food for a future life, the first great consciousness and departure from all vertebrate life before him appeared. This was the dawn of the soul-life, or the religious personality of man. It was the spiritualization of protoplasm which could not be expressed by his vocabulary, but was recognizable in his behavior. We can not separate the universe from a creative power and understand it; we can not separate creative power from Supreme Intelligence and understand it; we can not separate Supreme Intelligence from an absolute consciousness of purpose. We find in the intellectual class of man some evidence of all of these, and speak of it as the soul class. We do not presume here that the soul is a negative abstraction, with an absolutely independent existence having a chosen residence in the highly intellectual class, or in man characterized by the highest degree of perfection; but think of it as a positive, growing personality, having an expansible consciousness, with changing attributes and variable limitations, whenever it is released from its anchorage to protoplasm. It may be dominant or recessive, depending upon the character of its bondage. We could hardly think that the soul of an infant at birth would be equal in conception to the soul of the mature thinker who had spent three score years in the study of the universe and of life, in its material and spiritual associations. We prefer to think of the infant soul as a spiritual bud, capable of constant growth and always in harmony with its new environment, advancing by virtue of its perfect freedom from all restraining influences, while the soul of the mature thinker, gradually disposing of the conflicting experiences of life, approaches the boundary of physical limitations and reaches out into a new existence, with the serene satisfaction of returning home. It is the soul that appreciates death, and not the protoplasm. The thought of human life extending over a period of a thousand years, even under the most favorable circumstances, is unendurable, while the thought of a spiritual eternity is most satisfying, for the soul is not conscious of time. Who would live forever? Age is out of tune with its environment. It has the restless wings which are anxious for flight. One by one the senses fail, little by little the physical values decrease, gradually we shun the mirror which formerly was our pride; silently we retire within our own solitudes, and, looking out of the frosted windows, seem to be waiting for something, we know not what. As the sun goes down in a flood of mellow light, and the stars come out, we realize, with new hopes, that a new day is coming, and we hail it with a delight that we have never had before, only too glad to forget all that is past and gone. The greatest pleasure of a burdensome life is found around the thought of an unburdened life. During war we long for peace. After our final separation from this world, is there any one who would care to return to it, or even to remember it? Can it be possible that a spiritual existence of personality is made happier by a recollection of its protoplasmic association?

There are three lives, viz., the pre-natal, post-natal and post-mortem, and each life has its experiences. The pre-natal, or embryonic, is a life of unconscious labor, the post-natal of conscious labor, and the post-mortem of consciousness. Death marks the passing of the first to the second and of the second to the third. In each case it is the beginning of another and different life. It has no existence as an entity, but notes the transition from one state to another following a period of preparation. As we have forgotten our pre-natal lives, so we must forget our post-natal lives if happiness is to be our lot. Is not the termination of the pre-natal life, the birth of the post-natal, and the termination of the post-natal the birth of the soul life? A transformation and not a continuation of protoplasmic life is a requisite of happiness. A post-natal life, long continued, is doomed to unhappiness because of the failure of protoplasm to maintain itself. The soul is dependent upon a certain refinement of protoplasm by which it is made known in post-natal life, or upon an absolute freedom from it, which is its natural condition in post-mortem life. To compare the soul with anything else in the universe is absurd; to describe it, is impossible and to think of it, is folly. As well might a thought think of itself. As the refinements of protoplasm vary in different individuals, the soul varies in the manifestations of its existence; that is, the more highly refined the protoplasm the more clearly evident is the soul. If we deny the existence of a soul, we deny the existence of a personality. The soul and intellect are complements of each other. The intellect may be right in one sense and wrong in another. The most intellectual mathematician or physicist may be the most brutal murderer; his superior knowledge of mathematics or physics will not neutralize his protoplasmic character. "Thou shalt kill," remains supreme within the confines of his protoplasm and he can not disobey the command. There is nothing in mathematics or physics which says, "Thou shalt not kill;" there is in the conscience. The Moral system is necessary to give a purpose toward good, and good is, or should be, the ultimate end of intellectual purpose.

We may say that there are three intellects in the human race—the Black, Yellow-brown and White, and each one has its own Moral system. They are alike in definition, but quite unlike in expression. Their standards are different. Each one is better satisfied with its own than with the standard of another. The endeavor to decide which one is right has made an immense amount of trouble in the world. Unequal development can not agree on one standard of living. It has been said that all men are equal; they are not, can not be, and ought not to be. We have no intention that they shall be. What a dead, uninteresting world this would be with one intellect, one thought, one conception, one purpose. We would not have such a world, here or hereafter, if we could. Oneness is nothingness.

By a law of the universe, we are constantly changing, and could not tolerate a permanent state of sameness. Even happiness must change to be endured. Knowing that we are not all equal, we say, with a hopeful modification, "All men are born equal." We do not even believe that. It is a theory which has no foundation in fact. They are not born equal. All of our social affairs, based upon such an equality, are in constant turmoil and conflict, and will be until we are willing to be honest enough to allow that they are not born equal and are not equal. We do not seem to be able to recognize our own difference and unequal limitations when we think of the equality of the races or of individuals. We can not rise above our levels, and fortunate is he who knows it. It is very difficult for one to know his level and be satisfied with it.

Several years ago, slavery was an institution of this country and was based upon the inequality of man. By a stroke of the pen it was abolished. Emancipation was based upon equality. Every one believed in the truth of the former, no one in the latter. There is a biological reason for slavery, and it can not be eliminated by legislation. It is not a matter of color, but a stage of development. The slave does not, and perhaps can not, know his limitations. He supposes that he can be raised to a higher level by a law of the land. This can not be. As a matter of fact, nobody really thinks that it is possible, and nobody, even the slave himself, really believes that it ever happened.

This idea of the equality of mankind was illustrated in a conversation which was carried on between a white man and a colored preacher, who was also a colored waiter. The white man asked the preacher the following question: "If a large tract of land, situated in Africa or in some other country, was presented to the colored race, do you think that the colored people would accept it and build up their own country, establish their own government and civilization?" The preacher replied: "Well, sir, the colored man is an American citizen just as much as the white man is. Why should the colored man leave his home-land and go to some undesirable country and suffer the losses and privations of pioneer settlers in an attempt to build up another country when he already has one? This is the colored man's country just as much as it is the white man's country. Our Constitution says that 'all men are born free and equal'."

It is strange how willing we are to talk about the equality of the races and how unwilling we are to believe it. Doubtless each race thinks itself the equal of any other race, although it may not be able to show it. Most of us have a stock of trite sayings which we employ on certain occasions for certain purposes, chief of which is self-glorification. We are known by this stock as a grocer is known by his groceries. As students of the various departments of our university, we remember the set phrases and stock sayings of our highly intellectual professors The platform thought and vocabulary remain unchanged as long as the orator or professor. We are pleased and satisfied with vain repetitions, perhaps because it does not require any brains to express them. Probably there are no two persons living who were born equal. The claim of equality among unequals has been and is, the foundation of our many dissensions. While we are saying, with wonderful stage effect, "All men are born equal," the world is engaged in a succession of conflicts which prove that our statements are false. If we could recognize our limitations, and our developmental differences, and abide by them, we could avoid most of our troubles and accelerate our progress toward a higher civilization. We all have many newspaper virtues which we are willing to exchange for popularity, and at an expensive rate of exchange. Harmony and disharmony are founded on chord and dischord, and it is silly to think that harmony may arise from discord or disharmony from chord. Our very continuation as a race depends upon our inequalities. Equalities imply the same structural bases, the same structural bases produce the same phenomena, and the same phenomena, long continued, are transformed into prophecies of extinction.

If we select a great singer, we may suppose that any one who is his or her equal has the same musical conception, the same physical formation of the vocal organs, and the same psychological character. There probably is no such person. We do not think that there is, and we are glad of it. Two singers equally great in all respects would neutralize each other, and obliterate their comparative values, which, after all, are our delight. Equality in attribute depends upon equality in structure and as the latter does not exist, the former can not.

We may ask, in this connection, what is it that sings in the singer, protoplasm or soul? We can not think that it is protoplasm. Does the soul, then, depend upon a physical basis? Was there a soul before there was protoplasm? Does it have any other means of expression than material means? Can the soul of the dead singer be recognized or expressed by the phonograph? Or is it merely the reproduction of the vibrations of the vocal chords that the listener is conscious of, whenever a song is reproduced? Does it not, after all, depend upon the receptive power of the hearer whether or not he is in tune with the singer? The head hunter of Borneo could not appreciate a phonographic record of an aria produced by a great singer because he is not in tune with the singer. The soul of the singer plays upon a refined protoplasm as a musical instrument, and the phonographic disc takes the vibrations. If, now, it is possible for a soul to play upon a refined protoplasm as one plays upon a musical instrument, it is just as possible for the soul to exist independently of protoplasm as it is for the player of a musical instrument to exist independently of his instrument. If the player is separated from his instrument he does not any the less exist than when he is with the instrument and playing on it. We have thoughts without words, songs without vocal chords, and acts without physical means of expression. Perhaps our highest thoughts and grandest themes are inexpressible on account of the coarse, unrefined nature of our protoplasm. The soul understands and expresses them in proportion to its release from material anchorage. Instruments and words are the crude means of expressing our thoughts, but they are not the thoughts themselves. If we ascend a hill, lie upon our backs on the ground, and look up into the clear, starlit heavens at night, our thoughts have no means of expression; if we speak, we destroy them. The best moments of life are those in which we can commune with the invisible, inaudible, immaterial and utter not a single word. But this is not true of all; some may look at the starlit sky and fall to sleep; the observation arouses no inward feelings. They are most profoundly impressed with a piece of metal, with the stamp of the government upon it than they are with the universe with the stamp of God upon it. Small minds, small thoughts, small souls are they, looking out from an illumined protoplasm. Inequality is the rule. The population of the world looks at the stars and is moved or unmoved, depending upon individual levels, and the individual level depends upon the stage of development. Different levels carry with them different thoughts; for one level is necessarily above another, and therefore unlike it. All things considered, we may suppose that the soul, and intellect, are on different levels,—the former above the latter and unlike it. If we understood the soul as a part of ourselves, it must be that part which we all acknowledge as the good. If the soul is a part of the Divine Spirit, then a bad soul is unthinkable, while a bad intellect is willingly granted. The idea of penalty belongs to the intellect, because it is subject to error. The soul is the throne of judgment before which the acts of the intellect are brought for trial.

Goodness, pleasure, happiness, sorrow, remorse, love, beauty, are soul attributes which protoplasm can not understand. We can not dispose of the personal pronoun "I" without disposing of all that is dear to us and all that is real to us.

Here again we may seem to be departing from the original subject of Bone as a measure of development. It is with difficulty that we can in any way associate the soul with bone. However, when bone was introduced into animal life, a most important change in animal life began. The whole world acknowledges the existence of a soul, and by common consent agrees that it exists in the vertebrate rather than in the invertebrate series, and in the highest type of the vertebrate series rather than in the lowest. This may be wrong, since it is just as difficult to explain behavior in a single cell without a personality as it is that of a higher vertebrate. The multiplication of cells does not change the character of the single cell. The realization of a form-producing energy is necessary to the understanding of cell or vertebrate personality. The highest stage of development is found in man, and the highest type of bone of the vertebrate series is also found in man; therefore we conclude that bone type is in harmony with the attributes which a vertebrate possesses, and since bone is the only tissue common to all vertebrates that shows visible variations in structural type microscopically, it may be taken as a reliable measure of development. As the bone level is, so is the level of development.

THE IGNORANT CLASS.

This class is very difficult to define, either by word or boundary. Strictly speaking, there is no other class of man; however, for our purposes here, it is that very large class composed of the illiterate, the literate who read infrequently, unwillingly, unintelligently and with difficulty. The diameters of their field of comprehension are very short. To them words, phrases and sentences are more blocks cut out of great virgin quarry, and are unilluminated by thoughts. They leave no impress upon the sensorium, and therefore perish with the sounds of their last utterance. There is a center of speech in the brain which issues words, but no center which defines those words. The ignorant mind is conscious of its own limitations and readily acknowledges the authority of its superior brother. It willingly becomes the slave of the intellect, and obeys its commands with pleasure, recognizing in them an evidence of a higher power than their own. Ignorance will bow to knowledge if it is not too dense to recognize it.

A capacity for knowledge is governed by development. Man can not exceed the knowledge of his type of differentiation, and stage of development. While the ignorant class is marked off by no distinct boundary line, on either side of which individuals may be unerringly placed, yet we are satisfied that there is such a line, vague though it may be, and there are many on one side of it who ought to be on the other, if capacity for knowledge is adopted as the basis of classification. The ignorant class is surrounded by an enclosure which it can neither see through nor over. It may be elevated somewhat by education, but the impresses made by education are easily erased by the prolonged grinding power of its biological history. There is some kind of a cell consciousness which recognizes limitations, and it is satisfied that they can not be exceeded, although the desire to exceed them may be great. The desire to know may be even greater than it is in the intellectual class, but the power to know is much less and is fixed by the law of its development.

A teacher knows that in a class of students there are some who do not and can not know what others know. Although at the termination of the courses of study he may declare, by his signature that they have all passed a satisfactory examination, and are entitled to receive a certificate of graduation. It is perhaps not incorrect to say that some colleges, at least, graduate students to get rid of them. Such students have come up through the grades and preparatory schools, have entered the freshman class of college, have passed their examinations to each succeeding class, and have finally received their diplomas. They have had all the advantages which all of the various schools could give them and have answered all their requirements, and are entitled to receive their diplomas. Doubtless they have done as well as they could do, with the biological background which they had, but it was not sufficiently cleared of the deep impresses of the vertebrate past to make it possible for them to approach a high stand scholarship in their college work, and they were mercifully given their degrees to make room for others who might have a more favorable background. How often we hear the more or less confused impresses of a vertebrate past trying to speak through the speech centers of the vertebrate present, while we are conscious of an inherent determination in the racial mind to liberate those centers from the tyrannical thraldom of the past by the liberating power of education. We can not educate until we have the proper background, and we can not have the proper background until we have procured it by the selective principles of eugenics. The present psychological tests for the classification of individuals are conclusive evidences of the recognition of unequal developments in the human race. The industries, religions, arts and sciences of the present age suffer greatly on account of the fact that so many persons occupy important positions in them which they are not qualified to fill.

Lifting one's self by one's boot straps is no more absurd as a proposition than holding a position which one is not qualified to hold. Doubtless many of our labor disturbances could be successfully adjusted if employers and employees could know their own individual limitations and were willing to acknowledge them. One great obstacle in the way of making such an adjustment is due to the fact that all men are supposed to be born equal and, like the students of a class, they have all received certificates of graduation. If, for example, the pick and shovel are the tools of one's industry, it is folly for him to assume an ability to work out the intricate problem of cell life, although he may have a compound microscope and the delicate tools required in cytological research. Why not acknowledge the truth and avoid the troubles which are sure to follow the research work? There are too many pick and shovel men trying to determine the values of the chromosomes in cell division. The estimation of labor on a dollar basis does not change labor values. The fact that the pick and shovel man and the research man both receive the same amount of money for their services does not place them on an equal basis, as the pick and shovel man too often claims. How foolish it would be for a draught horse to enter the trotting races, but the draught horse is not foolish enough to make such an entry unless he is forced into it, when, of course, he fails. Ignorance is not always responsible for its failures; it may be the descendant of a type from which it has received an inferior legacy by inheritance. One cannot change his ancestors as he might like. Generally speaking, ignorance has a biological basis.

Suppose a brain cell said to a liver cell: "I am better than you are; I produce thought while you produce bile; I can reach out into space and comprehend the universe. You are only a scavenger and have to be contented with the removal of the waste products of my superior activity. You have no higher aim in life than to keep the streets clean of refuse that my operations may not be impeded." The liver cell replies: "Yes, but your very existence depends upon me; you would kill yourself with your own vile productions were it not for me, and the thought of universe would not save you. In cell administrations there is no superiority nor inferiority. One is just as high and just as essential as the other. The work which I do you can not do, and the work which you do I can not do."

Overhearing the discussion, the blood enters a protest to this effect: "Your discussion is a foolish one; neither of you would exist if it were not for me. I bring to you both everything you require to sustain life and protect you from hostile invasion and destruction. I am the life."

Bone, listening in silence for a time, finally remarks: "You are all wrong. I have made you all possible. I have brought down from remote ages the power which decides your values in our great citadel of life. I have collected myriads of impresses made by countless forms of life before you, and stamped indelibly upon you all, and it is not for you to discuss the superiority and inferiority of protoplasmic values, but to do what you can do and are prepared to do by the long discipline of the ages. Ignorance is a blessing if it is dense enough to enable one to mind his own business. I provide you with the red blood corpuscles or respiration, with the white blood cells of protection and with the exchange place of inorganic salts. Why discuss your relative merits on the ground of superiority and inferiority when neither you nor your host could exist without the harmonious operations of you all. I have measured and recorded your developments. They are fixed for you. There is an age value which you represent, and which you have not the power to surpass. Metabolism is infinitely better than decomposition. Work for the good of all and do not discuss subjects which you know nothing about."

There are some things which can not be settled by argument, as the superiority and inferiority of the different forms of life, of protoplasm and grades of perfection. So much depends upon our definitions which are usually personal and therefore changeable. If a definition should include everything that a thing is and exclude everything that it is not, evidently there are few good definitions. Many, if not the most of our quarrels resulting in disastrous termination or general warfare, have as a cause a misconception of the definition of the terms which form the foundation of their arguments. Definitions depend upon the different points of view of the disputants, and these, in turn, depend upon their degrees of differentiation and stages of development. The ignorant class is a class which has not reached the highest degree of structural differentiation and stage of development and it can not wisely discuss such topics as the superiority and inferiority of any particular form of protoplasm with the intellectual class which has reached a high degree of differentiation and stage of development, for the reason that there is no common ground on which they can both meet. When we can not understand each other we fight, and often with no very clear conception of what we are fighting for except a victory. A fight does not and can not change the point of view any more than it can change the stage of development or degree of differentiation.

Thus the ignorant class may be taken as the representaive class of man when it is considered from all angles, and it would be expected to display a greater range of differentiation than any smaller class. Ignorance and intelligence admit of so many grades that they are very close together and hardly distinguishable at their point of departure. It can not be expected then that this class would be represented by any one type of bone, but by type combinations, which seems to be true, as may be seen by reference to the foregoing table in which the type combinations in the Black race are 74%, in the Yellow-brown race are 65% and in the White race are 26%. The future of the ignorant class is dependent, therefore, upon its ability to raise its degree of differentiation and its stage of development to the third type. Perhaps our greatest hope, after all, lies in the ignorant class which gives the greatest promise of advancement. The pure third type has reached its limit and can not advance.

THE POOR AND WEALTHY CLASSES.

These are comparative classes which represent different degrees of self-preservation. They are allies of the unlaboring and laboring classes. Man, by the nature of his origin from the lower vertebrates, has always been divided into two great classes, viz., those who possess little and those who possess much. The former is the natural result of a misunderstanding of the productive value of labor as it is estimated by the better judgment of the more highly developed minds and finally resolves itself into a refusal to work and into a reckless conclusion that the world owes them a living without work. It is the unlaboring principle of early animal life carried forward into a later development. It is protoplasm with the power of speech. To possess without work, had an early origin and the possession of property indicated power. Why should intelligence impose the penalty of hard labor upon itself because it is intelligence? The fear of death is the cause of the continuation of life, and is expressed by the saying, "Self-preservation is the first law of Nature." This has later been transformed into, "Might is right." As a rule, the real poor class is the ignorant class. If work or starvation faces the ignorant and indolent he works, no matter what his natural inclinations are. If his labor is not worth his living, he becomes disgruntled and throws himself upon the charity of his more successful brother. Having once begun an existence, life is driven to maintain itself by the most extreme demands of the law of its protoplasm. Self abides in and for itself. Protoplasm, which has a very complex chemical formula wherever it exists, undefinable, incomprehensible, the secret abode of an unfathomable mystery, the author and framer of those laws which govern the whole animated universe, is a kingdom by itself, and unlike any other kingdom, was established primarily to continue itself by virtue of the authority vested in the atomic associations of such a complex chemical substance.

If we ask the question, "Why do we live at all?" it is not any single individual who is able to answer, but the sum total of all living things in the universe. Chemistry tries to answer the question and fails just before it answers it. There is no chemical formula of life itself. We can not take any one element from the formula of protoplasm and have protoplasm left. All elements are necessary to the living substance, and each one has something to do with the succes of all. The loss of one element would throw the whole out of adjustment unless the elimination of that element was necessary to restore the disturbed equilibrium of the whole. We can not assume that one form of protoplasm is precisely like every other form, although chemistry is unable to detect a difference. For example, the protoplasm of the monkey and man can not be one and the same, otherwise animals would all be monkeys or man. In like manner the protoplasm of one man is not precisely like that of another man, otherwise there would be only one man. We judge of the differences by their attributes. It is quite probably that there are recessive and dominant characters in man today which represent the same characters in the vertebrate life before him. Variable man, as he is, could not have lived in the Devonian Age of the world, for the experiences of life at that time had not been sufficiently extensive to prepare any particular form of life for a higher plane of existence than that of the fish. We are conscious of recessive and dominant protoplasmic class strains which, summarized in man, account for his varying characteristics, and the struggle between the two for ascendency gives rise to the remarkable differences in individuals. These differences are equivalent to our poor and wealthy class. The recessive strain is prominent in the poor, and the dominant in the wealthy class. The wealthy class is wealthy because it is dominant, and the poor class is poor because the wealthy class is dominant. Communism does not exist in the vertebrate world. There is no basis of equality upon which it could succeed.

Competition is a property of protoplasm. If all the wealth of the world was equally distributed among the people of the world, it would only be a short time until the poor and wealthy classes again existed as they do now, and each class would be composed of about the same members as at present. Humanity unconsciously divides itself into these two classes by the exercise of its protoplasmic prerogative. The wolf and the lamb, for instance, among mammals, could not share equally in the race of life which evidently belongs to the strong. There are wolf and lamb attributes in man. The equal division of wealth is, in the vertebrate nature of man, as impossible as the equal division of the traits of character which he inherited from his vertebrate forbears. The recent acquisitions of the higher consciousness gave advantage to the dominant strain in man, which might be lamb-like, wolf-like or reptilian in nature. The lamb and the wolf can not change the controlling laws of their natures. The lamb must be contented with its lot in the struggle for existence. Its only hope is in the depreciation of wolf values in the wolf by the acquisition of higher standards by the wolf. Since there has been no gap in the vertebrate series, man will naturally fall into the poor or wealthy class, depending upon the origin of his dominant strain from the lamb or wolf vertebrate.

It is remarkable that so large a portion of the human race is directing its greatest energies toward the accumulation of wealth which it can hold for a brief period only.

It exacts the uttermost farthing that it may satisfy the greed of its protoplasm before it enters into a state of decomposition. It lives, it acquires, it dies, it leaves all it has and is forgotten: nevertheless it is the prevailing principle of our modern civilization. Strange idiosyncrasy; living to accumulate that it may die and leave the accumulation.

Since man has existed, the poor and wealthy classes have existed, the former making the latter possible by its labors, and the latter making the former probably by the appropriation of the products of those labors. The one who labors is not always the one who receives the reward of his labors. If we ask the question,

—which is fittest to survive, the poor or the wealthy class, there are included in the question the thoughts of labor and capital. These are the equivalents in value, and should be complements of each other. They are transferable or not according to circumstances. Labor, by itself, may have little or no conservative power. Like the stream of water flowing over a dam, its energy is wasted until applied. To a great extent the wealthy class has been the conservator of the poor class and has increased the value of labor. Although the complete understanding of one class by the other is not yet accomplished and dissensions are frequent, the educational value of community interests depending upon co-operation is increasing and each begins to see the viewpoint of the other. How much of our present civilization would have been constructed by the poor class and how much of that same civilization would have been constructed without it? When labor stops, progress ceases, and capital is dormant. The poor man thinks that the possession of wealth is happiness, the wealthy man knows that it is not. The pursuit of wealth is protoplasmic by nature and happiness has never been achieved by protoplasm. Protoplasm can not look beyond its own decomposition, which occurs at death. Some other vision is required; it is the soul vision to which the adjectives "poor" and "wealthy" can not be applied. It is impossible to conceive of a soul desiring a substance which it can not use. Entombed within protoplasm, it chafes for liberty. It has a vision beyond the chemical transformation of substance, or the final play of electrons. I can not be happy with a cyan compound such as protoplasm is. It is tuned to a higher key than protoplasm and responds to the higher vibrations sent out by the Infinite, which establishes that state known as happiness. The poor and wealthy classes, both, desire one common object, and neither one fully knows what that object is until it understands clearly the meaning of substance and the meaning of happiness. The dominant power of protoplasm, which is the controlling power of vertebrate life, leads the way to its own destruction, and unconsciously opens the door of the tomb for the escape of the prisoner within. Many good words of our language have been worn out with fatigue in the hopeless discussions between labor and capital, and no agreement is yet possible. Discussions do not terminate arguments, they continue them. Probably the most effectual means of settlement (Nature's method) is the extinction of one or the other. It is not to be supposed that those classes are made known by any one single type of bone, but by such type combinations as belong to those vertebrates which live at the expense of the others, viz., the carnivora and omnivora, and these type combinations are the first and third, the second and third, or first, second and third.

SURVIVAL.

The struggle for existence presupposes the survival of the fittest, without explaining why the fittest survive. We are too willing to grant that the survivor is fittest because he survives. The desire to possess for the sake of possession is fundamentally protoplasmic. Large possessions signify wealth and power and for this reason the wealthy class assumes the right to survive. The enormous possessions of King Tut-ank-amen are convincing evidences that the young king expected survival in another world. He evidently had no thought of the survival of others, unless it was of slaves to serve him and add to his comfort. The peculiar feature of such a plan was the apparent willingness of his subjects to accept *his* right to survive and their own doom to destruction. Was the King made of better stuff than his subjects that he ought to survive? The answer was written on the walls of his tomb.

The attitude of a slave to his master is that of an inferior to an acknowledged superior.

Survival is no more important than extinction. Judging from the fossils of extinct animals all over the world, we are quite unable to understand why these animals ever came into existence unless it was to go out of existence and by their existence to extend some necessary character to the life succeeding them. If we take a long period of time, how can we decide what vertebrates were fittest to survive, how long they remained fittest to survive, and what necessitated their extinction, by which we are to suppose that they were no longer fit to survive. There is no way of telling when the time limit of survial will arrive. It will depend upon the projectile force on the one hand, the resistance on the other. The projectile force was one, the resistances have been many and therefore survival will have a time limit.

For convenience, the vertebrates are divided into large groups or classes, as the classes of Fishes, Amphibians, Reptiles, Birds, and Mammals, but we have not always had them. They did not all appear at once, but in orderly succession, and while the members of each class have not all survived, the class has. One class followed another, gave its impress to another, by which its extension was made possible, and by which it was able to reach a higher level. Obviously, the unlimited extension of all members of the vertebrate series would not be in harmony with the highest Intelligence. While they all have a right to live, we can see, with our limited vision, that it is not best, in the interest of all life, that they should all live.

EXTINCTION.

It seems strange that the cause of beginning should carry with it the cause of its ending, and yet it is by this principle that the vertebrate classes have been able to survive. Hand in hand with the original power of extension was the opposing power of extinction, both forces operating within as a method of cancellation and reduction. The uninterrupted expenditure of energy is an impossibility. Action is followed by inaction, a kinetic by a potential period. Astronomers tell us that there are very many dark bodies in space which once glowed with the fires of Creation, but which are now dead worlds, waiting, perchance, for some reviving power to bring them back to new life. Although their fires are gone out, they have lost nothing of their values in the great plan of celestial physics. Our own Moon, with its great extinct volcanoes, monuments of a living past, is a dead world, but although dead, its influence in the Solar System, and especially upon the earth, is no less than it was before it became a dead body. The tides still ebb and flow; the power which binds together the universe is unchangeable. A live Moon is no better than a dead one in the economy of the Solar System. How foolish it would be for the different classes of men to wrangle over the questions of their rights, which are really based upon their particular stages of development.

The Moon holds up a mirror into which her Mother Earth may look and behold her fate. Her fires are also going out, and in course of time a dead earth will circle the Sun. Her influence, however, in the Solar System, will remain the same. It can not be taken out of it without wrecking the universe. The life of a world is merely an incident in its history. The sum total of the great number of dead bodies in space has made no apparent difference to the universe,—it goes on just the same. Suppose a great discussion had arisen among the living worlds concerning their rights; such a discussion might have come to an abrupt end if they had been told that they were worth just as much dead as living, and therefore their discussions were meaningless. The power which gave motion to the bodies of space, gave life to their surfaces. A dead world retains the axial and orbital motions of the living world, and may be rejuvenated by the heat of arrested motion, or a collision. Disturbances which can not be settled in any other way may be adjusted by catastrophe. Death is only one of the incidents of life. The substance of which man is composed is as immortal as the universe of which it is a part. The chemical elements of that substance are star-wide in their distribution. The value of a dead body in space is fixed. It may have lived millions of years before its life became extinguished; it continued its orbit in space because it could not help it, as a dead and useless world, or until its fires were relighted by a collision with another dead and useless world, and a new and different world was begun. The extinction of one life was essential to the beginning of another, and if the two colliding worlds were not precisely the same in chemical composition, their fusion by incandescent heat would produce a different world, and maybe a different life,—grand prototype of the variations brought into existence in the kingdoms of life on Earth!

As we read life histories in the rocks, we can not fail to notice that the various classes of animals have met with tremendous losses by extinction. More especially is this interesting in regard to the vertebrate series, with which we are most closely associated. Perhaps we have gained as much information about vertebrates from the book of the dead as we have from the book of the living. The ganoid fishes, the Saurian reptiles, the reptilian birds and the mammalian mammoths have become wholly or partially extinct. The same can be said of the higher mammal, Man. The Pithecanthropus erectus, Piltdown, Heidelburg, Neanderthal and Cro-Magnon man are all extinct. The Aztecs, the shell-mound Indians, and some of our later tribes have gone out of existence, or become extinct. Furthermore, we are all familiar with families of our own time which have become extinct, or soon will be. From this we conclude that they were no longer fit to survive and yet, with all of their losses, the trend of vertebrate life has been and is upward and forward. Survival carries with it the thought of extinction, for there could be no survival of the fittest unless there were the fittest to survive and this would mean the existence of those less fit than the fittest. While the vertebrates became extinct in great numbers, the bone types and the characters which they represented were extended. These types and their characters, as they were extended, were sufficiently distinct to give names to the ages, as the age of Fishes, age of Reptiles, and age of Mammals and Man. If the gigantic Saurians of the Reptilian age were not necessary to the general plan of life, why should they ever have lived at all? They were all fit to survive, but their fitness was adequate for a comparatively short period of time, that is, fitness to survive is a temporary state and the fitness to die is just as necessary to the plan of life and its extension. From the vast fossil fields with which we are familiar, we must suppose that millions of animals were fit to survive in one age, but not in another and following age, or they would not have become extinct.

Although each class of vertebrates has lost tremendous numbers of its members, yet the class continues, and exhibits its peculiar characters. The fishes, for example, have not greatly changed in their bone types or general characters. Survival and extinction are complementary states; both are essential to the advancement of life. Man is no exception. His present state has been achieved by both.

Time and consciousness are one. When there is no consciousness there is no time. If a man is 75 years old, he has been conscious only fifty years, as one-third of his life has been a life of unconsciousness in sleep. He could not be conscious 75 years; his power of cerebration could not endure it. However much he may love himself he can not endure himself a great length of time. How he delights to get away from himself in the bliss of unconsciousness! He must become practically extinct at short intervals, and forget the world and himself in sound sleep. His very life depends upon his unconscious periods when there is no time. This is the protoplasmic life. It must lose in order to gain or to live. Each moment of time wears away a unit of consciousness, until we become unconscious. Who can tell what the loss in sleep or death is? Who can tell what the gain of the morning is? The consciousness of a conscience surpasses the comprehension of protoplasm which has no conscience. In his various action, man, when disentangled from his lower vertebrate impresses, finds himself asking the inaudible question, Is it right or is it wrong? His protoplasm answers "Right," his conscience, "Wrong." This question reveals the existence of a soul life within, which is not the same as the chemical, or protoplasmic life, which never asks such a question. This soul life can continue forever, for it is not conditioned by time. We can not, for example, think of the Earth as one hundred million years old. All we can do is to give it an age equal to two-thirds of our own. Anything more than this is an inference. If we would sit down with a time-piece before us, and take note of each second of time, it would not be long before we became unconscious and fell asleep. Now if man is a complex of the characters of the vertebrates which have preceded him, and this complex is the result of elimination by extinction, and of addition by extension, we would expect that he would present about the same characters as those which he does exhibit at the present time.

Man is the most difficult of all animals to understand, because the development of a soul life, in addition to a protoplasmic life, has introduced a dual nature which has not existed before, and which has separated him from all the other vertebrates by laying the foundation of an ethical system.

As a result of this remarkable history of man in his dual nature, we find his race divided into groups or classes, as mentioned above. It is strange that there should be such a mammal as man, having the same structural bone types, as other mammals, and yet, admitting such a progressive classification, the appearance of which was made known when structural variations began to appear. It is impossible to think of a definite time in vertebrate history when mammal became man, as his departure from that great class of mammals seems to have been very gradual.

It is hard to think of a head hunter of Borneo as a man, if man was made in the image of his Maker. It would seem like sacrilege. It is much easier and more satisfactory to think of him as an extension of the higher mammalian types under the direction of the original Fiat.

SEX.

Sex is probably the greatest character of life. It is an undefinable, recognizable, interchangeable state which has been responsible for the continuation of animal life. Taking its rise in the protozoa in which reproduction is effected by conjugation, it is practically coeval with life itself. The words male and female are convenient terms to call attention to a certain difference existing between animals which is, perhaps, as well understood by all animals as by man. In the conjugation of protozoa it is not only two cells which unite, but a *certain* two. These two cells recognize the difference between them, which is called sex. It is not two male or two female cells which unite, but a male and a female cell, so that sex was recognized about as well by the protozoa as it is now by the later vertebrates, and no great change has occurred in the plan of reproduction: it is still a fusion of two cells. How it is recognized by the protozoa is, perhaps, no more difficult to explain than how it is recognized by the later animals.

SEX IS INTERCHANGEABLE.

In the Supplement of "Science" of December 8, 1922, may be found the following article on changes in sex, as observed in the edible oyster:

"OYSTERS CHANGE SEX THREE TIMES A YEAR."

"The remarkable and long-disputed changes in the sex of the edible oyster are settled by the researches of Dr. J. H. Orton, of the British Marine Biological Association at Plymouth, and Dr. R. Sparck of the Danish Biological Station at Dimfjord. Working independently, both of these naturalists announced that these bivalves may be male, then female, then male again, all in one year. The rate of change, Dr. Sparck believes, depends largely upon the temperature of the water.

"The oyster either never has possessed or more probably has discarded all trappings of sex. There is a single genital gland and a single duct. At one time male cells were produced and discharged into the sea-water in clouds. At another time, egg cells are produced and are fertilized by male cells drawn in from the surrounding water. There is no difference in the external appearance of the oyster in its male and female phases, although if the shells be opened, microscopical examination of the sexual gland shows the difference between mobile sperm cells and the large inactive egg cells. When it is sexually mature for the first time, the oyster is male. Next after a varying period, it becomes female, and very soon after the discharge of the embryos it again begins to liberate male cells. One oyster has been known to change three times in a single season. Dr. Sparck, however, thinks that the duration of the male stage depends upon the temperature. The colder it is, the longer the male stage lasts. The oysters in Southern Europe have been found to begin breeding at an earlier age than those of Northern Europe. Oysters in the northern waters can produce young only every third or fourth year, and therefore only three or four times in their whole life."

Sex has come down through the ages and brought with it a certain kind of impress which has shaped the character of the whole animal kingdom. It has fused together different characters into one and unified them. It has introduced heredity into animal life by the incorporation of a divergent membership. Had the sexual method of reproduction prevailed, the animal kingdom would terminate about as it began. Merging two different characters into one, led the way to different objectives. Both sexes have added their share of influence to the common good of all animals including man, and one can not be considered of more importance than the other. It is in man, however, that we are especially interested, inasmuch as the male has received the larger share of attention. This is probably an impress from the lower vertebrates, in which the male has always been the dominant character. Added to this is the great importance given to the male sex in Genesis, where man was made lord of Creation, and dethroned very early in his reign, by the female sex. The human sexes have made more trouble in the world than any other character of man. They have not been understood by each other. They are two fraternal organizations into each one of which the other does not know the pass-word. When a number of people of both sexes are assembled together, it is not long until the men are grouped in lively conversation, and if a woman approaches the conversation ceases, or turns to some entirely different topic, just as though she had intruded upon sacred ground, or could not grasp the profound arguments in progress. The pronoun "I" has a pleasing sound to the musical ear of man, and if pluralized it loses much of its pleasantness. In marraige the twain are one flesh, but that flesh is his by the sovereign power of primogentiture. The question of the equality of the seves has never been satisfactorily settled, as neither sex is willing to admit the supremacy of the other. Doubtless there is a physical inequality, due to the maternity of woman, which she has received as a legacy from the lower vertebrates. This is the one tremendous act which makes all the female world akin. Man has nothing analogous to it and knows nothing about it. During the reproductive life of the female, she is physically the unequal of the male, but in type of differentiation and stage of development she may be his superior. The biological demand of maternity upon her physical value for the best period of her life reduces her to a lower level in the estimation of the male until, by the consent of both, she becomes, in a way, the unconscious slave of her lord and master. Such sweet words, spoken by his loving wife, are so satisfactory to him that he is only too glad to accept them as explanatory of the real state of woman. Wife and slave had a common origin in the mind of the male. If the question is proposed, Which is the higher level, that of maternity or that of conquest by combat, that of construction or that of destruction, the answer would favor the former unless it were given by the latter. However, the winner in combat, where physical forces are matched, is not always the winner in the struggle of life. Every physician has seen great strong men reduced to the softness of babyhood by a little pain which is of more consequence to them than the labor pains of a whole nation. Man has heard it said that it is a part of a woman's nature to suffer, and he is perfectly willing to accept it as a fact. A division of labor is desirable and necessary in the family, but it should be by common consent of both parties and not by the superior physical force of the stronger. Woman, reduced to servitude, is an obstacle to the advancement of the race, but elevated to the same level as her so-called lord and master, is one of the most powerful agencies in the progress of civilization. Physical strength alone is a failure; it must have some directive power, higher in value than the force itself, and always in control, in order to make it successful.

Now in the study of many bones of the lower vertebrates and man, there were found no variations in type which were known to be due to sex. The type values were the same in both seves. There is, therefore, in differentiation, or development, no reason for thinking that woman has been, or is, inferior to man, if we take bone as a measure of development. One has no higher type than the other. It may be true that man has a greater volume of bone than woman, but this is merely an excess of inorganic salts. The supposed inferiority of woman depends upon the fact that man has written her history. There do not seem to have been any woman writers in the Bible, which added a considerable degree of conceit and self-importance to the glorified image of the Creator.

This has been a man's world. Created first, in Sacred Writ, man became conceited on the pure assumption that the first was the best. The unwritten work of woman has had as much to do with the advancement of the race as the work of man which has been written. Installed as lord of creation by himself, he looks out upon a world which is his by divine right. This divine right so long in his possession is being disputed at the present time. Now very often it has happened, in the history of marriage, which is supposed to be a solvent of difficulties, that a woman's judgment, or conception of a difficult situation has saved a man from the ignominous disaster which his own conceit has drawn him into and yet, if it were a matter of public opinion, how very, very often she has been buried out of sight by the verbal and written accounts of the affair. She furnished the brains that he displayed as his own, and took the credit of the successful issue or took the blame of failure.

We would hardly expect to find any bone type differences in the sexes, since sex, as a character of animal life, has not changed, from the beginning. It may be considered as a primordial cause of animal variations, and hence unchangeable. It accounts for perpetuation by the same primitive means as were employed in the first place. Its mission terminates as soon as this has been accomplished. We do not recognize different sex levels. There are not the male and female sexes for each class of vertebrate, but the same two sexes for all vertebrates. The transmission of sex characters from one vertebrate to another is a biological extension equivalent to the extension of life itself.

Thus we see in man unconscious and conscious expenditures of energy representing in comprehensiveness the whole vertebrate series and appearing in the form of conscious and unconscious labor. The conflict between the two has been the principal cause of the foregoing social classes. Unconscious labor is as old as life itself, or millions of years, and conscious labor is as old as human industries, or thousands of years. The transformation of the former to the latter could not be accomplished suddenly, but slowly and gradually, as the adaptive power of protoplasm would admit. The dawn of intelligence was the day-break of conscious labor. The days of the Piltdown or Heidelburg man were, perhaps, the earliest days of human industry, when labor was induced by purpose. The purpose and tools of such an industry were crude and simple, and the objects produced were on the same level. If this were three hundred thousand years ago, as some suppose, the time since that period has not been long enough for protoplasm to adapt itself harmoniously to the present higher level. The unlaboring and laboring classes of humanity are the natural division of man dependent upon the values which his degree of differentiation is able to establish. After conscious labor was instituted, at the cost of a long struggle, a fair estimate of its value was very difficult to understand, and this became a most important barrier to progress. Human advancement has not been one uninterrupted ascent from the beginning to the present time, but a long series of successes and failures, the successes, on the whole, exceeding the failures.

The most significant act of conscious labor was the digging of the first grave for the burial of the dead man, and the placing of articles therein for use in a future life; for here began man's belief in a future existence. Obviously, the thought of a future life belongs to a higher level of intelligence than to no thought at all, or a belief in annihilation at death. If civilized man, with his intelligence, believes in annihilation, he is not as fortunate as the Neanderthal man of fifty thousand years ago, who believed that he would live again, or the flower of the field which lives again after death, and without the worries of intelligence. If the Neanderthal man first began to bury his dead with the thought of a future life, he was the first to indicate, by this act, his departure from the animal life which preceded him. He had no evidence, traditional or otherwise, upon which to base his belief. He may have derived it from his observations of the vegetable world and even if this were the source of his new and remarkable thought, he was the first to be conscious of it. The new and beautiful life of Spring, which followed the passing life of Fall and Winter, may have been the starting-point of his belief. Comparing the life of the plant which each year passed away and each year burst forth into a new existence, with the life of man, it may have occurred to him that what was true of the plant might also be true of man. Here again a life of consciousness may have learned a most important lesson from a life of unconsciousness.

Different beliefs concerning death and the future life prevail at the present day, as might be expected. There are some who believe in a future life and others who believe in utter annihilation at death. All have not received the same instruction or inspiration. Both seem to be equally convinced that they are right; of course both can not be. How could such diametrically opposed thoughts find a place in the minds of men if they had the same degree of differentiation and stage of development? Or, if differentiation and development had nothing to do with these thoughts, whence came they, and why in opposites? The inference is that they did not come from the same degree of differentiation and stage of development, but from different degrees of differentiation and different stages of development and this is expected from the histological variations which are known to exist and which have different values. In these days the conscious world is demanding evidences upon which to establish a satisfactory belief concerning a future life which, after all, is uppermost in human thought. Maybe it looks too far and in the wrong direction. The evidences are within us and can not be located, analyzed or described, any more than hope or love.

Death is the beginning of a new life; we must not look for that which is to be with the eyes of protoplasm. There is no evidence of tomorrow which is visible, but we believe that there will be a tomorrow, because we know that the earth revolves on an axis. There may be no evidence of a future life, but we believe that there will be because we know something of the cycles and orbits of life. We may have lived before this life, and begun a cycle which is not yet completed.

MEMORIES OF THE VERTEBRATE AGE.

Whence come all our traits of character? If man is an extension of the bone stem of the vertebrate series, and the various classes of vertebrates are outcroppings of periodic, cumulative, biological forces, operating along the course of that stem, it is difficult to conceive of these outcroppings as independent, isolated groups of vertebrate life, separated by impassable barriers. On the contrary, the very fact of a continuous stem would imply an extension of character, as well as differentiations, from one outcropping to another. Such characters would then become indices of the impresses which were derived from each outcropping, and, finally were summed up as a final development in the last culmination, or man. Such a relation might easily be expected to establish, by an act of thought reversion, memories of former existences. Transmissions forward of impresses, by the very nature of those transmissions, imply psychic reversions backward or memories as long as the uniting medium remains. If, now, man is a developmental total of the impresses of all of the foregoing outcroppings or classes of vertebrates, this total would include each class impress, as a whole includes its parts, and must, therefore, in a biological sense, be conscious of those impresses or parts; that is, man would be in possession of the memories of the vertebrate age and be able to recall, perhaps, subconsciously, some character, or characters, of a former existence, which then become familiar to him. There are some persons who have a feeling that they have lived before. They know not when, where, or in what form. They have a sense of the extension or the continuation of life, rather than a sense of an interrupted series of lives. So far is this carried in some persons that they will not willingly kill any form of life, fearful that they might be destroying some ancestral character in which they have an especial pride.

There are many other persons who delight in ancestor worship, as long as they are not obliged to include any of the lower vertebrates among their ancestors, because they may, by chance, be able to trace their own virtues back to a remote, and perhaps royal stock. They are not at all inclined to allow that their own particular characters were created at birth, but prefer to think that they were extended along a bond of union reaching far back into an honorable past, and which had never been severed. Our family trees are very concise records of certain individuals whom we like to trace back as far as we can, both in form and attribute, and if we examine their traits of character as we go along, without prejudice, we are drawn backward, beyond the dim boundaries of human life, before we are aware that we are among the lower vertebrates.

Animal attributes have a common foundation which was laid at the beginning of animal existence, as, for example, the love of offspring, which is no more an attribute of man than of the lower vertebrates, and can not be distinguished from that of the lower vertebrates, and if we try to trace its origin backward, we certainly could not stop at the beginning of the human family, and if we should continue our search we would be unconsciously carried into the remotest period of vertebrate life, and even there we would be obliged to look across the boundary into the invertebrate kingdom.

Motherhood did not begin with man, mammal, bird, reptile or fish, and the peculiar characters that belong to it do not essentially differ in their fundamental values. Why, then, should we suppose that man was a separate and distinct creation and not an extension along the stem of which he is an outcropping? In the comparative histology of this bone stem, there was not found a break in continuity, but on the contrary there were found distinct evidences of an orderly succession of differentiations, distinguished by the many type combinations, and these appeared without reference to function or environment. The same is true of the general traits of character or attributes. Nutrition, growth, reproduction, and the traits of character developed during the exercise of these attributes are fundamentally the same along the whole course of the bone stem. It is, therefore, more satisfying to our investigating minds to think of the vertebrate series as a collective unit composed of many individuals, each individual having received indelible impresses along the course of his development, which become memories of the whole vertebrate age through which he has passed, the validity of the memory, in any case, being proportional to the intensity of an impress.

The unconscious flower lives and dies and lives again, involving a few months of time; conscious man lives and dies and lives again, involving aeons of time. What is the difference? One is no more remarkable than the other. If we could converge all of our desires, ambitions, thoughts and hopes upon a single point, that point would mark the entrance to another life, which would be a higher form of life than the present one.

Now, we may ask how all this is concerned with bone levels, and what possible connection can there be between bone structure and character.

Both questions may be answered by saying: bone is a measure of development and upon the higher stages of development depend the high characters of life. We have seen that bone levels are found at the stations of advancement in bone history, and that the lowest and highest bone levels are found together with the lowest and highest stages of development, and also that the lowest and highest stages of development are found with the lowest and highest degrees of character and intelligence. Furthermore, it was found that intermediate levels are coincident with intermediate degrees of character and intelligence, taking intelligence as a standard of character. In short, bone differentiation may be taken as a measure of development and the measure of development may be taken as a measure of intelligence, which is a measure of character. If we take the conception of a future life as the first great conception of man, that man must have advanced in type of differentiation and stage of development, beyond the type of any other animal, that is, to the new type of soul man which had not existed before. From all we know of the amphibian, reptilian, bird or mammalian levels, such a conception was impossible. It did not begin with human history, but in the course of human history, somewhere between Pithecanthropus and modern man, possibly in Neanderthal man. If we take Industry, Religion, Art and Science as the stairway leading from the lower vertebrate to modern man, and Pithecanthropus, Heidelburg man, Neanderthal man and the Cro-Magnon man as four development elevations of man as he ascended the stairway, we find Pithecanthropus on the first stair as an animal, the Heidelburg man on the second stair as an animal capable of Industry, the Neanderthal man on the third stair as an animal capable of Industry, Religion and Art, and the Cro-Magnon man on the fourth stair as an animal capable of Industry, Religion, Art and Science. The ascent of this stairway has occupied five hundred thousand years, according to some paleontologists. The dawn of the soul man was the dawn of the spiritualized animal, which was the first animal who had a conception of a future life as expressed in the burial of his dead and the food and utensils in the grave. Here was the birth of religion and the soul. This required a higher and more advanced type of structural differentiation and a higher stage of development than any that had preceded it. The soul man never spoke from the amphibian level, or buried his dead from any unspiritualized level.

Thus the history of conscious labor is the history of man's advancement. It gradually introduced into his life Industry, Religion, Art and Science (in the order mentioned) and separated him forever from his unconscious antecedents. As we look at man today, after thousands of years of experience, nothing new is being added to this quadruplex armamentarium of human life. Man is simply working out more perfectly the details of each, according to his likes and dislikes. If Industry, Religion, Art and Science could be personified and given tongues, each one would speak one language, in all ages and in all places. Man alone understands that language, and understands it in proportion to his intelligence and as his intelligence varies according to his degree of differentiation, and stage of development, his results are thrown into confusion by his bungling interpretations.

The aggregate of the above classes, and the results of their labors constitute what is called civilization. The human race has had many rises and falls, or culminations and reversions, or civilizations and their downfall. Each civilization was on a higher level than the one before it. It was the index of the stage of development of man. Old civilizations have passed away, leaving their impresses on modern civilization. They were achieved by subjugation. A few leaders constructed monuments for personal glory by dominating the masses. Such civilization can not last.

The general conception of a higher level of man in all of his aspirations is, or should be, the basis of a true civilization. It is too soon to expect this. Man is still too near his animal source to accomplish it. Altruism is in process of formation only. The passing of one race and the coming of another, with an extension and preservation of the higher, selected impresses, is the necessary course to be followed. A few can not build up a civilization which the majority do not want and are ever ready to tear down as soon as the opportunity is presented. Civilization must have a common purpose, based on the good of all and not the few. The suppression of idealism and the elevation of realism may erect an idol of gold which will sway the ignorant world with its grandeur for a time, but such a civilization will fall of its own weight.

THE FUTURE OF MAN AS INDICATED BY BONE LEVELS.

Man is unfinished. The low type combinations of bone show this. However, the many variations found in this bone structure indicate that some directive force is in operation, and it must be supposed that that force is made directive by several causes, which had a remote origin. A variable product means the presence of variable factors and in the bone history of man, variability has been the rule.

We are familiar with infancy, childhood, youth, maturity and age, and recognize them by the phenomena which they present at intervals of time. Each one of these stages of development seems to be struggling to declare itself by means of some power within, which can be understood and recognizd. We can also conceive of that which might be called phylogenetic infancy, childhood, youth, maturity and age, by closely observing the different classes of vertebrates, as they march in one long unbroken line from the Silurian to the present age. Each one of these stations of phylogenetic development is likewise struggling to declare itself by some power within, which is constant, progressive, and which can be understood and recognized. There seems to be little doubt that each one of these phylogenetic stations has reached a higher level than the one before it. As we have already seen, structures and the phenomena which they present are inseparable, and changing the structure changes the phenomena.

Now the value of the changeable structures in bone depends upon two ancestral causes, one remote, phylogenetic, and the other immediate, ontogenetic, and these, in turn, depend upon the phylogenetic history of the class of vertebrates from which it sprung, and with which it is most closely identified. We can not suppose that the union of two factors exactly alike would, in any way, change the character of the original sum from which those factors were derived; but we must suppose that the union of two unlike factors will produce a sum of higher or lower valuation depending upon the dominant factor. From opinions which we are able to form during the study of cell-division after fertilization, we feel confident that two exactly similar causes of cell-division, viz., two exactly similar germ and sperm cells, have never existed and therefore two exactly similar individuals were never born. The affairs of the chromosomes are still beyond our reach and comprehension. Their actual union has not been observed. All we know is that they have united and even then we can not explain just what we mean by the union of chromosomes which we talk about so freely. Chemistry and physics do not seem to show separate and distinct evidence of one state of protoplasm, but of two,—one comprising the chemical elements employed, and the other indicating the directive force. This again introduces sex as the saving power in the perpetuation of similars or dissimilars, in the elevation of one development above another, in the establishment of levels and in the escape of desirable strains from extinction. It does not seem to be possible for any force to maintain itself indefinitely. The whole universe is running down, at least so we are told by physicists who have already forecasted the date of the probable failure of the Sun to support life on earth. There are cycles of activities and inactivities in all things; some are long and others are short. There is a rise, culmination and extinction of all living animals, and our lives are not long enough to fully understand or comprehend the true values of these periods in the scheme of life. To live is to lose, and if we would maintain a constant state of life we must add something to counter-balance the loss sustained by the demands of time. If the water of a mill is low, and the wheels or terminals of actions are moving slowly, we must add more water or the mill will stop; so if the vital force of an animal is running down, some additional power must be applied or it will become extinct. This is the primary object of sex, which introduces a new power between senescence and death, and rejuvenates cell life. The protoplasmic molecule is large and complex and fails during the stress of chemical changes. If we suppose that it contains one thousand atoms and during its chemical activities it loses one hundred of them, the remaining nine hundred would still be protoplasm, but not the same protoplasm; it could not represent the same amount of energy as the original one thousand atoms. Its phenomena would be like the original, but not precisely the same. This is senescence or the running down of protoplasm ,and is the fate of all living cells, unless prevented by sex, which adds new energy to the failing cells. As we have seen before, there are two protecting forces in operation in sex, which account for the continuation of cell life; one is phylogenetic and the other ontogenetic. The combined action of the two is essential. The phylogenetic force projects the basic characters from remote ages, through the agency of an unbroken medium which extends from one end of life to the other and by means of subtractions and additions gradually tends toward higher and higher levels; while the ontogenetic modifies these characters by the local influences of sex.

Cell division is essential to the continuation of life. There is no satisfactory explanation of it. A cell fearlessly allows itself to be divided into two parts, for the purpose of self-preservation. It is a property of unconscious protoplasm, for a conscious protoplasm would not dare to attempt it. It is as old as life itself and as undefinable. To account for the different forms of life today we are obliged to assume the constant presence of some directive, projective power operating upon protoplasm, which gives it an onward and upward tendency that is independent of individual interference. This may have been the original Creative Power, or, as we like to speak of it, the power of phylogeny; while the ontogenetic power of recapitulation adds the special characters of immediate ancestors by which the individual is recognized.

The Creative Power was sent through a vast series of vertebrate similars from beginning to end, producing phyla in regular order. It is in this sense that the different classes of animals are creations. Ontogeny has no explanation except in terms of phyongeny, and therefore is a creation.

Man that is born comes to earth from antiquity through the intervention of sex, and brings with him the conflicting impresses of the ages. In spite of all of its variations, human nature still remains the same, because its origin is the same. It is fundamentally unchangeable. Infancy, childhood, youth, maturity and old age are about the same the world over; pathological changes are about the same; conception, foetal life, birth, growth, development and death are about the same. The orderly differentiation of one structure from another and the corresponding development of one state or level from another, form a concept of man. If he could see himself through a reducing lens, applied to the whole vertebrate series, he would be able to understand much more clearly his complex nature. The most important of all of his characters, sex, has a phylogenetic origin. He can not change it. It is indeed strange that the sexes should be so equally divided and still more strange that they should remain so. Embryonic life is life among the ages. Man may be fashioned in the uterus but the materials of which he is made and the characters which he displays had their origin in the universe of substance. Whether or not a creature shall swim, fly, walk or think was decided millions of years ago and a tremendous interval of time has been required to bring it to its present unfinished state.

We do not know what a perfect man is. We have no analysis of perfection which we can make. The best we can do is to take the highest known type of structure and character as a basis and compare others with them. Employing this method in bone observations, it is not difficult to see that man is at present unfinished and that his forecast as a race promises a forward and upward movement. Bone, on account of its inorganic composition and many structural variations, all of which remain unchanged after death, provides a reliable source of the kind of information we are seeking. As we have seen in the foregoing, the highest type of bone is the Third or Haversian System type. There is nothing beyond it in the form of bone differentiation, and therefore it may be taken as the culmination of bone structure. It has also been found that while this type of bone is a frequent type in man and not in the lower vertebrates, it is by no means universally present in him. There is still a large percentage of mixed high and low types to be found which indicate incomplete developments. This being the case, it is clear that if we would establish the Third or highest type as the universal type, we must eliminate the First and Second or the lower types. As types have no power to change themselves and will not undergo a change by a change in evironment, some external force must be employed, and this is found in a selected crossing. There is no form of continuous protoplasmic life; it depends upon cell division. Whether Protozoon or Mētazoon, one-celled or many-celled forms of life, they all have a birth, culmination and death, following therein some law of cycles which is biological and universal in the history of life. There are two methods of cell division which account for the extension of life, viz., the Direct and Indirect. The first is a simple division of the cell into two equal parts and is without adequate explanation. The second is the melting together of two different cells from two individuals and then the division of the result into two equal parts. The former is the method of division of the lower and the latter of the higher forms of life.

It is obvious that the first method is the method of cell continuation, without gain or much loss, while the second is the method of gain or loss depending upon the character of the crossing and is the one which it is possible to control by exercising the power of selection in the crossing. The difference between the two methods may be made clearer by an illustration: If a small mass of gold is divided into equal parts, one part is exactly like the other part in composition; nothing is added, nothing is subtracted. This illustrates the first method, and merely accounts for the continuation, as there is no reason why a variation should follow the mechanical division of a single substance into two equal parts. On the other hand, if a small mass of gold and an equal mass of copper are melted together, the resulting mass is gold and copper, so fused together as to be beyond visual recognition. It is a new and different substance, with the mingled properties of both metals. Now if we divide this mass into equal parts, each part will be composed of two different metals in equal proportions. If, instead of two equal masses of gold and copper, one part of gold and two of copper are fused together, the result will be a gold-copper mass in which copper is the dominant metal. This illustrates the second method of cell division. It is the addition of two unlike substances and the division of the sum into parts, each part having the properties of both. By this method the latent forces of variation, or, as it is called, Heredity, are established and made the controlling agencies in the continuations of similars. It is evident that by the proper selection of the original substances, almost any result may be obtained. In early cell life, this is the idea which underlies a selected crossing. In a true crossing, one cell can not be crossed by another which is exactly like it, as the result is not changed. In a selected crossing, two cells from two different individuals must be fused together and then the variation in the result will depend upon the desired object indicated in the act of selection. It places within reach a power to control biological results. Such a power is not possible with the first method of cell division. We could multiply one into itself any number of times and change nothing or we could add gold to gold, divide and add again and again divide, and change nothing excepting the volume; but if we add gold and copper, divide and add again, we have produced a variation which can never be wholly eliminated. We may therefore look upon the second method of cell division as the beginning of a new era in animal life.

Evidently the possibility of crossing in animals may be conditioned by circumstances, for example, the migratory character, too great differences in relative sizes, differences in species, differences in the numbers of chromosomes of their germ and sperm cells.

Once a crossing has occurred it is practically impossible to eliminate all traces of it from the following line of successors, at least for a very long period of time. As may be seen by referring again to the gold-copper mass, it is clear enough that no number of arithmetical divisions of the mass will entirely eliminate either metal; there will always be a remainder. So, for the same reason, no number of cell divisions will entirely eliminate a strain which has once been incorporated into a cell by crossing with another and different cell. The unexpected frequently happens in cross-breeding. Sports, freaks, recessives, are terms which refer to the unexpected occurrence of an unusual offspring, when it really might be and perhaps ought to be expected whenever the cumulative stress of an ancestral line of impresses, of a particular character, rises to an unusual importance in the affairs of cell life.

Now, all animals are composed of cells, and while the cell of one animal can not be distinguished from the cell of another animal, microspoically or chemically, yet it is possible for the cell mass of an animal to be represented by a single tissue, as, for example, bone which may be taken as a visible index of the degree of differentiation and stage of development of an animal; for example, a cell of the jackass could not be distinguished from a cell of a horse, but the degree of differentiation and stage of development of the cell-mass of the jackass is indicated by the second type bone, while that of the horse is indicated by the second and third type combination—which is a higher bone type than the second by as much as the Haversian System is a higher type bone unit than the lamina. If the second type jackass is crossed with a second and third type horse, the result is a second or second and third type mule, in which the second or third type will predominate, depending upon the selection exercised in the crossing. The value of this type variation is also seen in the reproductive changes presented by these animals; thus, if the mule is the offspring of the mare, and jackass of the dominant second type, the mule will be sterile, but if it is the offspring of the jackass which has been raised to a second and third type combination by a selected crossing and a mare which has also been raised to a dominant third type combination, the mule may be fertile and produce an offspring having the general characters of the horse. Such a result has been derived from selected cross-breeding of these animals. (5) Here is an instance where the most important means of animal extension, viz., reproduction, is made possible in a sterile hybrid by raising the degree of differentiation and stage of development from one level to another by a selected crossing. It is really changing a jackass to the horse by the play of biological points. It is a matter of common observation that vertebrates can be raised from a lower to a higher type or level by selected crossings. This includes man.

Unfortunately, however, we are obliged to derive our knowledge on this point from stock-breeders. People do not like to be compared with animals or stock, and seem to be unwilling to admit that the raising of the type of stock and offspring of man can be accomplished by the application of the same principles. The means which are known to be successful in stock raising are, as a rule, ignored by the human race. It is certainly clear enough that the future of our race must depend upon the strict employment of precisely the same means of raising values in man as are used by stock breeders. If the type of man is raised at all, the lifting power must come from an external source, since type has no lifting power within itself.

We do not seem to care as much about improving ourselves as we care about improving our stock of animals. We hope, in some way, that the original laws which have been in operation in the reproduction of animals from the beginning, will be set to one side in our case and that our First and Third type cells will produce a pure Third type offspring. We do not expect that this will ever happen in other animals, but the protoplasm of man loves itself supremely and strongly objects to being included in the protoplasmic class of animals.

In some quarters of our advanced civilization, the distinction between man and animals is carried to an absurd degree. For example, when man drinks, one verb is used, and when an animal drinks, quite another verb is employed; when man eats, one particular verb is used and when an animal eats a different verb is employed. To such people the comparison of man with an animal is the greatest insult. Detaching himself from the animal kingdom, man was then obliged to rely upon his own resources and, of course, failed. It is just as possible to raise man to a higher type and level as it is any other animal; but he must remember that, in the matter of reproduction he is an animal and the same biological laws will operate in him as in other animals.

The results obtained by crossing are generally dependable. In the first place, no vertebrate can reproduce itself; two are required and these must be fused

(5) Journal of Heredity, Vol. No.

together in a third. If we take the types of bone as indicators of degrees of differentiation and stages of development, we can derive different results by controlling the crossing, with about as much certainty as we can produce different arithmetical products by controlling the factors.

As we look over bone types, it is quite evident that man has not reached the end of his development, since the third, or Haversian System type is not universally present as it is in those individuals who have reached the limit of bone differentiation. He still retains the First bone type as an important part of his bone structure and this must be entirely elimianted before he is released from his anchorage to the lower mammals and takes a position on a higher human level. Man can advance in physical type simply because he is an animal and as he advances, the sphere of his comprehension is enlarged until he looks more clearly beyond the horizon of his former self.

In the crossing of vertebrates, two different types or type combinations are essential in order to secure a result. This is the foundation of the many variations in type and character which are found. If a First type bone crosses with a First type bone, the result is a First type bone; evidently nothing is gained or lost, as this is merely an extension and not strictly a crossing. Adding together two things precisely alike changes the volume, but not the charatcer. It remains for such animals to maintain themselves by extension. Each class of vertebrate has its First type representatives, which ,of course, do not cross, as fish with amphibian, amphibian with reptile, reptile with bird, bird with mammal, or mammal with man. There are important fundamental differences between them which the microscope does not reveal. The First type fish, amphibian, reptile, bird and mammal are introductory evidences of basic principles in each class, which are directed toward higher levels and appear in the form of second and third types or of some combination of these types. The few geological fish levels, viz., shark, gar-pike, bowfin, sea trout, ten pounder, sunfish and muscalonge still retain their structural bone identifications, which is bone substance, lamellae or First type bone. From this stem the present great variety of fish arose. Evidently, if these few families had remained true to type, they would represent the fish of the present time, but somewhere within that small original number were latent factors of variation which gradually worked their way out into higher and higher levels as different species; however, they are all fish and are limited in structural type to the lowest or First bone level. Any crossings of the fish families, therefore, would be followed by no very marked degree of advancement provided a crossing was possible. A new species of fish would arise very slowly, since the converging lines of variation, as seen in bone, for example, are too nearly parallel to focus on a point recognizably different from the source. The fish has a First-type bone and as long as first types unite, the results will remain within the First type level, no matter how long they are continued. It is crossing of unlike types which produces differences in the offspring. It is, perhaps, impossible to tell what a species is, how long a time is required in making it, or when it can be said to be made, and especially is this true as long as it is visualized object. No one has ever seen a species in the act of making. The actual rise of one creature from another is beyond the power of observation and is evidently extremely slow. If the formation of species has been going on during the past ages, there is no reason for supposing that it is not going on now. The trouble is we expect to see it in operation and are disappointed. Furthermore, no one really knows what the making of the species is. If it is merely a group of similars, it would imply the presence of similar operating forces at the beginning working over crude substance into definite variations.

If we could know how or why undifferentiated bone substance becomes lamellae, laminae and Haversian Systems, or what controls the remarkable changes in the circulation, the origin of species might come within the limits of our understanding; but we do not and can not know very much about the changes which we do not and can not see, and are then left to formulate a theory which may be a mental satisfaction rather than fact. In the light of biological studies, we are led to think of progressive, not retrogressive principles, employed in the formulation of a higher from a lower type. We can not think of a lower type arising from a higher since it does not include the biological unit of the higher type. As, for example, a First type bone arising from a Secord or Third. We might as well think of the past arising from the present. But we are satisfied that a higher type may arise from the lower since it includes the biological units of the lower type. If a high reverts to a low type, it was never fully established as a high type; for instance, there is no way by which an Haversian System can become lamellae although it is composed of lamellae. It can not be disorganized without destruction. If the starting point of the vertebrates was the lowest type fish, taking bone as the measure of type, it is difficult to decide which one represents that type, there is so little difference between them, and if it could be decided with accuracy it is still more difficult to decide why this lowest type has not disappeared by evolution into a higher long before this time. We would naturally expect that the lowest type would be replaced by higher types in succession unless it was lost in the ascent. This has not been the case since some representatives of the species still survive. The two limits of bone structure—undifferentiated bone substance and Haversian Systems—also still remain as constructive bone units. The bone substance is represented by the shark and gar-pike of today and as there is nothing less than bone substance that is bone, the fossil fish would show no earlier bone type than the shark or gar-pike. If the fish appeared during the Devonian Age, bone advancement in that class of vertebrates has been extremely slow. Again if we grant that one of the early fish above mentioned was the lowest in type of differentiation, we must assume that it was crossed with a higher type in order to initiate the line of bone advancement with which we are now familiar, and we have no knowledge of such a crossing. We are, therefore, led to think that there was, in the beginning, either a single bone stem of earliest and lowest differentiation which producd higher types by virtue of some inherent, impelling force derived from the original Creative Fiat, or that a low and high type bone came into being at the same time, which suggests a double origin. There is no evidence of the latter. The first of these theories finds support in the advancing differentiations seen in the bone of the human embryo. The First type bone has never been seen in the act of becoming a Second or Third, but in the embryological and early post-natal bone differentiations of man, an animal in which all three types may be found in the adult, the First, Second and Third types may follow each other with such a degree of certainty as to give rise to the conclusion that a Directive, Impelling Force is in operation toward an objective Third Tye culmination. In this case the Directive Force has its beginning in a long line of ancestors, by which we mean, in the converging forces of the whole period of vertebrate history. A bone stem extends from fish to man, forming a continuous, uninterrupted bond of union, and if a force is once started along this material line of transmission, it will continue to the end unless it is interrupted by a gap in the transmitting medium, or by the cessation of the cause of the force.

There has evidently been no gap in the transmitting medium and no cessation of the original force implied in the Creative Fiat and hence there has been no interruption in the passage of this force. Physical man is one of the terminals which was made effective at the beginning of the world and hence he is associated with the First Cause of living substance. Concerning the theory of a double origin, it may be said that the visible structural variations observed in the original fish stem are not sufficiently marked to establish a recognizable low and high type and thereby to lay the foundation of a double origin. The circumference of its cycle does not differ essentially at its various points; it is a small cycle. Knowing the final bone differentiation as it exists in the later mammals and man, it is obvious that the differentiation is just beginning in the class of fishes and that no marked advancement in type has yet been made. In the amphibians, the same conclusion follows a somewhat extended observation. They are all true to the First type, with a slight advance in some of the toads; this slight advance, however, becomes an indicator of further possibilities in bone differentiation as it points toward a higher type and increases our expectations of finding it. In lizards and snakes among reptiles, the same unfinished type is present, with very little evidence of advance. Perhaps, then, the fishes, amphibians, lizards and snakes may be regarded as forming one large cycle. In alligators and turtles, among reptiles, there is a recognizable advance in type, since the second and third types have appeared; however, the incompleteness of these types exhibits an unfinished differentiation and leads us on to further expectations. We are now satisfied that a general development is in progress and that it is shown in the changes which are registered in bone.

In birds we are introduced to a combination of early First, Second and Third types—the Second most prominent. An advance is evident, not only in the type combinations, but also in the degrees of differentiation of the single types. However it is not difficult to see that the bone is unfinished. In bats, among mammals, we seem to find a reversion to the amphibian and lizard type, by losing the Second and Third types which were present in some birds and in turtles and alligators. It is difficult to understand how bats could ever lose these types, if they had ever had them. It is much easier to think that they have never had them, that they are flying reptiles with a placental reproduction. However in fruit-eating bats, (the Pteropus) there is an indication of advance on the presence of the earliest Third type units, which again suggests advancing but unfinished bone differentiation. From monotremes to ungulate, the three types are found in a profusion of combinations and incomplete differentiations. The First type is finished, the Second well advanced and the Third is approaching a higher degree of differentation than has appeared before. It is in the ungulates that the most important differentiations have occurred in mammals. It is here that the second and third types are completed, which is the most important level in bone history. From ungulate to primate the complete Second and Third type combination is the most common type. In the primates the Second type has practically disappeared and there is a return to the Second and Third combination.

If the type of bone meets the functional requirement, it is strange that the Second type should practically disappear in man. The two remaining types, First and Third, singly and in combination, are the prevailing types in all three races, the Black, Yellow-brown and White. In the three races there still remains quite a large percentage of unfinished Third type units, and there is a decided increase in the percentage of complete Third type units in the White race.

Thus we see that no class of vertebrates has reached its final degree of bone differentiation. This unfinished condition, after such a long bone history, may be taken as a basis of prophecy of the progress of bone differentiation of man in the future.

The division of the vertebrate series into fishes, amphibians, reptiles, birds, mammals and man is a convenient way of calling attention to different elevations of structural types along an ascending line of bone differentiation. Such divisions we call classes of animals with about the same degree of accuracy as we have in mind when we think of the twenty-four hours of the day. The day is the time of the revolution of the earth on its axis and man can divide it into parts to suit himself and so doing change nothing. The earth will revolve anyway and requires just so much time in which to complete a revolution. So with the vertebrate classes; they will continue to advance in regular order, no matter how they are divided or what they are called. A certain time will be required in which to complete their structural differentiations and stages of development. When this time has elapsed, man will have reached the completed Third type bone differentiation, and acquired the stage of development which belong to it.

It is impossible to say to what extent checks in development have delayed the advancement of type. In the matter of crossing of types, there are various hindrances which may prevent it. The crossing of vertebrates is a sexual function which has no representation in bone. The prevention of indiscriminate crossing is a wise provision in Nature—otherwise there would be a world of horrid mongrels. Natural antagonism, or war of protoplasm, disproportion in size, numerical variations in the chromosomes of the sperm and germ cells and the neutralizing chemical substances produced by the sum total of the somatic cells—all work towards the prevention of indiscriminate crossing and tend to establish physiological unity which is an essential to a successful crossing.

It is necessary that animals be within equal spheres of development before the union of two individuals can or will be accomplished. Sex seems to be a peculiar endowment of protoplasm for the purpose of its continuation and links the past to the present and the present to the future by a promise which does not fail. It keeps the animated world moving toward an objective by installing the steps of an ascending stairway, which may be called stations, or levels.

Our interest here largely centers in man, and the future of man as indicated by these stations or levels, as they are seen in bone. In the first place, as we have already seen, different bone levels exist in man at the present time, otherwise he has reached his limit of differentiation. These levels are indicated by structural heights. The possibility of reducing these levels of different degrees of differentiation to one and raising that one to a developmental limit, by means of sex and a selected crossing, is the foundation of his future state. If we take bone differentiation as the indicator of the stage of the development of man, neither one of the three races—Black, Yellow-brown or White—has reached its culmination. They are all racially in an unfinished state. Herein lies our great hope for our future. If man is finished now he is a failure. Not one of the three races has arrived at the Third or Haversian System type of differentiation, even at this late date in bone history. They all have the First, Second, early and late Third differentiations or types, although the proportion of these types are not the same in all; for instance, the Black race has 71% of unfinished types (by unfinished types are understood the First, Second and early Third); the Yellow-brown has 82% of unfinished types and the White race has 50% of unfinished types. The race as a whole has 75% of unfinished types, that is, after a half million years of human history and unselected crossing, only 25% of the human race has lost its lower animal or unfinished bone types, and acquired the finished Third type, which is the culmination of bone differentiation. This, of course, does not necessarily apply to the population of the world, as only a small part of it has been examined. It simply applies to a collection of human bones taken at random and answers the purpose of a general indication.

Now if 75% of the human race is still unfinished in bone type, as a result of an unselected crossing, a reasonable inference is that this percentage could be rapidly decreased by the exercise of a selected crossing. The raising of types without selection is extremely slow, as might be expected and as shown by the above percentages. It is by no means the case that advancing types in man follow an uninterrupted line of ascent, or are even able to maintain a constant type which they have reached by a sudden crossing. The checks which are instrumental in causing modifications and delays in development are pathological and physiological; the former are insanity, syphilis, tuberculosis and malignant tumors; the latter are the sucessive unions of type equivalents or equals. The more closely two individuals, for example, approach each other in the degree of differentiation and stage of development, as may be the case with close blood relationships, the more slowly the type of the offspring will be raised and the more readily it will yield to the processes or degeneration, for its tendency is to run down unless reinforced by external power.

The most common bone structure in man is the First and Third type combination, while the least common is the pure finished Third. In the bones of the First and Third type combination there are about as many different proportions of the single types lamellae and Haversian Systems as there bones examined, that is, there are no two of them precisely alike.

If a First and Third type is crossed with First and Third, the result will be a First and Third—the one or the other predominating depending upon the dominant type in the immediate or Mendelian ancestor. In this case the result might be a slight rise or fall in type. The same or a similar result would follow the crossing of the First, Second and Third type combinations, that is, the result would be a First, Second and Third, one or the other predominating. If a First and Third type combination is crossed with a pure Third type, the type of the offspring may be raised by a replacement of the First with a Third type unit, the higher type unit assuming the dominant character, by virtue of its more advanced organization. If this could be continued for many generations the lower types could be gradually eliminated and the higher types installed in their places. The future of our race, therefore, will depend upon the exercise of this natural right of being well born. In animals we call it stock-breeding, in man eugenics.

The question may be asked here, how can we make a selection in the crossing? How can we know what types are crossing, as we can not examine the bone microscopically, to determine types?

Type values may be estimated by their displayed characters. We have already seen that bone types represent stages or levels of development and that these may be known by the social characters which are presented by individuals. We have no difficulty, as a rule, in recognizing the higher levels of society by a study of its members. We are familiar with those traits of character which belong to the more advanced classes of society, if we take the degree of intelligence as the basis of judgment. Type represent development, and development indicates type; we may, therefore, make use of the stage of development in the selection of type. If we select those individuals in whom the traits of high character abound, we can be fairly certain of our results, barring Mendelian exceptions.

Sex has so long held the power of selection that we have been blinded by its irresistible allurements. The beauty and attractiveness of the female sex has been the most powerful influence in the world in controlling and shaping the types of man. Left to itself, it is a protoplasmic failure in its attempt to raise the stage of development; it may improve the type of beauty, but beauty has not raised our standard of intelligence or morals. It has been a check to advancement. The beautiful eyes of high character are not the eyes of material beauty. Our civilization has not been built of rainbows. Venus and Adonis built no enduring monument excepting in the making of themselves.

There is another serious check to the advancement of type due to a pathological condition or a too rapid rise in the elevation of type and that is senility. A full quota of time for each stage of development is absolutely necessary. It can not be reduced without sacrifice. Senility is found mostly in Third type bones, or in the bones of man. As stated above, it is the precipitation of inorganic salts in the lamellae around the Haversian Canals of the Haversian Systems. One by one the lamellae disappear until a narrow black ring is all that is left of the Haversian System.

During the microscopical examination of a large number of bones of the lower vertebrates and man (1300) senility was rarely found in the lower vertebrates but frequently in man, and more especially in the white race, as may be seen from the following percentages:

Senility was found in 38% of the Black race.

Senility was found in 18% of the Yellow-brown race.

Senility was found in 78% of the White race.

The ageing process is not a matter of years, but of checks or of interference in development. In the lower vertebrates it is not easy to determine when they reach the adult age, or the age when senility might be expected. It was found in the bone of two-toed sloth and of a mule, (age of both unknown). In man it was found in a bone 35 years of age.

From the above percentages it may be seen that senility is very low in the lower vertebrates and very high in man; that it was lowest in the Yellow-brown race, highest in the White race and intermediate in the Black race.

If, now, we arrange our findings of type and senility in man according to their comparative values, we find that the White race is highest in type and highest in the degree of senility; that the Yellow-brown race is next below the White in type and lowest in the degree of senility; that the Black race is lowest in type and next below the White in the degree of senility; that is, the arrangement of the races of man by type would be, White, Yellow-brown and Black; by senility, White, Black and Yellow-brown. From this we see that the highest type bone first becomes senile, which is an unfavorable outlook for the White race. There is nothing beyond the Haversian System in bone type, and a species has reached its limit when it has the Third type bone differentiation. How long it will maintain this type will depend upon the value of the force employed in establishing that type. There is, evidently, a difference in these values. A third type bone, or individual, of tubercular or malignant tumor history as a partial lifting power in development will maintain its elevation for a short time and then gradually fall to a lower level in the stress of life. A bone raised too rapidly to the Third type by the character of the crossing seems to have exhausted its capitol stock in the raising and left no reserve with which to mainain its upkeep and soon yields to the senile process; such individuals are born old. A bone which has been slowly and gradually raised to the third type by successive generations which have a normal lifting power behind them, go slowly and steadily onward with a reserve capital stock of energy sufficient to maintain it and even to increase its operating power until it is 60, 70 or more years of age, and may close its career with a surprising hold on life. Such a bone is the ideal bone and is possible by the exercise of an intelligent selection. On account of the more rapid rise toward culmination, which we have seen is indicated in its bone types, the White race has been the dominant race for a long time, (as man counts time), and quite naturally expects to hold that position indefinitely; but this is not in accord with the general biological law. There is no form of life which is able to maintain itself for an indefinite period without suffering a loss and falling below the level which it has struggled to reach. Having reached the top of the hill, there is only one way to go. The appalling conceit, together with other undesirable characters which go with it, acquired during the dominant reign of the White race, and which has lifted it rapidly to an imaginary high level, will as rapidly induce its downfall. Frequent wars, small percentage of reproduction, inordinate wealth, luxury, indolence and their results, diseases and faulty developments are undermining the foundations of the White race and it will not be long before it will be obliged to turn its head and look at the rapid strides which its Yellow-brown and Black brothers are making by the strict observance of the very principles which it is ignoring.

We have no satisfactory understanding of biological cycles which abound in the biographies of living things. The birth, rise, culmination, death, or the bud, blossom, fruit, seed, are cycles which come within our limited experiences; the greater cycles of classes, orders, genera, species, and the grandest of all, cycles of the heavenly bodies, stagger us as we attempt to think of them. The White race is completing its orbit.

If, now, we can read our declining history in the senile decadence of our bones, is there any possible way to check it or even to defer it, Man does not live long enough to have an adequate conception of his race. His period of activity is extremely short and his grasp of cycles is extremely feeble. He may look into the heavens, but he cannot conceive of the planetry or starry cycles; he may look at the living kingdoms of Earth, but he cannot conceive of the invertebrate and vertebrate cycles. He may look into the past life of man, may see his cycles of activity and inactivity, rise, culmination and fall, and yet fail to realize that it concerns him. There is no reason to suppose that these lesser cycles can or ought to be checked any more than there is reason to think that the collision of two dead worlds in space, followed by a new, living world, can or ought to be checked. We have no knowledge of life excepting it be by cycles. We compare our great cycles with the cycles of the heavenly bodies. When our solar system came into new life by the collision of dead worlds, the chemical elements of which we are composed were present and were engaged in the collision. The elements of all living things were there in that awful catastrophe, uncombined and in an incandescent state. Out of that fiery cauldron there emerged, during millions of years, the plant, the animal man. What, then, can he expect to do to check, or to change, such a plan as this? Without trying to effect any change or checks, he will probably conclude to conform to the inevitable course of things and do the best he can do to perpetuate the most desirable characters of his race.

We do not know what it is to be unborn, we do not know what it is to be alive, we do not know what it is to be dead, and to prevent our mental disintegration over such thoughts, we conclude that we began with the origin of worlds, and have been passing on from one estate to another, coming into consciousness now and then, long enough to declare ourselves and then passing on to other estates, in accordance with the great cycle plan of creation. It is not our business to know what it is all for. During the passing of our life, along the pathway of the ages, of which our present journey is a part, it is impossible now to protect it from destructive influences and defer its premature ending by agencies which are largely within our control; the rise of protoplasm to a higher level is possible through a selected crossing.

Why should these few brief years, which are ours now, decide our fate forever and especially when our association with protoplasm derived from ages of chemical constructions, disintegrations and reconstructions has entangled us in a warfare from which we are struggling to extricate ourselves?

We are familiar with the terms good and bad. If protoplasm is the means of our continuation in our present form, we must employ those agencies which ensure its highest stage of development. While we ourselves have nothing to say regarding our birth some one has, and it becomes the solemn duty of the responsible persons to see to it that we are well born, that we are endowed with a capital stock of energy sufficient to carry us through the average term of years of action. This is selfishness, but selfishness is the property of protoplasm. While we are willing to admit that we have the right to be well born, we are also willing to ignore the baneful influences of ancestry and allow the formation and birth of a new and helpless creature to come into an opposing world unprepared to cope with its antagonistic environment.

The power of choice does not reside in the unborn, and when the child is born it brings with it the good and bad and not the good alone, as we would like to think. Its whole life is impregnated with the strains of ancestral characters which it has no power to change. We speak of the new-born babe as pure and seem to be forgetful of the fact that it came from those that we are just as ready to call impure. It is entirely in accordance with reason, common sense and fact to conclude that as the ancestors are, so the child will be, and by ancestors we mean the immediate and Mendelian. Oftentimes the Mendelian strains rescue a child from complete failure and make a genius of him. We have no reason for thinking that First and Third type parents will produce a Third type child, since we can not estimate the value of the Mendelian strains in any case, but we hope that somehow, during its formative period, it will abandon its First type heritage and cling to the Third. Who knows anything about his recessive characters, whether they are good or bad, until they appear in a child and then we are often surprised. The division of mankind into a low and high type, into slave and master, into follower and leader, has not been obliterated during its whole history. The state of the White race, as suggested by its bone type, is nearer its highest level than that of the Yellow-brown or Black races and also nearer its descent through the gateway of senility or faulty development. While such a descent can not be avoided on the basis of cycles, it can be delayed by carefully selected crossing, or the principles of Eugenics. Granting that this is true, how can it be made an effectual factor in human affairs? Obviously the improvement rests with the unborn, and the unborn with the selected crossing. Marriage is the garden-spot of posterity. It must be cultivated by intelligence and not left to the mercy of accidental conditions if it is expected to produce the best results. The union of two people is too often based upon sex and ignorance, re-enforced by false statements made to each other. Human pride is not willing to concede the differences in level, which exist between them, but the child which is born holds up the fatal mirror before them in which false picturing of pre-nuptial state is plainly visible.

It is a difficult matter for two lovers to tell the truth about their origin. They like to go back into the past and hunt up the honorable stock from which they came, but they do not go far enough, they get as near royalty as they can and leave the rest to be inferred from a look or gesture. Infatuated by each other's charms, they plunge into an unknown abyss, at the bottom of which they recover their senses and then do the best they can to conceal the humiliating error they have made. If we could tell the truth before marriage, we would not have so much to fight about after marriage. How often we see the rosy tints of sunrise fade at noon and disappear at sunset. We try to be better than we really are by origin and make a failure of it. As we become wealthy and prosperous our child leaps to a high level only to become a pitiable object to those who know the truth. Wealth can not raise a First and Third to a Third type bone. We are a race of unequals. Our social classes are evidences of it. Our schools are filled with students of both types and a teacher is supposed to turn out a common product, which is absurd. Our industries, religions, art, do not represent the same level of development. They all present the complex problems of inequality.

How can such a state of affairs be changed for the better? By Eugenics and education. Elevate the level of development, by selected crossing and then educate the young. Eugenics offers to solve the problems of the unfit; it offers to eliminate the undesirable and to perpetuate the desirable. The people, the Church and the educational institutions must thoroughly believe that it is better to be well born than illy born; that there is a way to accomplish the former and to avoid the latter and then set themselves to work to do what they know they ought to do, to raise the lower to the higher types of differentiation and stages of development.

Thus we are able to see, in the histological variations in bone, the present unfinished state of man, after all these years of differentiation and development and can, furthermore, form some idea of the possible methods of raising these unfinished types and of lifting man to a higher level. Bone is the only visible measure of development we have and, as it tells us what has been accomplished in the past, we are better prepared to provide for the future. If we control future types by the exercise of a higher degree of intelligence and selected crossings we can eliminate undesirable type combinations, establish Third type levels and higher stages of development.

Bone as a measurement of development, therefore, indicates that man has the power to control his own destiny, if he chooses to exercise it, and points the way to a better future of the race.

Thus, Bone is the only visible measure of development of animal or man within our reach. It tells us what we are, where we are in the vertebrate series and what we may be. It is difficult to distinguish all grades of development by the observation of different characters or attributes presented by different individuals, since the differences between them may be too small to be recognized as differences. While man is willing to be called an animal, he is unwilling to be classed with them, although he knows that he exhibits the very characters or attributes which belong to them.

If we ask the question: Are we made of better stuff than the lower vertebrates, are some of us made of better stuff than others, we have an affirmative answer in bone as a measure of development. While all vertebrates are reducible to the same chemical elements by heat or decomposition and there is no way of knowing one carbon atom from another or the nitrogen atom of man from that of the dog, yet, during the primordial play of atoms which finally resulted in the formation of protoplasm, there must have been some difference in the number and arrangement of electrons or we would all be dogs or men. If an atom of oxygen has eight revolving electrons and the relative positions of those electrons are changed, the character of the atom would be changed.

From the foregoing investigation we would conclude that the "better stuff" above referred to is better because it is nearer its outermost limits of development and, therefore, capable of higher attributes. It is indeed interesting, satisfying and, at the same time not unexpected, that development differences should have differential distinctions in structure and that these should be found in bone.

It is not enough for us to know that men are unequal, but we desire to know why they are unequal, why one man is made of better stuff than another and what can be done to raise the general level of humanity. The circle of man's present possibilities is small and he can not get out of its confines, but his children or grandchildren or descendents may and this we conclude is possible by controlling the crossing. The fact that we have so many undesirable developments among our human races is humiliating to us all and the universal desire to elevate the level of mankind to a higher standard is an outgrowth of the confusion of developments arising from the many structural variations as we see them delineated in bone. It is not necessary to perpetuate the lower levels of society simply because we have them; it is only necessary that we recognize their causes and understand the social conditions which maintain those causes and then gradually eliminate or reduce them by the application of biological methods. We can not change low types of structure to high, nor attributes from one level to another by chance or by legislation, we must change the foundation upon which they rest.

Our biographies are written in our bones and are told by our characters; we can not change the past, nor the present, but we can change the future.

THE END

WHEN AND HOW WE ACQUIRED OUR TEETH—BASED UPON THE COMPARATIVE HISTOLOGY OF BONE AND TEETH.

BY

J. S. Foote, A. B., M. D., LL. D.
Research Professor in the Dental Department of Creighton University, Omaha, Nebr.

This Investigation Was Undertaken in Behalf of the Scientific Foundation and Research Commission of the American Dental Association.

PART I.
FISHES.

CONTENTS.

Index

A

B

C

P

R

S

T

U

WHEN AND HOW WE ACQUIRED OUR TEETH—BASED UPON THE COMPARATIVE HISTOLOGY OF BONE AND TEETH.

BY

J. S. Foote, A. B., M. D., LL. D.
Research Professor in the Dental Department of Creighton University,
Omaha, Nebr.

This Investigation Was Undertaken in Behalf of the Scientific Foundation and Research Commission of the American Dental Association.

PART I.
FISHES.

WHEN AND HOW WE ACQUIRED OUR TEETH—BASED UPON THE COMPARATIVE HISTOLOGY OF BONE AND FISHES.

THE INVERTEBRATE LOBSTER AND FISHES.

This investigation was suggested by the histological variations found in bone during the writer's study of microscopic sections of the femora and other bones of various animals from amphibian to and including man, and published in the Smithsonian Contributions to Knowledge Series, Vol. 35, No. 3, 1916.

WHEN AND HOW GET OUR TEETH—BASED UPON THE COMPARATIVE HISTOLOGY OF TEETH AND BONE.

A study of the comparative histology of the tooth was suggested by a former study of bone, during which unexpected variations were found.

The study of bone from fish to and including man disclosing several types and type combinations of bone, instead of one type as was formerly supposed, the gradual displacement of the lower types by the higher, as the study advanced, the general trend of bone history toward higher levels, as one followed the histological evidences presented in the bone sections of different vertebrates—all place an observer in a position of advantage from which he is better able to understand bone variations in man and to estimate with some degree of accuracy, the changes which are known as pathological or aberrant.

Since pathology has its starting point in some biological variation or departure from a true type which has been established by variable ancestral forces, instead of the single force of its own type, the study of the comparative histology on bone presented the only opportunity available, of observing the types of mixed ancestral crossings and the relation of the results to pathological conditions. It was this study of bone that suggested a similar study of teeth; it was thought that the study of the comparative histology of the tooth might throw some light upon tooth history, that is, it might enable us to understand how the tooth started and when, how its mechanical and functional services were developed, how a standard of tooth structure was established with which other teeth might be compared, and how the tooth is related to bone. It might also enable us to know something of the circulation in and around the tooth and some of its variations, to investigate the history of the shedding of the teeth and the variations in the appearance of the permanent teeth, to observe the epidermal and connective tissue participations in the formation of the enamel, dentine, pulp and cementum, and to apply the knowledge thus obtained to the pathological conditions of the human tooth.

It is only after such a study that we are in the most satisfactory position to have a fair opinion concerning pathological and physiological tooth problems as they arise. Pathology is not often purely local since the circulation is involved. Our conception of it is clear, or not, depending upon the knowledge we have of the particular organ involved and its relation to the whole body. We are sometimes misled by the physical characters of an organ, as for example, the tooth and bone.

We are inclined to think that they differ from the soft tissues simply because they are hard. But the same pathological conditions are found in them as in the soft tissues, because they are alive and dependent upon the same blood supply. They have a very extensive circulation and as important a metabolism as any other organs of the body, for they are concerned in the distributing interests of calcium phosphate.

In the study of the comparative histology of the teeth, it cannot be known, at the beginning, just what will be found or what application may be made of what is found. But it is more than probable that between the early and late forms there will be found certain variations which will have an important bearing upon some pathological or physiological problems of human teeth. We are conscious of many deformities, deficiencies, faulty developments and histological variations in human teeth which are classified and that is about all. Some of them are understood and some are not. Some of them require mechanical, some dietetic, some antibacterial, and some surgical treatment. By a study of the whole dental field it may be possible to devise better methods of correction and obtain more satisfactory results.

It seems natural and logical to associate organs or tissues having a common basis—chemical, histological or both.

It was found that bone did not have one and the same structure in all classes of vertebrates, but presented variations having important values in the developmental interests of a biological nature.

After protoplasm appeared on earth, it, at once became absolutely necessary, in the interest of survival, that it should be protected from unfavorable, environmental conditions and it made use of its original endowment and incorporated the inorganic elements to meet those conditions. Thus, the association of the living and lifeless forms of matter dates from the very beginning of life on earth and has continued ever since. Teeth and bone are the living representatives of that early association at the present time and such an association suggests a very important kinship between them.

We are accustomed to think that dentinal substance was produced by one cell, the odontoblast, enamel substance by another cell, the ameloblast, and bone substance, by still another cell, the osteoblast, and we have erected impassable barriers between them, but the fact remains, however, that all cells of any individual were derived from one cell which possessed the original endowment of protoplasm and it only requires the presence of certain environmental conditions to cause the descendants of that cell to exercise their original prerogatives. Teeth and bone have something in common which is fundamental and we have reason for thinking that, since bone shows variations during its long biological history, teeth may also present similar or analogous variations. The first chapter in the investigation of bone and teeth comprises the following studies and the conclusions derived from them.

1. A study of the shell and teeth of the invertebrate—Homarus americanus, Lobster.
2. A study of the bone and teeth of an elasmobranch Shark—Mustelus canis.
3. A study of the bone and teeth of the Ten-pounder—Elops saurus.
4. A study of the bone and teeth of the Bowin—Amia calva.
5. A study of the bone and teeth of the Sunfish—Lepomis pallidus.
6. A study of the bone and teeth of the Lake trout—Salmo ferox.
7. A study of the bone and teeth of the Gar-pike—Lepiodosteus.
8. A study of the bone and teeth of the Catfish—Siluridae.
9. A study of the bone and teeth of the Muscalonge—Esox.

These studies take us from the invertebrate through the elasmobranch to the teleost vertebrates or fishes and showing us the teeth and bone in the making during the formative period of vertebrate life and leading us to several conclusions which have important bearings upon the teeth of man. These conclusions, in brief, are:

1. That calcium corbonate was secreted by cells of Trilobites and Mollusks, for protective reasons, as far back as the Lower Cambrain Period of the Earth's history;

2. That the element phosphorus was incorporated in the calcium compound by the agency of living cells and a calcium phosphate shell was introduced as a protective covering of another class of invertebrates;

3. That calcium carbonate and calcium phosphate have survived as the essential inorganic constituents of animal life from the beginning to the present

time and are found in the shell, tooth and bone of animals because they satisfactorily answered certain requirements of those organs;

4. That an organic keratin compound, secreted by epidermal cells was added to the calcium compounds by association and, as a result, calcium carbonate, calcium phosphate and keratin compound formed a triple alliance for the general purposes of protection and resistance to mechanical stresses of all kinds;

5. That by this alliance we are able to account for the appearance of shell, tooth, bone, hair, nails, feathers and epidermis of the animal kingdom;

6. That the character of the products of cell life will depend upon the integrity of the cells producing them;

7. That enamel substance was first secreted by epidermal or epithelial cells, dentinal and bone substances by connective tissue (probably endothelial) cells;

8. That those substances by organization became enamel, dentine and bone;

9. That hyaline cartilage and calcified cartilage were necessary antecedents of bone;

10. That bone and teeth have been intimately associated by family ties since they both appeared as members of a protective union and that the success or failure of one is an indicator of the success or failure of the other;

11. That an unsound bone and sound tooth or sound bone and an unsound tooth are not harmonious relations of the biological members of one family:

12. That the lower teeth are better than the upper teeth, because the bone of the lower jaw is a better bone than that of the upper jaw;

13. That the usefulness of enamel, dentine and bone depend upon the physiological integrity of three cells, viz., ameoblasts, odontoblasts and osteoblasts and these three cells derive their energy from the same blood stream which has received elements from unlike ancestral sources and, therefore, a standard tooth or bone with which all other teeth and bone may be compared is not to be expected;

14. That tooth shedding began in the invertebrate and has appeared in all vertebrates as an evidence of geenral development;

15. That the many variations in function, food, environment and ancestral legacies, since the tooth first appeared in animal history, have had something to do with the present state of the teeth of man;

16. That the length of time during which an organ will maintain its original standard depends upon the character of its organization.

While it is probably true that the investigation herewith presented does not meet the office requirements of the busy Dentist, yet I think that the study of the formative period of teeth and bone may help us to understand some of the present tooth failures by a presentation of developmental points in biological history.

A STUDY OF THE SHELL AND TEETH OF THE CLAW OF AN INVERTEBRATE—THE AMERICAN LOBSTER—HOMARUS AMERICANUS.

A STUDY OF THE SHELL AND TEETH OF THE CLAW OF AN INVERTEBRATE—THE AMERICAN LOBSTER—HOMARUS AMERICANUS.

It would be interesting to follow tooth history from its early to its late development and observe, as far as possible, any mechanical and structural variations which might be serviceable physiological conditions in the tooth of men or any faulty development which might become a pathological condition in the human tooth. It would be practically impossible to cover the whole field of the comparative histology of the tooth on account of the vast number of animals having teeth, but, perhaps enough can be done with the subject to make it of some value in practical work.

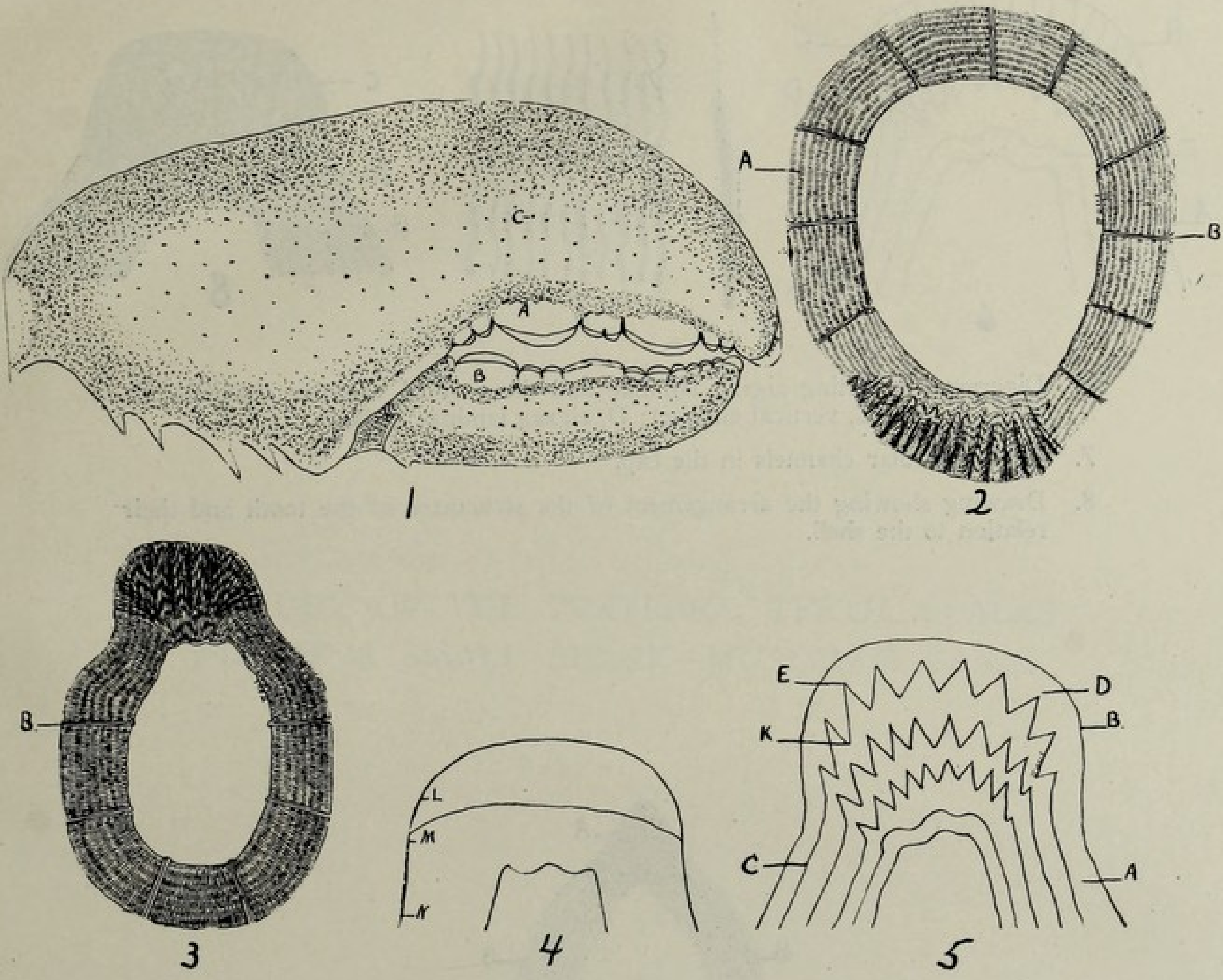
The essential object of this study is, to observe:

1. The structure of the early tooth as seen in an invertebrate.
2. The mechanical arrangement of that structure for functional services.

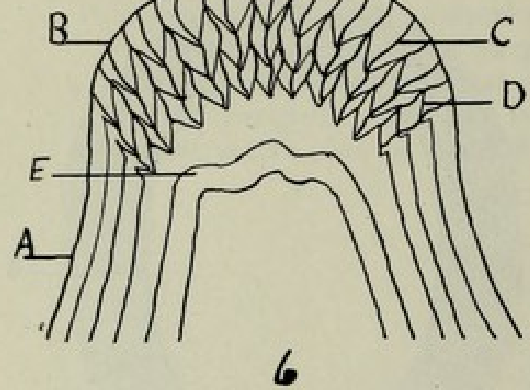
As may be seen from the drawing in Fig. 1, the lower jaw of the claw is shorter than the upper and has ten teeth, viz., two large and eight small. The upper jaw has similar and the same number. When the jaws are closed, the occlusion is irregular. The teeth of the lower are posterior to those of the upper jaw. The tips of both jaws are pointed and tooth-like, but do not come in contact. The claw and teeth are prehensile. The descriptions and drawings which follow are taken from sections of the shell and teeth of the claw through A and B, Fig. 1. (The lobster has also tooth-like structures in the stomach, called gastric teeth).

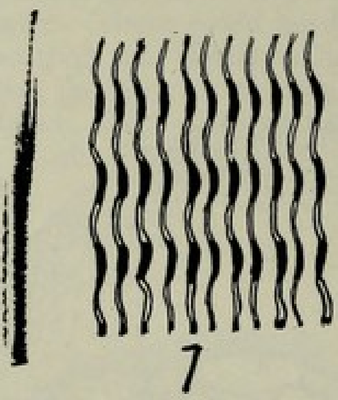
The claw tooth is a large or small protruding arch of the shell substance, having a body and cap, resembling in a general way the body and enamel of the later tooth. As the tooth is an extension of the shell and not separable from it, three parts, viz., the shell, the body, and the cap are presented for examination. These are indicated in Fig. 4 N. M. L. or in Fig. 8 B. A. C. The shell—(a partial chemical analysis of the shell made by Prof. C. F. Crowley shows 3.76% phosphates)—2 to 4 mm. in thickness, is composed of a large number of concentric laminae, Fig. 2 A. The lamina around the external border of the section contain pink pigment (the lobsters had been boiled) and were so arranged as to resemble somewhat the epidermis of the skin. This is not shown in the drawing. Passing through the whole thickness of the shell, at intervals, may be seen small canals or pores, indicated at Fig. 1 C, and shown in Figs. 2, 3 or 3 B. The canals are open on the outer surface and enclosed by conical elevations on the inner surface of the shell. They contain small hair like bodies which protrude from the external surface, thus completing the resemblance to the epidermis. The lamina which are seen in the cross section of the shell, Fig. 2, are formed by an arrangement of rather coarse wavy vascular channels, Fig. 7, extending the whole thickness of the shell. The channels present alternating constrictions and dilations. The constrictions are covexities and the dilations are concavities, Fig. 7. The convexities are light and the concavities are dark. This gives a light and dark or laminar effect. The channels are enclosed in the shell substance. If we look at Fig. 7 turned half around, we will get this effect.

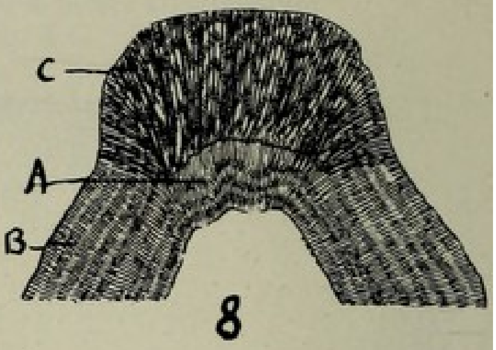
As the laminae of the shell reach the tooth, the pink color disappears and they are enxtended into the body of the tooth in the form of straight laminae, Fig. 5 C. They are then extended around the arch of the cap as zigzag arched laminae, Fig. 5 D or 6 D. Extending from the outer to the inner surfaces of the cap are seen wavy vascular channels, Fig. 6 C. The zigzag arches and the vertical channels are imbedded in a dense inorganic substance of flint-like hardness, the whole forming a mechanical truss of the most perfect construction, Fig. 8 C. This truss rests upon the body of the tooth, 6 C and 8 A, which is the small arc of the elliptically shaped shell. Thus we see how the mechanical structures of the invertebrate tooth are worked out into useful devices for such a functional service as the habits of the animal require. There could hardly be a better construction of a truss for crushing purposes than that displayed in Fig. 8 C. The series of zigzag arches, the vertical walled, double curved channels, all enclosed within a dense inorganic, flint-like substance, leave little or nothing to be desired in the constructive plan of a crushing tooth.



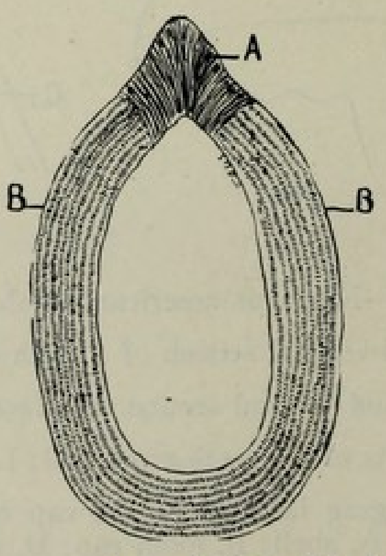
1. Right claw of a Lobster—Homarus americanus—showing the teeth.
2. Cross section of shell and vertical section of a tooth seen at A Fig. 1.
3. Cross section of a shell and vertical section of a tooth seen at B Fig. 1.
4. Diagram showing the parts of the tooth examined; L, cap; M, body; N, shell.
5. Diagram showing the zigzag laminae of the cap of the tooth as they are extended from the shell; A, shell; B, tooth cap; D, zigzag lamina of the cap. C, lamina of the shell; E, superior angle; K, inferior angle of the zigzag lamina.







6. Diagram illustrating zigzag laminae and the vertical vascular channels; A, shell; B, cap; C, vertical channel; D, zigzag lamina; E, body.
7. Wavy vascular channels in the cap.
8. Drawing showing the arrangement of the structures of the tooth and their relation to the shell.



Cross section of claw of a Lobster through a tooth. A, tooth; A-B, part enlarged in Fig.

A STUDY OF THE VERTEBRA, TEETH, SCALES FIN OF A SMALL SHARK—MUSTELUS CANIS.

A STUDY OF THE VERTEBRA, TEETH, SCALES AND FIN OF A SMALL SHARK—MUSTELUS CANIS.

As the fish belongs to the elasmobranch group the endo-skeleton is an irregularly calcified cartilage rather than bone, while the external covering is more like enamel and dentine than it is like a dermal structure.

The following ground sections have been examined, keeping in mind the early history of the fish and its possible bearing on the structures of the later vertebrates: a dorsal vertebra, upper and lower jaws, teeth, scales and fin.

1. Cross section of a dorsal vertebra with fin attached. A, ventral, B, dorsal portion, K, fin, J, joint of fin with vertebra, C, skin with tooth-like placoid scales which surround the whole vertebral section, D, blood vessel under the skin sending off minute tree-like branches into each scale as in 8, A, E, clear keratinized layer under the blood vessel and extending into the fin, F, calcified cartilage forming the central core of the vertebra and enclosing a central canal H. The calcified certilage is composed of closely packed cells filled with dark inorganic granules making it extremely difficult to grind the section to sufficient thinness to admit the passage of reflected light. Around the central canal L (and on a large scale in Fig. 2), is seen a ring of closely packed spindle cells also densely calcified and opaque. The calcified cartilage is interesting on account of its possible forecast of bone which appeared later as the foundation of the vertebrate series. There is a peculiar and suggestive relationship of the calcified cartilage in this early fish to the calcified cartilage which precedes the bone formation in the later mammals as may be seen by a brief examination of bone formation in the long bones of these animals; the long bone of the mammal is laid down, at first, in hyaline cartilage. A center of cell activity is established at the lineal center of the shaft called the center of ossification. The cartilage cells on the epiphyseal sides of the center are arranged in columns directed toward the epiphyses, the matrix between the columns is hardened by a deposit of granular calcium salts and an opaque calcified cartilage is the result. There is then an extension of vascular osteoblastic tissue from the under surface of the periosteum into the calcified cartilage which is then absorbed and in its place there is formed a true bone by the agency of bone cells or osteoblasts brought in by the osteoblastic extensions from the periosteum. Calcified cartilage, therefore, has been an antecedent of bone from the beginning to the end of vertebrate history.

Referring to Figs. 1, 4, 6, we notice that calcified cartilage is found in those situations which later, in vertebrate history, become bone. In Fig. 1, cross section of a vertebra, we see it at F, in Fig. 4, cross section of the lower jaw, we see it at D, in Fig. 6, cross section of the upper jaw, we see it at H. The purpose of calcified cartilage as a physiological factor in bone formation is probably one of calcium reserve and its long history as such gives it a value of great importance. It is this sense that it may be considered within the range of physiological tissue, otherwise as we will see later, it is considered as a pathological tissue.

2. A narrow ring of closely packed calcified spindle cells around the central canal of the vertebra as seen in Fig. 1, H. Calcified tissue is extremely difficult to work out for microscopic purposes, since it is opaque, no matter how thin the section is. The nucleus of a cell is anabolic and the cytoplasm is katabolic, the nuclei of these cells are packed with small inorganic granules which extend to some extent into the cytoplasm and the constructive power of the nuclei has not made the calcium available for metabolic purposes, but holds it in reserve for future needs.

3. Diagram of the upper and lower jaws in position. A, upper, B, lower jaw. The object of the diagram is to show the relation of the jaws to each other and the cross markings on their surfaces which indicate the positions of the teeth.

4. Cross section of the lower jaw at C, Fig. 3. A, external keratinized layer, B, blood vessel sending off tree-like branches into the teeth as may be seen at C. The vascular arrangement in the teeth is practically the same as that in the scale; D, calcified cartilage with clear nucleated areas (E) alternating with densely calcified nucleated areas (F) H, central canal extending lengthwise of the jaw and containing calcified nuclei, I, internal keratinized layer bordering the canal, O, oral membrane. It may be noticed here that calcified cartilage is enclosed between two layers of keratinized tissue thus, associating calcium and keratin at a very early period of life.

As inorganic calcium compounds and organic, nitrogenous, keratin compounds have formed essential parts of the endo- and exo-skeletons of animals since the foundations of the world were laid, it may be interesting to consider these compounds in their primitive relations to life. If the earth is one hundred million years old, as some geologists think it is, at least one-half of this period was occupied by the Archaeozic Age, when plant and animal life had begun to obey the call of the more congenial solar and terrestrial allurements. Animal life chose the aquatic route to higher objectives and reached those objectives at a later period on land. In the Cambrian era of the Paleozic Age, inorganic salts (calcium carbonate) enclosed a soft perishable creature between two shells, provided it with a wonderful protection and called it a mollusk; so protected, it has come down to the present day and promises to outlast its higher competitors in the race of life.

From this it may be seen that very early in the history of vertebrates calcium compounds were employed to serve a useful purpose as a protective covering, although protoplasmic hostilities had not reached a high point of venture at that early date in the calendar of living experiences. Calcium was thus selected as the inorganic element of choice to guide the long procession of frail protoplasmic ventures down through the unknown ages of the future. Reckoned in geological time, it was not long after its remote beginning that calcium carbonate was replaced to a great extent by calcium phosphate which is now the principal calcium salt in vertebrate life. In the somewhat later Silurian Age, the keratin substance formed the basis of the external covering, while the calcium salts were consigned to the endo-skeleton. Thus calcium and keratin have existed from Paleozoic time or for millions of years as fundamental chemical elements and compounds in animal history.

Calcium salts, established bone and teeth and keratin compounds, the basis of the epidermis, hair, nails and feathers of advanced animals today. However, the tranformation from the calcium exo-skeleton to the calcium endo-skeleton did not occur suddenly, but gradually as may be seen in the elasmobranch and teleost fishes. In the elasmobranch group, as in some sharks, the endo-skeleton is an irregularly formed calcified cartilage instead of bone and the external covering is more like dentine and enamel than it is like keratin substance, but the calcified cartilage is enclosed by layers of keratinized tissue indicating its close relation to that tissue. Fig. 1, E. Fig. 4 A, Fig. 6, E. F.

Thus, the sharks have brought down from the remote Silurian Age of the world interesting testimonies of a wonderful period of vertebrate differentiation and now present them to man in a tangible form in these days of high type levels and fulfilled biological prophecies.

When we listen to a sea shell we hear the songs of the ages broadcast from the Silurian station of the Earth's development and if we are tuned to hear them we are thrilled with overwhelming conceptions of Time and its biological presentations.

According to some geologists, life has existed on earth fifty million years and for most of this enormous period calcium and keratin compounds have entered into the composition of the endo-skeleton and external covering of animals and have finally become specialized in such organs as bone, teeth, hair, nails, horn, feathers and the stratum corneum of the epidermis of the skin. The calcium compound life was a calcium carbonate life and appeared first in the shell fish, it then changed to a calcium phosphate which together with the carbonate and fluoride appeared in three degrees of density in the vertebrate fishes of the Silurian Age in Enamel, Dentine and Bone, the first two antedating the third as may be seen in the boneless, elasmobranch group and the third or bone, in the teleost group which appeared later in the same Age. Thus shell life introduced calcium compounds into the life histories of vertebrates of which man is the most advanced member. Keratin substance, beginning in the elasmobranch fishes as a basic portion of the external covering has come down through the ages as a calcium associate in the specialized teeth of the later vertebrates, calcium and keratin substance are both engaged in the formation of the teeth of man at the present time—calcium as a connective product in the dentine and keratin substance as an epithelium product in the enamel. The association of horn and keratin substance with teeth and bone has been and still is very close. Horn has appeared as a sole or partial structure of the teeth in the following animals referred to by J. H. Mummery, in his "Microscopic Anatomy of the Teeth." The teeth of the fish—Petromyzon, Lamphrey—are composed of keratinized cells of the stratum corneum of the epidermis." "In the tadpole there are keratinized plates on the jaws preceding the teeth of the amphibian frog." "In the reptiles—Chelonia, Tortoise and Turtles—there are keratinized membranes covering the upper and lower jaws." "(In the aquatic mammal—Dugong —there are keratinized plates covering rudimentary, calcified teeth." In the monotreme mammal—Ornithorynchus—"the jaws are covered with keratinized plates in which are calcified teeth."

The association of horn or keratinized substance with calcified cartilage may be seen in the elasmobranch shark, Fig. 6, E, F, or in Fig. 4, A 1, with bone, it may be seen in the bills of birds, where the bills are composed of bone, of the same type as other bones of the animals, enclosed within a nicely fitting shell of horn; in some ungulates, as the ox, where the hollow horn takes its origin around a central core of bone, and in the later mammals, as in man, where a keratinized stratum cornuem of the epidermis of the skin covers the entire body and dips into the invaginations, as the mouth, where it is specialized as ameloblasts and forms the enamel organ of the teeth.

The epithelium of the mouth, like that of the epidermis of the skin, is stratified pavement, but differs from it in this respect, that in the mouth both the stratum granulosum and stratum lucidum do not appear as distinct layers and as these layers are chiefly instrumental in the formation of keratin, the keratinization of the stratum corneum of the mouth is incomplete; this absence of the keratinizing layers may be in preparation of the enamel formation of the early development, which is not a keratin development but a calcium development and the epithelial cells of the oral mucosa, from which the enamel is derived, assumes its early function of producing a calcium instead of a keratin compound.

5. Drawing of the upper jaw and a portion of the roof of the mouth: A, upper jaw, B, portion of the roof of the mouth, C, stomodeal denticles. The jaw is further described in Fig. 6. The denticles or small teeth, thickly set on the roof of the mouth, have about the shape of crow-quill pens and point toward

the stomach. They have practically the same structure as the placoid scales of the outer covering of the body, that is, each one has a tree-like circulatory system enclosed within an inorganic compound of the density of enamel and dentine.

Cross section of the upper jaw at A, Fig. 5. A, tooth, B, oral membrane, C, blood vessel sending off tree-like branches into the teeth as at A, D, supporting tissue, E, external keratinized layer, F, internal keratinized layer, H, calcified cartilage with clear nucleated areas alternating with densely calcified nucleated areas, I, portion of the roof of the mouth with small teeth or denticles, K, blood vessel sending off minute branches into these teeth, L, supporting tissue, M, portion anterior to the jaw, N, portion posterior to the jaw.

The interesting features of this section are the keratinized layers, the calcified cartilage and the teeth. The relation of the keratinized tissue seen at E and F, to the calcified cartilage H, is significant when we consider that the enamel of the human tooth is derived from the stratified pavement epithelium of the mouth, which is the keratinizing epithelium of the skin and the dentine is derived from the connective tissue and its circulatory system by the appropriation of the old-time calcium salts in the process of dentinification or odontification; that is, calcium and keratin tried out in the beginning and found to be serviceable as stress resisting tissues are employed in modified forms in the teeth of the latest mammals. The calcified cartilage seen at H offers a suggestion in regard to calcification which is so commonly used when speaking or writing of such calcium compounds of protoplasm as enamel, dentine and bone.

The calcified cartilage in Fig. 6, is composed of alternating areas of clear nucleated and opaque densely calcified cartilage of the hyaline variety. The regions between the clear areas are true calcifications since there is a deposit of calcium granules around the nuclei of the cells as well as in the cytoplasm making them impervious to transmitted light as calcified tissues necessarily are under the microscope. The clear nucleated areas are composed of cartilage cells of the hyaline type as may be seen in Fig. 7. It is also true that the cartilage preceding bone formation in the long bones of mammals is the hyaline variety.

Some confusion arises in regard to the signification of calcified tissue as the term is commonly used. Calcification is largely employed in the descriptions of such calcium protoplasmic processes as are engaged in the formation of enamel, dentine and bone. It makes little or no difference what term is used as long as it conveys the same meaning to everyone, but when a term has a physiological signification to one and a pathological signification to another, such a confusion becomes embarrassing and oftentimes leads to a misconception of the real process involved. The clearness of the conception depends upon whether or not it is thought that the calcium salts are deposited as calcium granules in the tissue or in the form of a calcium compound of protoplasm; in the former case the calcium salts (possibly the so-called spherocalcites) are storage reserves of calcium for future use in the formation of enamel, dentine or bone by specialized cells known as ameloblasts, odontoblasts or osteoblasts; in the latter case the calcium salts are combined with the organic base by virtue of the special metabolism of living cells. Thus calcified cartilege is found in the vertebrae, skin and jaws of the elmosbranch fish and the calcium compound of epithelial and connective tissues, in the enamel, dentine and bone of the later vertebrates. The occurrence of calcified cartilage in the formation of long bones in the later vertebrates is significant in this respect. From it may be seen that a calcified tissue may be a physiological tissue. In other cases calcium salts are deposited in degenerating or dying tissue and are no longer available as reserve calcium salts in development, but are foreign substances entirely beyond the reach of living cells and such a calcified tissue is a pathological tissue. Strictly speaking, a calcified tooth would be opaque in section under the microscope on account of calcium compound granules as the calcified cartilage of the early fish or the bone antecendent is and not clear as it is seen in the usual ground sections. In the formation of a normal tooth calcification or the deposit of calcium granules has been changed to amelification, dentinification or odontification and ossification. These words always have the same physiological significance which are respectively enamel formation, dentine formation and bone formation.

Calcification is a deposit of calcium salts in a degenerating or dead tissue, while the above mentioned terms, amelification, dentinification or odontification and ossification, refer to the formation of calcium compounds of protoplasm, known as enamel, dentine and bone, by living cells. In other words, the former follows as a result of a degenerating, dying or dead tissue and the latter, as a product of the metabolism of a living tissue. The former is opaque under the microscope and the latter is clear. For example, in the wall of an artery which has undergone an atheromatous degeneration there is usually a deposit of calcium salts, the condition being known as calcification or athero-sclerosis.

In amelification, dentinification or odontification and ossification, living cells produce a calcium compound of protoplasm of such an unstable character that the inorganic salts may be withdrawn by the circulating blood for general metabolic purposes in proportion to their respective volumes and physiological activities; we may, therefore, consider the vertebrate skeleton as a depository of inorganic salts constantly undergoing a change in balance depending upon the incoming food and the outgoing circulatory distribution. The result of cell metabolism in a cell degeneration is not a source of energy as the normal cell product is. For example, the fat of a fatty degeneration can not be appropriated for energy purposes, but remains in the cyptoplasm of the cell as so much inert displacing substance which may destroy the cell.

It seems, therefore, better to employ some such physiological terms as amelification, dentinification or odontfication and ossification, when speaking of physiological processes, than it is to use the term calcification or any of its derivatives which may have one signification in the minds of some and an opposite signification in the minds of others and ranging all the way from a normal or physiological to a diseased or pathological condition. If we believe that calcification is a biological and not a physical act in some cases and a physical and not a biological act in other cases, we are mentally confused whenever the term is employed.

An interesting and accountable adaptation of a calcium and keratin compound is seen in the egg-tooth of some birds. There is an air chamber in the blunt end of the egg; when the young bird is finishing its development within the egg shell, a small tooth—called the egg-tooth, composed of calcium and keratin compounds is formed on the tip of the bill of the young bird. When the developmental limitations are reached and the hatching time arrives, the young bird takes its first breath of air from the air chamber, feels the "call of the wild" and with its newly made egg-tooth breaks away the shell and comes forth from its prison house—which always looks too small for the prisoner—just as though it had planned the escape itself. Soon afterwards, the egg-tooth, having been used only once drops off. On account of the chemical nature of the egg, it would seem that if an egg-tooth is required at all, it would be of calcium salts alone, which are constituents of the egg and not of a calcium and keratin compound which is not a constituent of the egg. The association of calcium with keratin in this case is remarkable.

A reference to the customary usage of calcification in Histology and Pathology may be of interest in this connection.

Hopewell Smith, Normal History: "Enamel, the smooth hard glistening substance which partially or wholly envelops the crown or visible portions of the calcified teeth."

Shäfer, Essentials of Histology: "The enamel prisms have, when first laid down, a fibrous structure, but this becomes obscured after calcification is complete." Dentine: These fibres (dentinal) which have been especially investigated by V. Ebner and Mummery are difficult of demonstration in the fully calcified dentine; "Bone: True bone is always made up of lamellae (?) and these again are composed of fine fibers lying in a calcified ground substance."

Stöhrs, Text Book of Histology: 'The calcification of dentine begins shortly before the formation of enamel and spreads from the crown over the neck and root."

Mummery, Microscopic Anatomy of the Teeth: "Enamel either forms the external calcified layer of the crowns of the teeth or, in those teeth covered with cement, plays a most important part in maintaining an effective grinding surface; calcified dentine has a festooned outline made up of rounded bodies or spherical masses of lime salts."

We may now compare the above quoted histological calcifications with the following pathological calcifications and note the differences.

Adami and McCrae, Text Book of Pathology: "Calcification may occur is tissues that contain living cells, not in the living cells themselves, but in the inert, interstitial matter between the cells. It occurs in dead or necresent material and the statement may be that it does not occur in living functioning cells."

Thoma, Pathology and Pathological Anatomy: "Calcified tissues are more or less hard and may be as hard as stone; under the microscope fine very refractile granules are found in the intercellular substance and deposited in the cells of the tissue also. The tissues are more or less opaque."

McCallum, Text Book of Pathology: "If we ligate the blood vessels of a rabbit's kidney, the tissues become quite densely calcified within a few days."

Wells, Chemical Pathology: "In calcification the lime salts always remain in clumps and masses often fusing to a greater or less degree, but never with the diffuse even permeation of tissues seen in ossification. All the cells within a calcified area, which are not dead at the beginning of the process, eventually disappear for the most part and we have sooner or later a perfectly inert mass, practically a foreign body, instead of a specialized tissue as in ossification. Ossifications accomplished only in varieties of connective tissue, but calcification may involve any sort of cell or tissue provided it is degenerated sufficiently. The composition of the inorganic salts in calcified areas in the body seems to be practically the same, if not identical, whether the salts are laid down under normal conditions (ossification) or under pathological conditions."

Buchard and Inglis, Dental Pathology and Therapeutics: "It is believed that the deposit of salts in the dying tissue is more than a mere precipitation and that calcification results from a combination of the salts with an aluminous base and with fatty acids, such an affinity being favored by the degenerative changes."

Thus, it would seem that the use of amelification, dentinification or odontification and ossification in the place of calcification would disposses the mind of a doubt and confusion; these terms meaning the physiological formation of enamel, dentine and bone substance by the agencies of certain specialized cells or ameloblasts, odontoblasts and osteoblasts respectively. By the use of such terms we would all have one and the same thought in mind instead of diametrically opposite thoughts. The association of calcium salts with protoplasm or living substance dependent upon the living cell enables us to treat them as living organs and not as once as the word calcification would imply.

7. Cartilage cells taken from Fig. 4, E. The cells occur singly and in groups of two, they have a clear cytoplasm prominent nuclei and nucleoli and belong to the hyaline variety. Between the clear areas which are more or less circular in shape, the cells are densely packed with inorganic, opaque granules forming a primitive calcified cartilage, which, as we saw above, is a forerunner of bone in the later fish.

8. Cross section of the skin with its scales, blood vessels and keratinized dermal layer as seen at T, Fig. 1. A, placoid scale with its extremely dense, inorganic enamel-like substance in which is seen the tree-like circulatory system arising form the subcutaneous blood vessel at C. The body of the scale presents a finely striated appearance due to minute tubules extended from the branches of the circulatory tree and directed outwards toward the tip. The tip is clear and marked off from the body by the absence of recognizable striations. It may be remarked in passing that the identification of pure enamel substance, dentinal substance or bone substance under the microscope by any visual means is not possible; they can only be recognized by their morphological units as rods, tubules, canaliculi or lacunae. A calcification is extremely difficult to grind down to a visual clearness and may serve as an indicator. B, the skin which is pigmented with a black pigment and rests upon a loose supporting tissue. C, blood vessel under the scales and skin which supplies the scales with an extensive blood supply in proportion to their volume. D, keratinized dermal layer, homogenous in structure and yellow in color.

9. Section of a tooth of the lower jaw showing the remarkable circulatory system. A, blood vessel underneath the oral membrane from which the tree-like circulatory system of the tooth is derived. B, the circulatory system within the tooth which seems to be out of all proportion in extent to the demands of the mass supplied. The main vessel with its large and small branches resembles quite closely a tree and its branches. C, body of the tooth composed of a clear inorganic substance in which are immense numbers of fine tubules extending outward from the central vessel. The inorganic substance is evidently a product of the vascular system and by its situation and intimate relation to the vascular system is called dentine; as no cells are visible, the detinal substance is recognized by its tubules. E, a denser inorganic layer on the surface made darker by a more closely set arrangement of vertical tubules which are very minute extensions of the circulatory tree of the dential substance. D, tip of the triangularly shaped tooth which is a clear hard inorganic substance corresponding in position and flint-like hardness to what is called enamel. It caps the tooth, but unlike the later enamer, it is an extension of the dentine and its tubules with an increased percentage of inorganic salts in its inter-tubular substance.

Thus, in these early teeth may be seen the evidence of amelification and dentinification which became so essential to the structure and function of the teeth of the later mammals.

10. A triangularly shaped lower tooth showing the numerous tubules in the dentine and enamel all extensions of the central circulatory tree. The tubules are so thickly set that they obscure the dentinal substance.

11. Triangularly shaped tooth of the upper jaw showing the same arrangement of the circulatory system, dentine, tubules, enamel and clear tip.

12-13. Circulatory system of a lower tooth (12) and a placoid scale (13) placed side by side for comparison. The resemblance is striking in every particular position and character of dentinal substance with its tubules and border, the enamel and tip. In fact, a description of one would do for the other and yet

(12) is a tooth and (13) is a scale from the skin. It is difficult if not impossible to reconcile the similarities and to give a definition of tooth. Beginning on the outer side of the body as a protective organ of the skin, it was transferred to the invaginations of the skin and appeared on the surface of the jaws as an organ of prehension and finally of mastication. It would thus appear that a tooth was a scale before it was a tooth and that having been tried out as a protective organ on the outer covering of the body, it was later utilized as a protective, prehensile, masticating organ of the beginning of the food canal; but an interesting fact in this connection is the association of the tooth with the skin in the early history of the tooth and the intimate association of enamel formation or amelification in the tooth of the latest mammal, man, as seen in the derivation of the enamel organ from the stratified pavement epithelium which is a skin structure. It may seem somewhat peculiar and might be unexpected that the hardest known substance of the human body should be derived from the soft epithelium of the mouth, but the mouth is an invagination of the skin and there was evidently a time in the history of the skin when it produced the hardest known substance of the body as shown in the placoid scale of the early elasmobranch fish.

14. Placoid scales of the dorsal skin in position. The scales have about the shape of crow-quill pens and point toward the tail of the fish. The scales have three or four parallel grooves or furrows extending lengthwise and between the grooves the scale substance is raised in frosted columns with convex surfaces. The scales are closely set, the point of one overlapping the body of the scale next in line or not, depending upon surface pressure.

15. Various scales ground flat-wise by taking the dried skin and grinding the under surface until the scales are detached and appear in the microscopic field. The scales, in flat section, are clear acuminate or cordate in shape and leaf-like in appearance with their circulatory systems delicately portrayed.

16. Calcified keratinized ray of a dorsal fin. A, blood vessels, B, calcified portion of the ray, C, clear, yellow, keratinized base of the ray. In the calcified portion at B, the ray is closely packed with opaque inorganic granules made denser in zigzag rows by crowding the granules more closely together. It is a classification. At C, the base of the ray is seen to be clear with quite a sharp line of demarcation at the junction of the calcified portion. On either side of the ray is a channel in which blood vessels of considerable size (a) appear.

17. Cross section of the roof of the skull. A, scales and skin, B, blood vessel underneath the skin sending off branches into each individual scale, C, thin supporting tissue, D, external fenestrated, keratinized layer giving more or less firmness to the skull, E, thin layer of calcified cartilage, F, internal keratinized layer and supporting tissues. It may be noticed that the calcified cartilage is situated between two layers of keratinized tissue as was seen in sections of the upper and lower jaw, giving further evidence of the intimate association of calcified cartilage and keratinized or dermal tissue in the early vertebrates.

18. Circulatory system of one of the roof scales taken from 1, Fig. 17. A, outline of the scale, B, circulatory tree, C, portion of the underlying blood vessel.

The following interesting features have arisen during the study of the foregoing microscopic sections:

1. The relation of calcified cartilage in the early fish to the calcified cartilage which precedes bone formation in the later mammals; it is a forerunner of bone in both cases.

2. Early association of calcium compounds with keratinized or dermal tissue.

3. Calcium and keratin compounds are the bases of endo- and exoskeletons in the history of vertebrate life.

4. The antiquity of calcium compounds in animal life.

5. The extension of calcium compounds from the shell fish to the vertebrate as a serviceable means of protection and general usefulness.

6. Change of calcium carbonate to calcium phosphate, of shells to teeth and bone.

7. Early appearance of keratinized tissue in vertebrate history.

8. Calcium phosphate established teeth and bone, keratinized tissue, the epidermis, hair, horn, nail and feathers.

9. Teeth composed of keratinized tissue—examples.

10. The appearance of enamel and dentine before bone in the placoid scales of the elasmobranch fish.

11. Scales and teeth compared.

12. Calcification as a physiological and pathological process discussed.

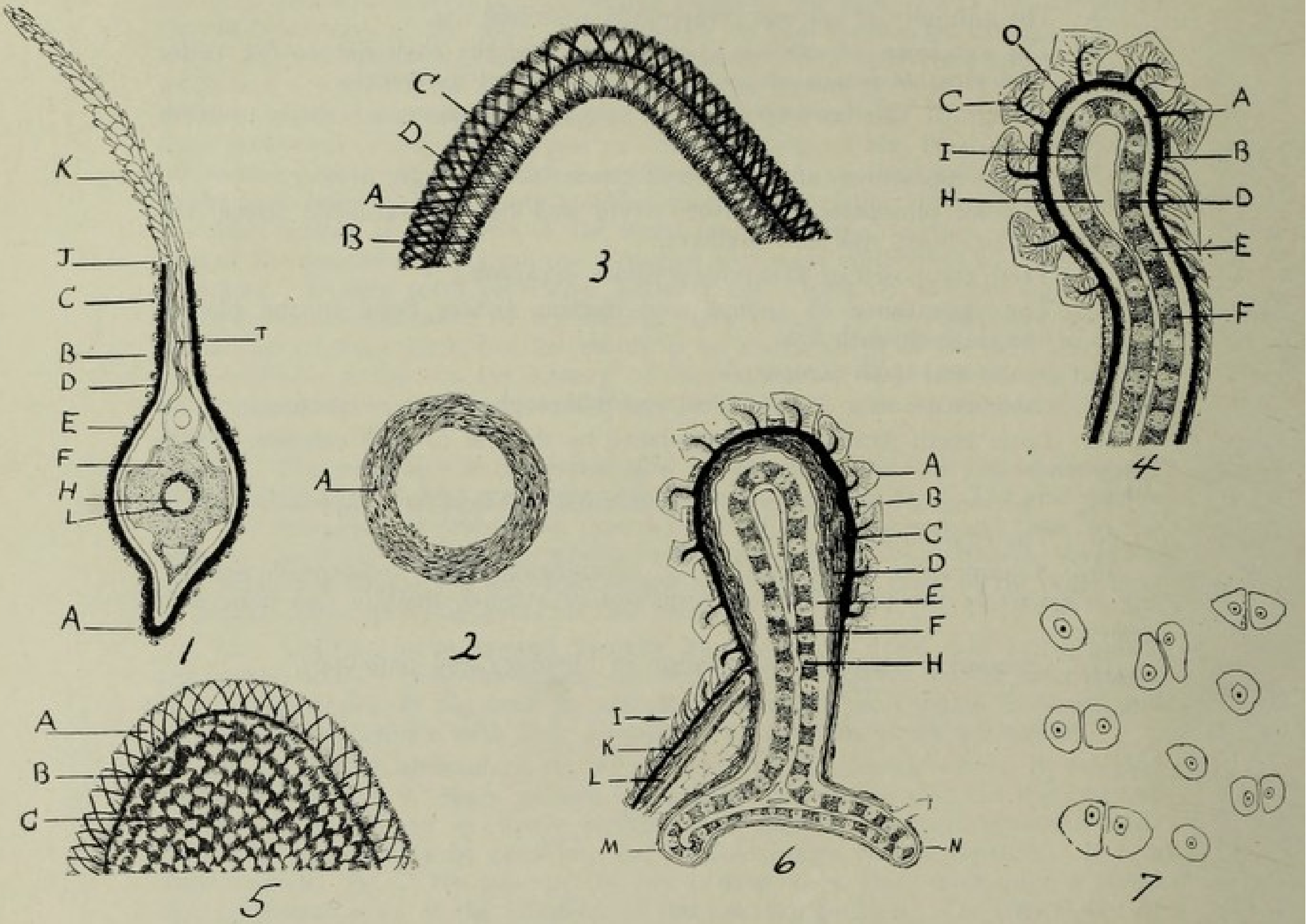
13. Later tooth formation accomplished by the use of both calcium keratin compounds.

14. The tooth of man derived from calcium and keratin compounds.

15. The egg-tooth.

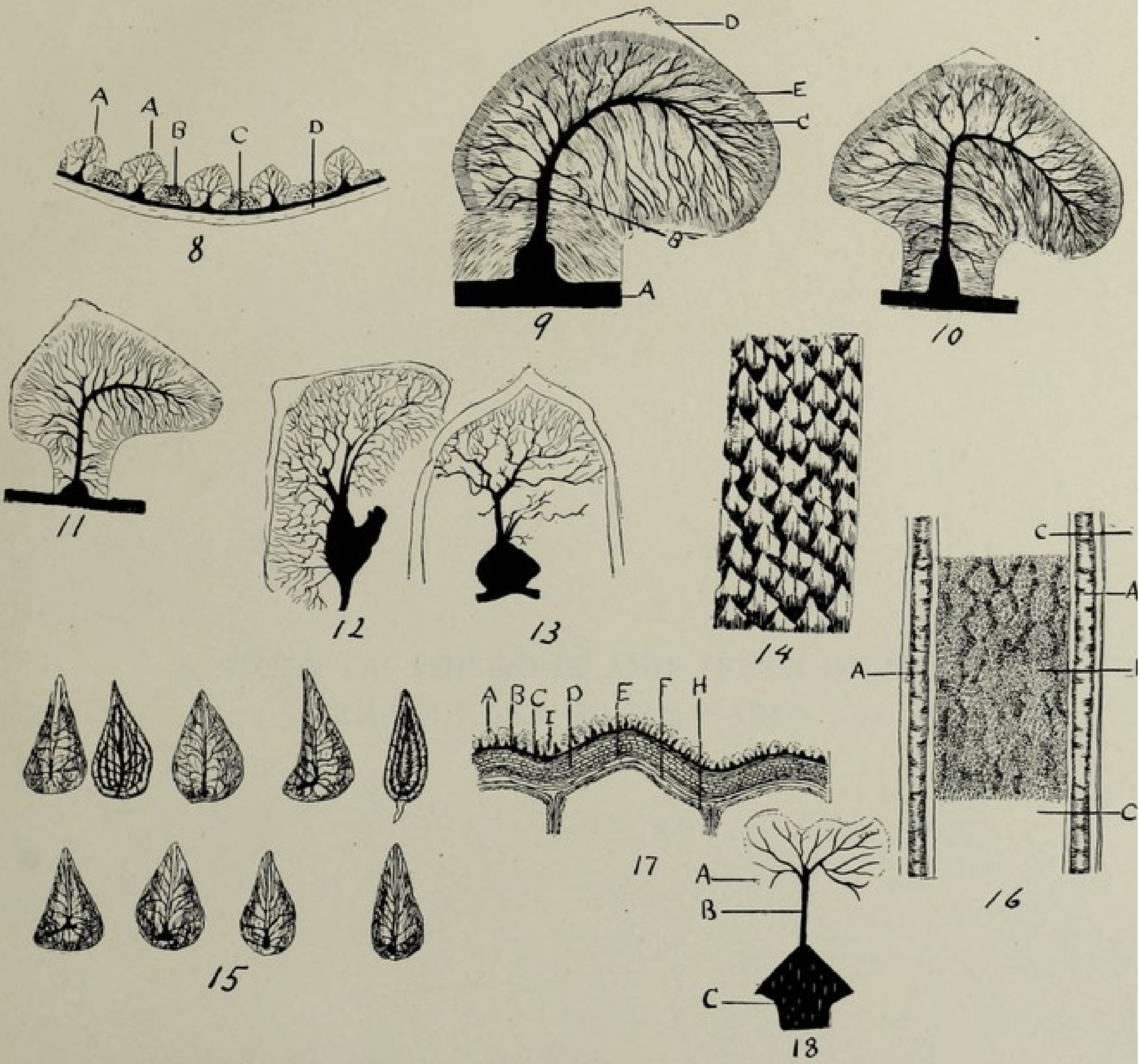
16. Amelification, dentinification or odontification and ossification signifying respectively the physiological formation of enamel, dentine and bone suggested.

17. Customary usage of calcification in histology and pathology.



VERTEBRA, CALCIFIED CENTRAL RING, JAWS—GROSS AND MICROSCOPIC CARTILAGE CELLS OF A SMALL SHARK—MUSTELUS CANIS.

1. Cross section of a vertebra with fin attached.
2. Ring of closely packed calcified spindle cells around central canal.
3. Diagram of upper and lower jaws in position; A, upper, B, lower.
4. Cross section of the lower jaw at C, Fig. 3.
5. Upper jaw and a portion of the roof of the mouth.
6. Cross section of the upper jaw at A, Fig. 5.
7. Cartilage cells from E, Fig 4.



SECTIONS OF SKIN, TEETH, SCALES, SKULL, FIN RAY AND THE CIRCULATORY SYSTEMS OF A SMALL SHARK—MUSTELUS CANIS.

8. Cross section of skin and scales as seen at T, Fig. 1.
9. Section of a tooth of the lower jaw.
10. Triangularly shaped tooth of the lower jaw.
11. Triangularly shaped tooth of the upper jaw.
12.-13. Circulatory systems of a lower tooth (12) and a placoid scale (13) compared.
14. Placoid tooth-like scales in position as seen on the dorsal skin.
15. Various scales ground flat-wise to show circulatory systems.
16. Calcified keratinized ray of dorsal fin.
17. Cross section of the roof of the skull.
18. Circulatory system of one of the scales as seen at I, Fig. 17.

A STUDY OF THE BONE AND TEETH OF THE TEN-POUNDER—ELOPS SARUS.

A STUDY OF THE BONE AND TEETH OF THE TEN-POUNDER—ELOPS SAURUS.

This fish represents a primitive member of the Teleost group of fishes when bone had, for the most part, replaced cartilage and calcified cartilage in the histology of the inorganic structures of the vertebrate body. Bone is a product of the bone cell and not of the cartilage cell and the change from cartilage to bone is impossible, although cartilage may be and apparently is a necessary antecendent. Its office may be mechanical. In the first place hyaline cartilage becomes calcified cartilage which then disappears by a process of absorption and in the place of it bone is produced by true bone cells, which is a more advanced form of cell than the cartilage cell. From cartilage to bone is an elevation of biological level and, therefore, the transition from the former to the latter did not take place suddenly, but gradually and it might be expected that some remaining evidences of cartilage or calcified cartilage would still be found in the primitive Teleost and this seems to be the case in the Ten-pounder.

Ground sections of the vertebra, upper and lower jaws, teeth, fin, and a mounted scale have been examined, a report of which is herewith presented.

1. Cross section of a dorsal vertebra with its bone extension into the fin, A, fin, B, expanded base of the fin, C, keratinized tissue, D, calcified cartilage, E, clear hyaline cartilage, F, bone stem connecting the fin with the vertebra; this is a slender bone composed of a clear bone substance in which are numerous multipolar bone cells as may be seen in Fig. 15. The bone stem is enclosed by two layers of keratinized tissue as indicated at H. I, two small vascular canals surrounded by bone enclosed within thin keratinized layers, J, external keratinized tissue, K, bone, L, internal keratinized—the three layers forming an outside vertebral covering, M, radiating loops of bone extending from the ring around the central canal to the periphery of the vertebra, the loops are composed of bone substance in which are small lightly branching cells of a later differentiation than the multipolar, N, granular matter with the loops, O, narrow ring of vascular, lamellated bone around the very small central notochord canal.

The section is interesting because it shows an association of hyaline cartilage, calcified cartilage, early and later bone differentiations and keratinized tissue—the three tissues which havce been concerned in the formation of bone and teeth from the beginning. The cartilage is found to a slight extent in both its hyaline and calcified forms and is very closely associated with keratinized tissues. The bone stem uniting the fin and vertebra, is early in differentiation as it is characterized by multipolar bone cells which may be seen in Fig. 15, while the radiating bone loops show a somewhat later differentiation.

Keratinized tissue seems to be a constant associate of bone in its early history. Around the small central canal is a thin ring of vascular lamellated bone which seems to be the starting point of the radiating bone loops.

2. Cross section of the upper jaw: A, large vascular canal appearing in cross section, B, external layer of keratinized tissue which practically surrounds the section, C, bone of an intermediate differentiation characterized by round, oval and long narrow lacunae with relatively few canaliculi, D, coarse plexus of blood vessels under the teeth sending a branch into each tooth, E, tooth.

The particular interest in this section centers around the extensive circulatory system indicated at D. The bone has a variety of differentiations and numerous vascular canals; the teeth are small, curved, sharp-pointed teeth with large central canals containing large blood vessels which send off minute lateral branches forming the dentinal substance in which they are enclosed as dentinal tubules.

3. Longitudinal section of the upper jaw: A, tooth, B, extensive circulatory system in the bone under the teeth sending off a branch into each tooth, C, bone.

It would seem from this section that the blood supply is out of all proportion to the metabolic needs of the tissue supplied and especially if a mechanical function is taken as creating the necessary requirements of those tissues, but it would be in harmony with the constant maintainance of the chemical changes and products which are demanded for the perpetuation of the highly organized dentine and enamel of the teeth.

The conditions of life requires a constant income of the chemical elements of the blood and a corresponding outgo of waste in order to provide the energy of being; in case this relation is greatly disturbed degeneration ensues which in the course of time becomes apparent as a visible pathological state.

4. Cross section of the lower jaw: A, tooth, B, keratinized tissue, C, bone, D, large central canal, E, Blood vessels supplying the teeth.

The section is surrounded by a thin layer of keratinized tissue, the bone cells of the bone are advanced beyond the multipolar as seen by the long, narrow lacunae which are the lacunae of later differentiation. The teeth are very small and sharp-pointed with enamel tips and richly supplied with blood vessels derived from an extensive underlying vascular plexus seen at E. The bone differentiation of the lower jaw is generally more advancd than that of the upper jaw as it is in this case.

5. Cross section of the skull: A, pigmented skin, B, B, external and internal keratinized tissue, C, a very thin layer of bone with the early differentiation of the lacunae, D, brain cavity, E, E, small areas of calcified cartilage.

The skull is a very thin shell of bone between two layers of keratinized tissue, the two lateral wings are divided into small compartments which are surrounded by bony walls bordered with keratinized tissue. The compartments are filled with opaque granules or, in some instances, with calcified cartilage as at E. The central cavity is surrounded by opaque granules.

6. Longitudinal section of an upper tooth: A, homogeneous tip of enamel substance, B, dentinal substance with dentinal tubules extending from the central vascular chamber seen at C, to the borders of the tooth, C, vascular chamber containing a relatively large blood vessel which arises from a large underlying blood vessel seen at D and from which the dentinal tubules are derived, E, clear external border more prominent on the convex side of the tooth.

7. Longitudinal section of upper tooth showing a slightly inferior differentiation from that seen in Fig. 6. A, homogeneous enamel tip, B, a brush-like arrangement of the dental tubules, C, central vascular chamber with its large blood vessels, D, blood vessel supplying the tooth, E, wide structureless dentinal substance with border. The tooth is shorter and stouter than that seen in Fig. 6. Many of these teeth show the brush-like central tubules and wide structureless dentinal substance.

8. Longitudinal section of a lower tooth: A, enamel tip, B, brush-like central tubules, C, central vascular chamber with its large blood vessel, D, supply vessel, E, clear structureless dentinal substance with border.

The teeth are very small and closely set with a relatively large blood supply indicating a higher degree of organization in process of development.

9.-10. Cross sections of upper and lower teeth resepctively showing the central vascular chambers, dentinal tubules and clear dentinal surrounding substance.

In the early teleost vertebrates in which bone and teeth have reached a functional stage of development the dentine shows a higher degree of advancement than the bone; in fact, as soon as dentine appears at all, it seems to be fully differentiated with no indication of an antecedent stage; like the secretion of a secreting gland, it seems to be complete when produced. It would, therefore, be difficult to tell the difference microscopically between early and late dentine.

11. Longitudinal view of the tongue and its bone extension: A, tongue, B, cylindrical bone extension from the tongue backward dividing into three branches at D, C, small teeth on the surface. The organ was attached along its under surface excepting at its anterior portion, the bone appearing as a prominent cylinder. At D, it divides into three distinct branches which are also composed of bone.

12. Cross section of the tongue at A, Fig. 11. A, keratinized tissue surrounding the section and dividing it into quadrants as may be seen at H and I, B, bone trabeculae composed of a clear bone substance with small multipolar cells, granular matter in the meshes of the trabeculae, D, cross section of the cylindrical bone extension as it appears in the tongue, E, granular matter in the canal of the extension.

The section is a reticular arrangement of keratinized tissue and bone enclosing the bone extension and irregularly shaped meshes after the manner of cancellous bone.

13. Cross section of the cylindrical bone extension at C, Fig. 11: A, plexus of blood vessels under and around the teeth, B, external keratinized tissue, C, internal keratinized tissue, D, teeth, E, bone composed of clear bone substance in which are multipolar cells.

The section shows two layers of keratinized tissue between which is a rich plexus of blood vessels underlying the small teeth of the surface composed of dentine and enamel tips, thus presenting the close relation of keratinized tissue and the circulatory system to the teeth. The multipolar bone cell bone forming the base of the organ is also significant of the primitive association of keratinized tissue, bone and circulatory system in the development of the teeth.

14. A plate from the roof of the mouth covered with small teeth. A, a very thin base of connective and osteoid tissue, B, very small pointed teeth directed backward. There are two plates, one on either side of the median line.

15. Multipolar bone cells from the bone stem of the fin and vertebra. The cells vary somewhat in shape and their dendrites and are not symmetrically placed in relation to the cell body; the bone substance is very slightly striated indicating an early lamellar plan.

16. Longitudinal section of the upper jaw showing a variation in the cells. The bone cells are long and narrow and slightly branching occupying lacunae in the bone substance, thus showing a departure from the multipolar stage.

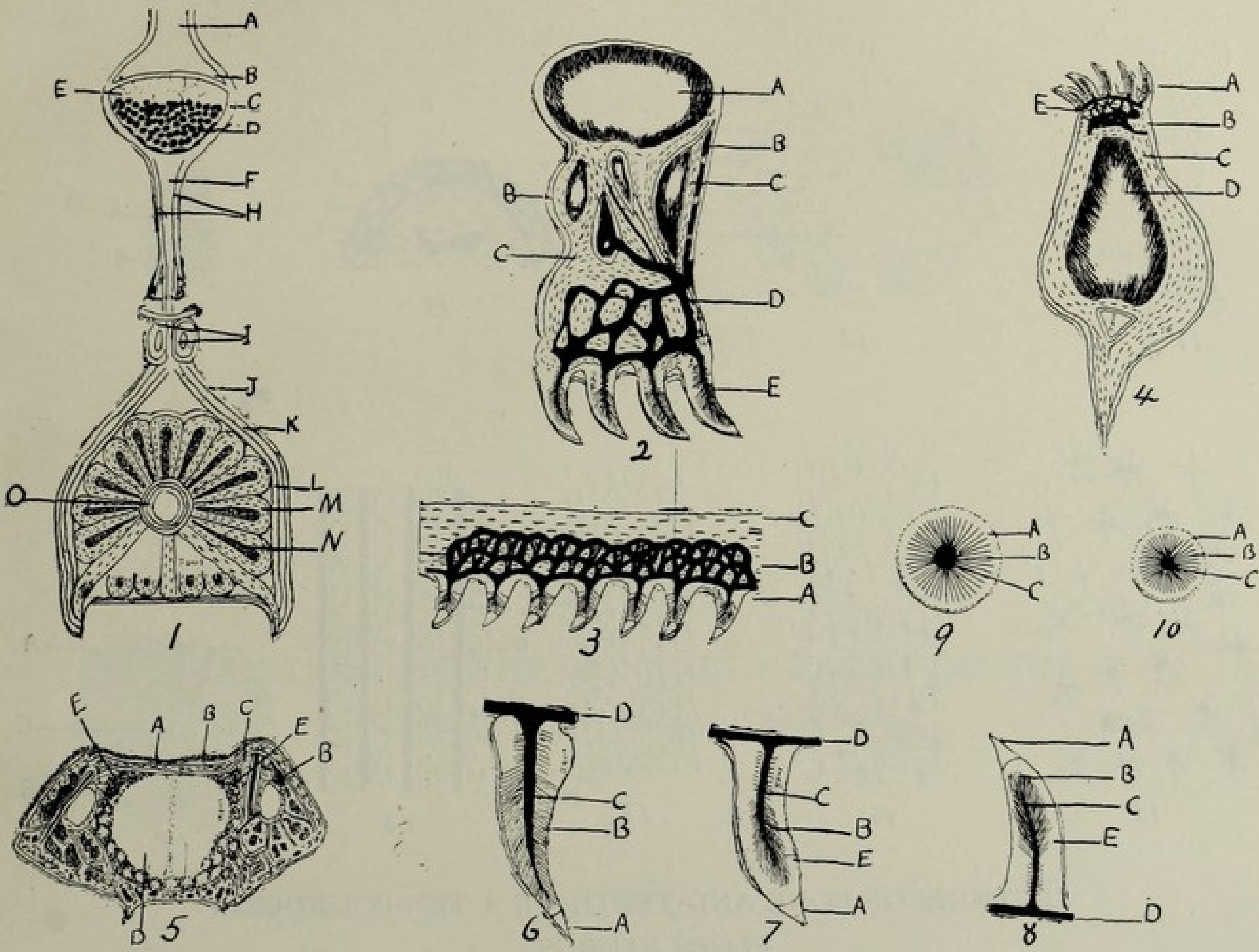
17. Longitudinal section of the lower jaw. The bone cells are long and narrow and arranged in parallel rows indicating a lamellar plan of differentiation. Figures 15, 16, 17, call attention to the progressive differentiations of bone in the different portion of the skeleton indicating that development is not uniformly advancing in the skeleton as a whole, but shows a greater degree of differentiation in some portions than in others.

18. Longitudinal section of a portion of the dorsal fin: A, bone, B, blood vessel, C, keratinized tissue, D, cross, vascular canals. The bone cells are long and

narrow, the bone substance clear, the blood vessels are large and arranged adjacent to the keratinized tissue; small vascular canals cross the bone at frequent intervals. The fin, therefore, shows the intimate association of the same tissues as were seen in the formation of the teeth.

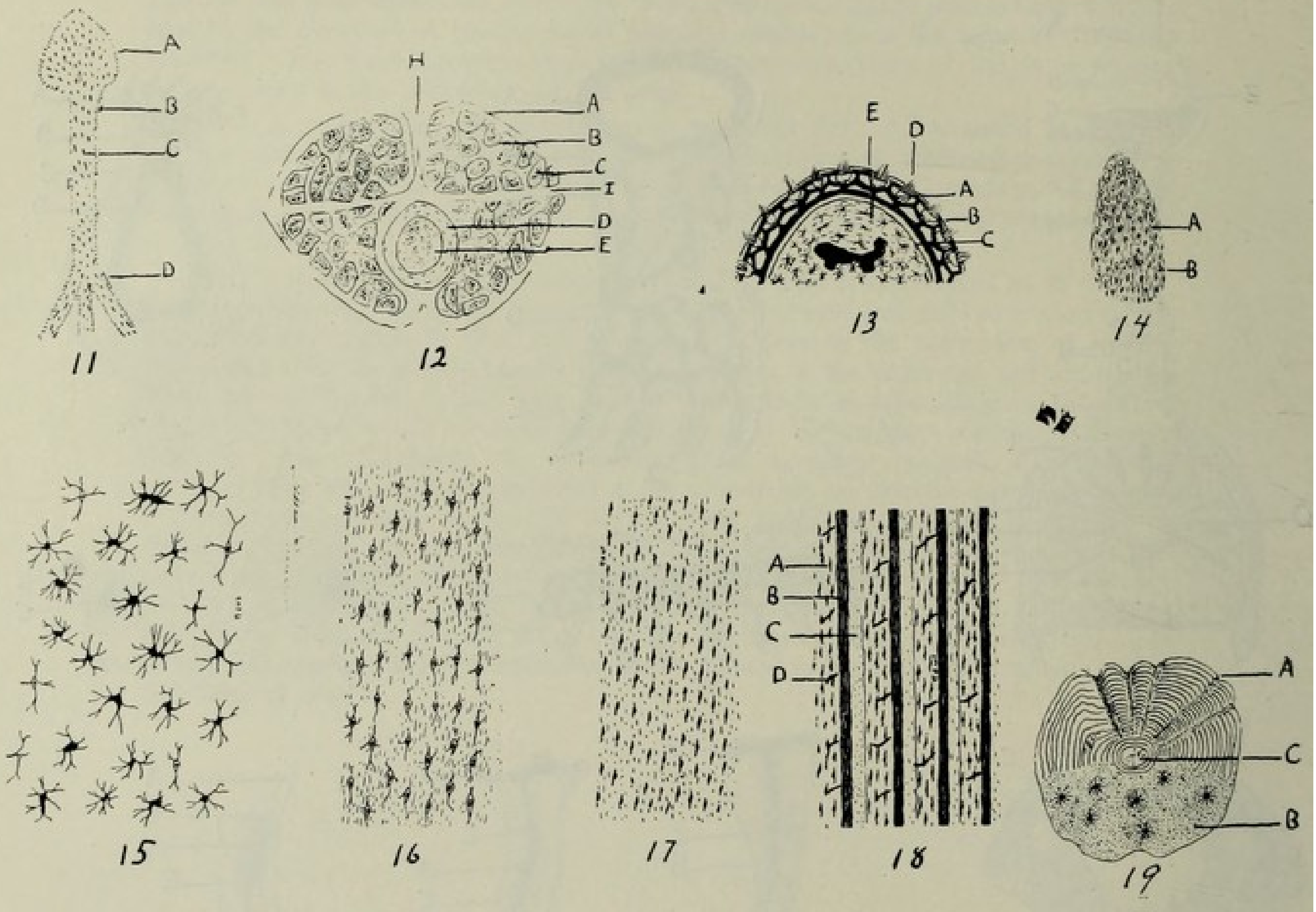
19. A scale from the dorsal region mounted flat: A, detached lamellated portion arranged in radiating, large and small divisions, B, attached portion composed of a granular substance in which are pigmented cells, C, nucleus. There is no evidence of dentine or bone in these scales as was found in the elasmobranch or later fishes.

The Ten-pounder is especially interesting because it introduces us to the distinct departure of the vertebrate from cartilage to bone and calls attention to the continued association of bone and keratinized tissue in the formation of important organs like the fins and teeth. The bone varies in the degree of differentiation from the multipolar to the long narrow cell which is advancing in character. There are found small areas of calcified cartilage indicating a structural antecedent of bone. Evidently the transition from cartilage to bone was gradual, while dentine and enamel appeared at once without an intermediate antecedent, that is, from cartilage to bone is the rule, but not from cartilage to dentine or enamel; however, in some instances as indicated in the Bowfin, the transition from bone to dentine without a cartilage antecendent is determined. The absence of bone, dentine and enamel from the scale, the presence of bone in the vertebrae, jaws, skull and fin and the presence of dentine and enamel in the teeth only shows the approaching limitations of these tissues to their objective points in the histology of organs.



SECTIONS OF BONE AND TEETH OF A TEN-POUNDER—
ELOPS SAURUS.

1. Cross section of dorsal vertebrae with its extension into the fin.
2. Cross section of the upper jaw.
3. Longitudinal section of the upper jaw.
4. Cross section of the lower jaw.
5. Cross section of the skull.
6. Longitudinal section of an upper tooth.
7. Longitudinal section of an upper tooth.
8. Longitundinal section of a lower tooth.
9. Cross section of an upper tooth.
10. Cross section of a lower tooth.



SECTIONS OF BONE AND TEETH OF A TEN-POUNDER—
ELOPS SAURUS.

11. Longitudinal view of the tongue and bone extension.
12. Cross section of the tongue at A, Fig. 11.
13. Cross section of the cylindrical bone extension at C, Fig. 11.
14. A plate from the roof of the mouth with small teeth.
15. Multipolar bone cells from the stem uniting the fin to the dorsal vertebra.
16. Bone cells from a section of the upper jaw.
17. Bone cells from a section of the lower jaw.
18. Longitudinal section of the dorsal fin.
19. A scale from the dorsal region.

A STUDY OF THE BONE AND TEETH OF THE BOWFIN—AMIA CALVA.

SECTIONS OF THE BONE AND TEETH OF THE BOWFIN-AMIA CALVA.

1. Cross section of a dorsal vertebra.
2. Floor of the mouth.
3. Section of the central upper jaw with tooth in position.
4. Section of upper middle front tooth and a portion of the jaw.
5. Section of the upper jaw with a small tooth in position.
6. Three small teeth of a central group in the upper jaw.
7. Section of a single upper tooth showing its relation to bone.
8. Section of the lower jaw with a tooth in position.
9. Section of a single tooth of the lower jaw and its setting in the bone.
10. Cross section of an upper tooth.
11. Section of lower jaw with tooth in position showing its relation to bone.
12. Tangential section of the lower jaw showing multipolar bone cells.
13. Longitudinal section of two rays of the pectoral fin showing bone structure.
14. Cross section of two rays of the pectoral fin showing slight bone differentiation.
15. Cross section of the frontal cranial bone showing skin-like arrangement.

THE BOWFIN-AMIA CALVA.

The Bowfin is one of the existing survivors of the Ganoid fishes which extend backwards in geological history as far as the Silurian Age. The fish is interesting on account of its prehistoric ancestry and its close relation to the line of ancestry of all the higher bone fishes. It may, therefore, be expected to show structural types of bone and teeth and their histological relations to each other at an early period of vertebrate history.

Sections of the vertebrae, cranial bones, mandible, fin and teeth have been made and examined microscopically, a report of which is submitted below: It has been assumed, in these comparative studies, that the early type of bone is accompanied by an early type of teeth and it is for this reason that studies of the teeth have included studies of bone.

Fig. 1. Cross section of a dorsal vertebrate through the proximal portion of two ribs. The body of the vertebrate is irregularly hexagonal in shape, the ventral half, V, having three concave surfaces between the ribs, the dorsal, D, having one and each one of the lateral halves, one. The body is, therefore, divided into six irregularly shaped triangular compartments by narrow partitions of bone carrying blood vessels and extending from the center to the angles of the ventral and dorsal surfaces, A. In the center is a very small canal, C, surrounded by a clear nucleated ring of bone substance, B, which, in turn, is surrounded by a dense plexus of blood capillaries, L, from which vessels are sent off through the radial bony partitions, N; on their way from the center to the surface angles, these vessels send off branches into the alternating layers of bone F. The triangular portion of the body are composed of concave alternating layers of bone and vascular channels in the ventral and lateral portions F, O, and of globular, granular masses in the dorsal and inner portions of the lateral divisions, M, D. The proximal portions of the ribs are composed of central narrow-like vascular masses enclosed within walls of bone which contain blood vessels H. In the outer portion of the central capillary plexus is a cross section of a blood vessel K,

extending parallel with the vertebrae. The bone substance of the section is extremely early in type since it contains few cells and these are multipolar resembling nerve cells.

The section shows several interesting features: The alternating narrow layers of bone and vascular channels in the ventral half and the vascular granular masses in the dorsal half; the extensive circulatory system coming up from the center and throwing off radicals and laterals which produce bone and lay it out according to the architecture of the circulatory system. By developmental pressure, the vascular channels diminish in width as the bone increases and we catch a glimpse of lamellae in the process of formation.

The dorsal half of the vertebrae is earlier in the degree of differentiation than the ventral since it has less bone and more vascular channels. The intimate connection of the central vascular channel of the ribs with the alternating similar channels of the vertebrae, making the rib a part of the vertebra and both important parts of the vascular system. The early character of the multipolar bone cells in their relation to the branching type of connective tiusse cells is suggestive of the common origin of tissue varieties. The vascular character of the vertebrae suggests a physiological rather than a mechanical importance to bone.

The Mouth: Fig. 2, represents the floor of the mouth as seen within the mandible and is about natural size. There are four toothed bony rays, A, on either side of a bony toothed tongue, E, all converging from the posterior portion of the mouth to the anterior, lateral portion of the tongue forming a bluntly triangular body which presents a formidable surface of teeth. Each ray has a center of vascular bone of very early differentiation with gills along its inferior and bony buds of small teeth, C, along its superior surface. The rays are separated by spaces B, freely admitting the passage of water over the gills. The teeth are small pointed cones curving backwards. The tooth buds alternate on the two sides of the rays. The tongue-like body, E, is composed of very vascular bone covered by a sharp toothed surface. There was no evidence of shedding of the teeth.

The mandible is a vascular bone with a large central canal having large curved pointed teeth along its free margin none of which show signs of shedding. They are firmly anchored to the jaw. The bone of the jaw is composed of undifferentiated bone substance and multipolar cells resembling some branching connective cells or multipolar nerve cells.

Fig. 12. The superior maxilla has a bone structure of the same early differentiation. It has two rows of pointed curved teeth of varying sizes along its free border and behind them five separate groups of small curved teeth, sixteen in each group, all firmly set in the bone. The roof of the mouth is thickly set with very small teeth.

The whole mouth presents a formidable display of prehensible powers by such an array of organs called teeth and which give significance to the first and perhaps the most important function of teeth in vertebrate history, prehension. The change from prehension to mastication produced a very important change in the mechanical character of the later teeth as we find them in man, since the transformation of the primary function of an organ to a secondary may be followed by a pronounced disturbance of a physiological nature which reduces the functional value of that organ to a pathological degree.

3. Antero-Posterior Section of the Central Portion of the Superior Maxilla with Tooth in Position.

A, A, cross section of a portion of the cranial bone enclosing a large space or cavity represented at S. The bone is perforated by numerous vascular canals extending transversely as at C, it is composed of clear bone substance dimly marked off in coarse lamellae which are occupied by rather infrequent multipolar bone cells F, and crossed by canaliculi L. The bone is very early in type of differentiation. D, group of branching blood vessels at the base of the tooth which are enclosed in bone. E, brush-like extensions and expansions of these vessels into fine radiations R, which become the dentine tubules at H. I, a very wide pulp chamber enclosed by a narrow dentinal wall H. K, homogeneous tip. The section is interesting on account of the vascular early type bone and the relation of the dentine of the tooth to the circulatory system and the enclosing bone which apparently merge into the tooth.

4. Longitudinal Section of an Upper Middle Front Tooth and the Portion of Bone from which it Sprang.

A, Multipolar cell and channelled bone also very early in type of differentiation, the channelled bone substance being produced by cells (possibly endothelial) within the circulation and the bone substance of the multipolar cell bone by cells external to the circulatory vessels. B, vascular canals extending transversely in the bone. G, group of blood vessels in the bone at the base of the tooth sending off fine vascular radiations which, with the fine intervening bone radiations, merge into the dentine of the tooth D. E, nucleated dentine, F, homogeneous border, P, pulp chamber. In a study of this section no line of demarkation between the bone and tooth was determined, but the former seemed to merge into the latter. Large prominent nuclei were seen in the lower portion of the dentine which were in direct connection with the dentine tubules as at N. The nuclei do not represent the multipolar type of bone cell seen in the bone from which the tooth was derived, but a later type of bone cell seen in the bone structure of later bone differentiations. During the process of grinding these combined sections of bone and teeth, a subjective sense of increasing hardness is experienced at the junction of the bone and the tooth. While the difference in inorganic percentage of bone and dentine is recognizable, the exact location of the site of transformation is beyond microscopic vision. If bone substance is 67% and dentinal substance is 72% inorganic, the one could not be told from the other by the sense of vision. In both there is chemical combination of an inorganic base with inorganic salts of such a character that they may be separated by heat or acids, but not by a sense of vision. If we could have dentinal substance alone and bone substance alone, a comparison would be altogether chemical and not histological. Such an intimate relationship suggest a common origin.

5. Longitudinal Section of a Small Tooth in the Upper Jaw and the Bone of Its Setting. These small teeth were situated posterior to the larger teeth described above.

A, Bone of the same multipolar cell type as described above, O, small areas of channelled bone are also seen. B, Bone at the base of the tooth merging into dentine. C, Dentine. E, Border of the tooth. N, Nuclei of the dentine. D, Vascular canals and circulatory system around the base of the tooth. P, pulp chamber. T, Homogenous cap. The bone of the jaw, A, has a lower degree of differentiation than the bone of the base of the tooth and also lower degree of hardness.

The cells of the jaw bone are the early multipolar cells, O, while those of the base of the tooth are the long narrow cells, N, of the later bone differentiation and are found extended into the dentinal walls where they communicate with the dentinal tubules as they do in bone by the canaliculi, making an osseous dentine. The external homogeneous border, E, takes its origin around the base of the tooth as a bone product and gradually becomes thinner as it extends along the dentinal wall where it is reduced to a thin envelope until it reaches the tip where it expands into the homogeneous cap, T. It has the appearance of an enclosing capsule.

6. Three Small Teeth and Their Setting of a Central Group in the Upper Jaw.

A, bone of the jaw, showing the early multipolar cell differentiation. B, circulatory system and bone at the base of the teeth merging into dentine, C, horn-like layer covering the bone. D, Dentine or osseous dentine. N, Nuclei. E, Border.

This section is cut through the centers of the teeth and shows the enclosing border, dentinal wall, pulp chamber and the extensive circulatory plexus in the bone at the base of the teeth. It presents the same interesting features as section 5.

The early type of bone differentiation of the jaw bone, A, indicated by the clear bone substance and multipolar cells, compared with the later bone differentiation indicated by the long narrow lacunae, with their enclosed bone cells, N, and the gradual transformation of the former to the latter, together with the increased density which accompanies the change, suggests the possibility of the increased calcium percentage in the osseaus dentine to meet the requirements of the new and different objective, prehension. The extensive circulatory system in the bone under the teeth indicates the site of great metabolic activity and the part which the vascular system has in the adaptation of a general bone differentiation to a special. The homogeneous border, E, is also seen as an enclosing capsule with very little in the form of a cap. The cells occupying the lacunae of the dentinal walls, N, sections 3, 4, 5, 6 ,7, 8, 9, 11, do not have the location or shape of odontoblasts which, in later teeth, belong to the pulp chamber. Their long axes are parallel with the long axes of the teeth and most numerous in the basic portion of the teeth. They resemble osteoblosts in shape, arrangement and situation rather than odontoblasts and may be supposed to produce an osteo-dentine if anything.

7. Section of a Single Upper Tooth Showing its Relation to Bone.

A, A, Bone of the jaw with long narrow lacunae and long straight canaliculi; the bone differentiation is in advance of that seen in the foregoing sections. B, dentine of the tooth. C, nuclei of the bone. N, nuclei of the bone and dentine. D, junction of the bone and dentine. The bone, A, A, form the cells of a large cavity in the cranial bone, indicated by S. In this section the tooth is seen arising from the junction of the two bony walls of the cavity, S. Along the interior borders of these walls is a dense arrangement of nuclei and coarse canaliculi, C; the canaliculi extends across the thickness of the wall of bone passing through the long, narrow bone lacunae on their way. At the junction of the two walls, D, the nuclei increase, the canaliculi change their direction and as we follow them the canaliculi apparently become the dentinal tubules and the bone nuclei are arranged in the dentinal walls about as they would be in bone. The section is interesting in that it shows the close relation of bone to dentine in the earliest forms of vertebrates.

8. Section of the Lower Jaw with Tooth in Position.

A, dentine of the tooth. B, jaw bone of the early differentiation. C, vascular canals of the jaw bone. N, nuclei of the dentine. This section shows one of of the tooth. E, bone between the extensions. F, structureless border. H, vascular canals of the jaw bone. H, nuclei of the dentine. This section shows one of the larger teeth of the middle, front region of the lower jaw and its setting in bone. The jaw bone is very vascular as may be seen by the numerous vascular canals as at H and C. The bone is composed of a clear bone substance crossed by long canaliculi and containing the early multipolar cells of primitive bone. Such bone has little or no resemblance to the bone of the later vertebrates. Just underneath the tooth is a prominent vascular canal C, which, with its many extensions, assumes the form of a vascular plexus. It throws off many bush-like vascular extensions which enter the site of the tooth. Between the extensions are small areas of bone E. The fine vascular radiations, with their intervening radiations of inorganic substance, advance by the developmental force within the circulatory system carrying with them cells which have the power of producing an inorganic instead of an organic substance and become the dentinal tubules and intervening inorganic substance of the tooth. The cells are enclosed within the dentinal wall in lacunae which communicate with each other and with the circulatory system of the pulp chamber by the large canaliculi called dentinal tubules. The lacunae of the dentinal walls are much more numerous in the basal portion of the tooth and diminish in frequency toward the upper portion where they finally disappear. The lacunae are bone lacunae and by their peculiar shape and arrangement suggest osteoblasts and not odontoblasts. The structureless border F, arises in the bone around the base of the tooth and follows the advancing dentine until it is a mere envelope and then very gradually expands into the cap of the tip of the tooth. The pulp chamber is relatively large and is occupied, as the tooth formation progresses, by the vascular system and its supporting tissue. The order of change in the production of the tooth of this early vertebrate may be stated as follows: 1, Bone; Specialized and localized circulatory plexus; 3, Centrifugal radiations of vascular and inorganic extensions from the plexus; 4, Vascular extensions become the dentinal tubules and the inorganic the osteo-dentine of the teeth.

9. Sections of a Single Tooth of the Lower Jaw Showing Its Setting in the Bone. A, Dentine of the tooth. B, Portion of the jaw bone. C, Plexus of blood vessels in the bone at the base of the tooth. D, Structureless border. E, Wide pulp chamber. N, Lacuna of the dentine. The bone of the jaw is very vascular and shows the early type of differentiation as was seen in other sections. Underneath the tooth is a dense plexus of blood vessels, C, enclosed in bone, from this plexus fine vascular and inorganic radiations extend upward where they become the dentinal tubules and substance. The cells coming up from the plexus are enclosed in the lacunae in the dentine N. Minute interglobular spaces were seen just under the outer border. The circulatory system of the dentine is very close to the general circulatory system, the dentinal tubules being extensions from the vascular plexus C. The border takes its rise, as in other sections, around the base of the tooth in the bone underneath the plexus.

10. Cross Section of an Upper Tooth.

A, Structureless border. B, Pulp chamber. C, Dentine. D, Outer concentric row of nuclei. E, Inner concentric row of nuclei. The cross section shows some interesting features: a spray of bone, dentine or osteodentine producing cells arising from the bone substance and circulatory systems of the jaw, Fig. 9, H, separates into two diverging columns, outer, D, and inner, E, arranged in the osteo-dentine of the tooth as shown in Fig. 10. The two concentric rows of lacunae or cell spaces D and E are connected by long, large canaliculi or dentinal tubules C. The inner lacunae E are situated in the osteo-dentine just outside of the pulp chamber and are long and irregular in width; they communicate with the pulp chamber by short tubules which, after passing through the lacunae, extend across the field of osteo-dentine into the outer row which is also composed of irregular spaces and situated a short distance within the external border A. After passing through this outer row, the tubules, often thicker than elsewhere, terminate in branches which communicate with very small irregularly shaped spaces reminding one of very minute interglobular spaces. By this structure and arrangement the circulatory system of the tooth of this early vertebrate is very extensive and admits of an inorganic metabolism of great activity, which is housed by the pulp chamber.

11. Sections of the Lower Jaw with Tooth in Position.

A, Area of blood vessels and bone merging into the osteo-dentine of the tooth. N, Lacunae and their cells arising from bone cells and becoming the cell spaces and cells of the osteo-dentine. B, Multipolar bone substance of the jaw bone. C, channelled bone and D, vascular canals in the bone. E, External border arising from the bone at the base of the tooth. V, Vascular canals. S, Small teeth. This section is highly interesting on account of the apparently close relation of the tooth to the bone of the jaw. In the various sections of the Bowfin in which both bone and teeth have appeared, the possible origin of tooth from bone has been suggested so frequently that it has become almost a conviction. In the present section there is further evidence of it. There is an extensive plexus of blood vessels under the tooth and in its meshes is a bone substance of early differentiation. From this plexus, small vessels are sent off into the base of the tooth which is nearly enclosed by the external border of the tooth E. There is no visible line of demarcation between the bone of the jaw and the tooth, but the former seems to become the latter by the bone canaliculi becoming the dentinal tubules, the bone cells becoming the dentinal cells and the bone substance, the dentinal substance by virtue of a transforming power residing in the biological demand for a new tissue to meet the requirements of an advancing level. The bone from which the tooth is apparently derived is very early in type of differentiation and, perhaps, the last to be thought of in tooth formation; but this animal belongs to the very early vertebrates and in the interest of self preservation, the operation of a biological law toward the fitness of survival was essential and introduced prehension as a means toward that end. There was no adequate tissue, exclusive of bone, which promised success and even if this was available, it required additional strength in order to serve the purpose of a new and different office. In the interest of survival of the early vertebrates, prehension was a necessity; in the interest of prehension, special organs called teeth were necessities; in the interest of spcial organs or teeth, a special act of metobolism under the direction of a biological impulse was a necessity. There had not been established in the early vertebrate an inorganic substance of greater density than the early differentiation of bone and if Nature intended this for the special purpose of prehension, it would be necessary to increase its inorganic percentage and this was done by a biological transformation of a bone cell to a cell of higher organization, called for convenience, a dentinal cell and bone substance to osteodentinal substance. In this section may be seen the early multipolar cell bone at B, and the later differentiation at A and N, which is indicated by the change in the cell from multipolar to the long narrow cell of later bone and the change in the density of the bone substance at B to a higher degree of density at N and recognized by the subjective feeling of increased hardness during the process of grinding. As the bone of the vertebrate, and especially of the early vertebrate, is very vascular, metabolic changes are active and structural variations are numerous.

12. This is a tangential section of a portion of the lower jaw showing the clear bone substance A and multipolar cell B. The cells are very thickly set and communicate with the blood vessels of the vascular canals by means of their branches.

13. Longitudinal section of the two rays of the pectoral fin. A, Early type of bone showing the outward spread of the ray at B. C, Reed-like cross divisions of the ray. D, Circulatory vessel. The object of making a section of the fin is to determine its connective and degree of histological differentation. A physical division of labor might be expected to show a histological division of differentiation. The fin is a specialized organ of locomotion, a part of the osseous system and some variation in histological structure which would adapt it to a different purpose than that required of the general skeleton might, in the nature of things, be expected. There is, however, no difference in structure. The rays have the same early multipolar bone cell structure; but their purpose is indi-

cated by their fan shaped arrangement. As the rays leave narrow hinge-like attachment to the body, they split as at B, and the parts diverge to form the outer wide portion of the fin.

14. Cross Section of Two Rays of the Pectoral Fin Showing a Slight Indication of Differentiation.

A, Early bone type. B, Circulatory vessel between the rays. C, Indication of the bone substance marked off in lamellae. By this plan of arrangement the strength of the organ is increased. The rays are held together by a supporting tissue which carries a blood vessel of considerable size, B. The fin is very vascular.

15. Cross Section of the Frontal Cranial Bone.

A, Outer covering or skin. B, Underlying papillary bone. C, Vascular canals. The section is interesting in its resemblance to a cross section of the skin. The outer covering, A, is thin and fits over the bone which has an upper papillary arrangement like the dermis, B. The bone has the early type of differentiation with numerous vascular canals extending antero-posteriorly; from these many small canaliculi come off and traverse the bone substance which is dimly marked in parallel lines.

SUMMARY.

The outstanding features of this examination of the Bowfin may be enumerated as follows:

1. The vascular osseous character of the entire mouth thickly set with teeth of various sizes apparently arising from bony attachments.

2. The absence of any evidence of shedding of the teeth or the formation of new teeth from any portion of the mouth.

3. The early vascular multipolar cell bone of the whole skeleton.

4. The apparent origin of more or less bone-like teeth of a later differentiation.

5. The localization of long narrow lacunae containing cells of the same shape, in the dentinal walls instead of odontoblastic cells in the pulp chamber.

6. The apparent origin of the external borders of the teeth from bone at the bases of teeth and their clear, structureless character which bears no resemblance to enamel or the cementum of later teeth.

7. The dense plexus of blood vessels in the bone under the teeth sending off spray-like extensions of fine vessels, accompanied by long, narrow cells, into teeth.

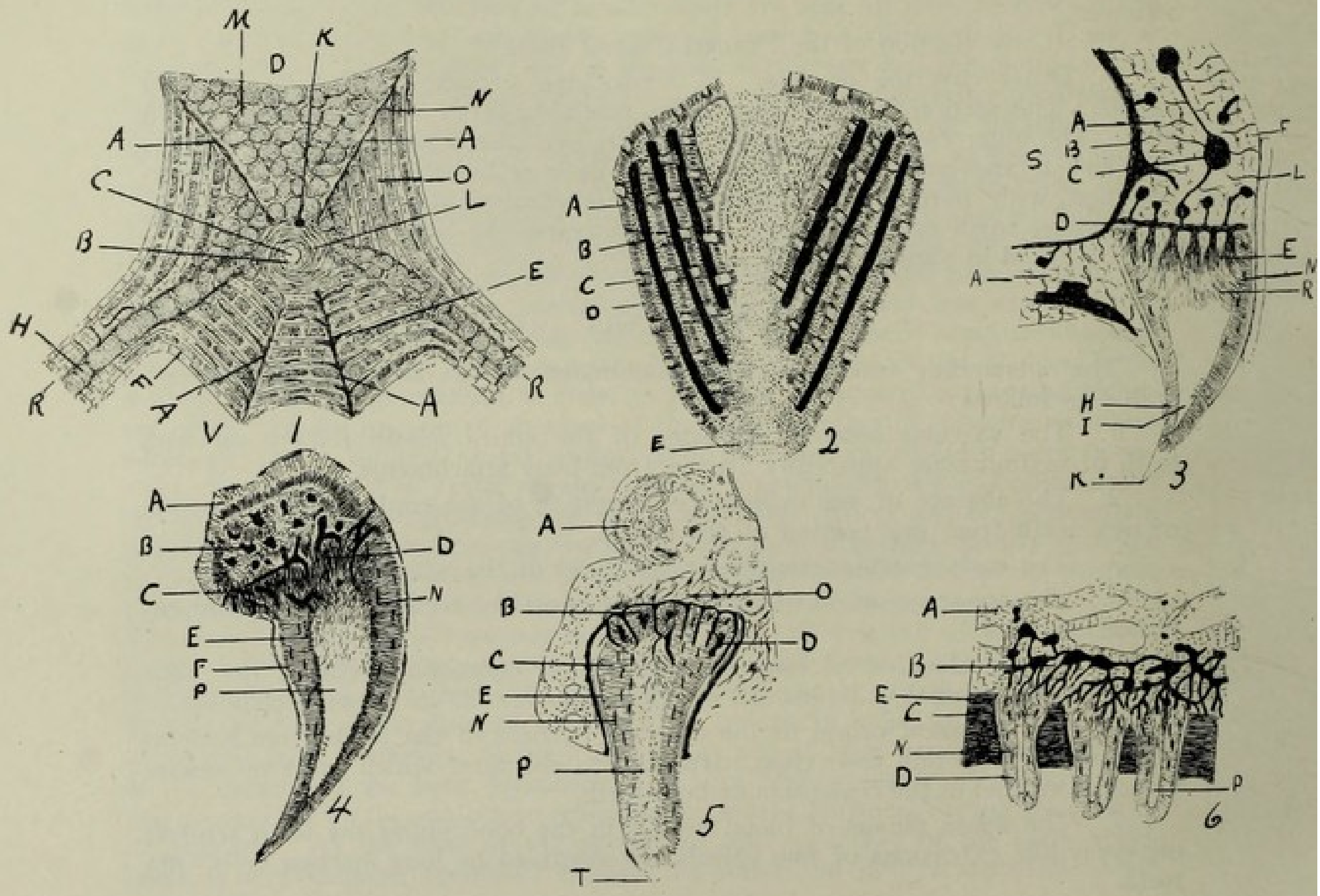
8. The origin of dentinal tubules from the canaliculi of bone.

9. The relatively wide pulp chambers and dentinal tubules.

10. The vascular condition of the dentine or osteo-dentine dependent upon the size of the tubules and their passage through two parallel rows of dentinal lacunae and their communication by means of minute interglobular spaces situated under the external borders.

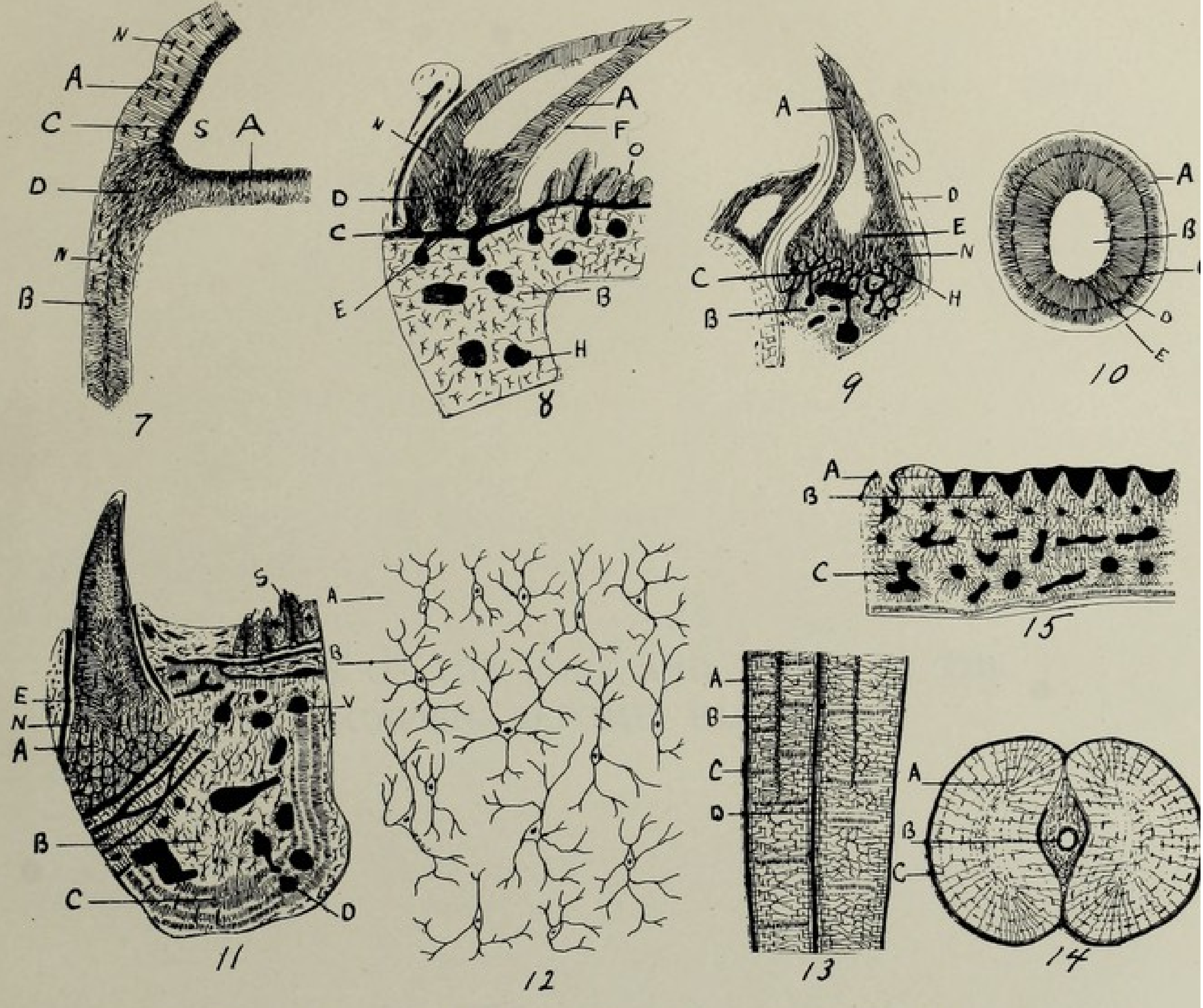
The most interesting and perhaps the most important of the above mentioned features is the apparent origin of tooth from bone or as it may be stated more precisely, the apparent origin of both from the circulatory system; the circulatory system first, the formation of bone second and the formation of the tooth third. The steps of the process may be briefly indicated as follows:

The localization of the blood plexus in a definite area of the early type jaw bone, the spraying off of fine vascular extensions and cells from the plexus, the change from the early type of bone to a later, indicated by an observed change in the shape of the cell from multipolar to the long and narrow cell of later bone, the vascular extensions of the plexus becoming the dentinal tubules, the arrangement of the new bone-like cells in parallel rows at the base of the tooth, the production, by these cells, of an inorganic substance of higher inorganic percentage than that of bone substance, called osteo-dentine for convenience, the growing away of the newly formed organ from the vascular plexus as a tree from its roots, seems to be the crude picture of the origin of the bone and tooth in the early type of vertebrates.



SECTIONS OF BONE AND TEETH OF THE BOWFIN-AMIA CALVA.

1. Cross section of a dorsal vertebra.
2. Floor of the mouth.
3. Section of the central upper jaw with tooth in position.
4. Section of upper middle front tooth and a portion of the jaw.
5. Section of the upper jaw with a small tooth in position.
6. Section of three small teeth of the upper jaw and a portion of the jaw bone.



SECTIONS OF BONE AND TEETH OF THE BOWFIN-AMIA CALVA.

7. Section of a single upper tooth showing its relation to bone.
8. Section of the lower jaw with a tooth in position.
9. Section of a tooth of the lower jaw and its setting in the bone.
10. Cross section of an upper tooth.
11. Section of a tooth of the lower jaw and its setting in the bone.
12. Tangential section of the lower jaw showing multipolar bone cells.
13. Longitudinal section of two rays of the pectoral fin.
14. Cross section of two rays of the pectoral fin.
15. Cross section of frontal cranial bone.

A STUDY OF THE BONE AND TEETH OF THE SUNFISH—LEPOMIS PALLIDUS.

A STUDY OF THE BONE AND TEETH OF THE SUN-FISH—LEPOMIS PALLIDUS.

The sun-fish is a primitive member of the highest group of Teleosts or bony fishes.

In this section the cartilage has been displaced by bone.

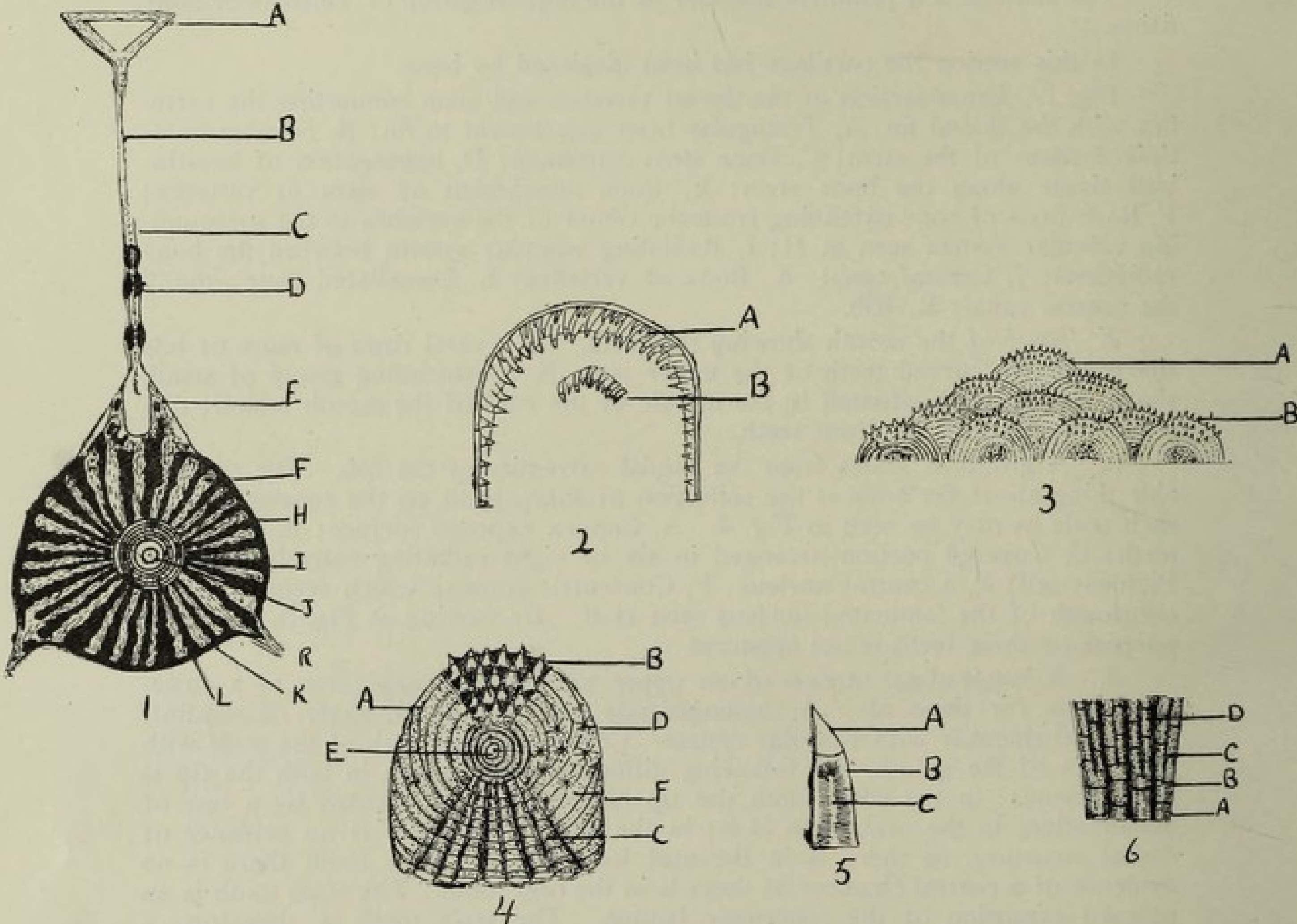
Fig. 1. Cross section of the dorsal vertebra and stem connecting the vertebra with the dorsal fin. A, Triangular bony attachment to fin; B, Slender keratinized tissue of the stem; C, Bone stem continued; D, aggregation of keratinized tissue along the bone stem; E, Bone attachment of stem to vertebra; F, Radiations of bone extending from the center of the vertebra to the surrounding vascular system seen at H; I, Radiating vascular system between the bony radiations; J, Central canal; K, Body of vertebra; L, Lamellated bone around the central canal; R, Rib.

2. Roof of the mouth showing the teeth. A, several rows of more or less sharp pointed, curved teeth of the upper jaw; B, a protruding group of small, sharp, curved teeth situated in the middle of the roof of the mouth a short distance posterior to the front teeth.

3. A group of scales from the caudal extremity of the fish. The remarkable thing about the scale is the collection of sharp teeth on the convex area of each scale as may be seen in Fig. 4. A, Convex exposed surface; B, Group of teeth; C, Covered portion arranged in six or eight radiating convolutions; D, Pigment cell; E, a central nucleus; F, Concentric laminae which seem to be the outgrowth of the laminated nucleus seen at E. By looking at Fig. 3, the exact purpose of these teeth is not apparent.

5. A longitudinal section of an upper tooth which may serve as a structural type for them all. A, homogeneous enamel tip; B, shaft of dentine. C, central chamber with vascular system. Comparing the tooth of the scale with the tooth of the mouth, the following differences are noted; in both the tip is homogeneous; in the scale tooth the tip is not sharply indicated by a line of demarcation, in the oral tooth is it; in the scale tooth there is no evidence of dental structure, as there is in the oral tooth; in the scale tooth there is no evidence of a central chamber as there is in the oral tooth. The scale tooth is an upward extension of the concentric lamina. The scale tooth is, therefore, a tooth in shape and general appearance, but not in structure. Physiological death has a purpose of great value in animal life as may be seen in the epidermis of the skin; the cells of the stratum muscosum of the epidermis are living, actively dividing cells; as they multiply, they push their way toward the surface and on their way they receive from the stratum granulosum and stratum lucidum, a kerato-hyalin incorporation and as they become cells of the stratum corneum, they are flattened, lifeless keratinized cells of the nature of horn (whence the name stratum corneum) for protective purposes. A callous is an intensified example of such a physiological death. There being no blood supply the cells become, by concentration, hard and horn-like. Physiological death with inorganic concentration may account for the formation of the tooth-like scales of this fish.

6. A portion of the dorsal fin seen flat-wise: A, reed-like jointed ray separating at B, into two, which accounts for the widening of the fin as it leaves the body; C, joint; D, blood vessel and pigmented connective tissue holding the reeds together.



BONE AND TEETH OF THE SUN-FISH—LEPOMIS PALLIDUS.

1. Cross section of a dorsal vertebra and stem leading to dorsal fin.
2. Diagram of the roof of the mouth showing location of the teeth.
3. A group of scales from the caudal extremity.
4. A single scale.
5. Longitudinal section of an upper tooth.
6. Portion of the dorsal fin.

A STUDY OF THE BONE AND TEETH OF THE LAKE TROUT—SALMO FEROX.

THE BONE AND TEETH OF THE LAKE TROUT—SALMO FEROX.

The vertebrae are differentiated into complete bone, having lost the cartilaginous characters of the early types of fishes. The vertebral column is divided for convenience, into the trunk and caudal regions. Cross sections of the vertebrae are introduced for the reason that they represent the bone differentiation of the animal and may influence the differentiation of the teeth, and because they furnish convincing evidences that bone substance is produced by cells in the circulatory system.

Fig. 1 is a cross section of a trunk vertebra. The section is taken a little to one side of the mid-lateral line. It has an irregular peripheral boundary and a central canal which is nearly circular. Beginning with the central canal and working outwards are the following structures: The central canal is small and has a fine connective tissue framework which carries blood vessels that appear in cross section, Fig. 1 C. Passing radially from these vessels to the periphery of the canal are seen small branches which assume a circular arrangement around the wall, Fig. 1 D. From these branches very fine vessels intermingle with larger ones, pass outward into the bone substance which forms the enclosing ring, Fig. 1 E. External to this ring is a narrower clear layer containing a few scattering lacunae in a homogeneous bone substance, Fig. 1 B. This layer, however, shows a fine longitudinal striation with the fine adjustment. The radial vessels are faintly visible. External to this layer is a wider, distinct ring, very finely striated circularly and having long narrow lacunae arranged in parallel circles which indicate the lamellation although the separate lamellae are not plainly distinguishable. The ring is crossed radially by large and small vascular canals passing outward from the central canal, Fig. 1 A. Between the circular striations and the radial canals, is the bone substance. External to this ring is the wide irregularly shaped ring of bone substance forming the principal portion of the vertebra, Fig. 1 N. This is crossed by the small and large radial vascular canals from the central canals and these again are crossed by concentric groups of fine, more or less wavy canals which appear as evidences of incremental expansions of bone substance. Around the mid-line of the section are seen open spaces which are cross sections of the cone-shaped indentations around the smaller circumference of the vertebra, Fig. 10. The bone substance of this ring is striated circulary and is lamellated as indicated by the long, narrow lacunae in parallel rows. As a whole this picture presents a view of the organization of bone structure which appears in different stages in the vertebrae of the fish. It is especially interesting since it calls attention to the early formation of bone and its relation to the circulation. The incremental circular additions and their relation to the radial vascular canals remind one very forcibly of the incremental rings of a cross section of the trunk of a tree, in their relation to the circulatory system.

The mouth of the Lake Trout is large and well supplied with the prehensile teeth, situated in the maxilla, in the palatine and vomerine bones, in the mandible and in the tongue.

Fig. 2, is the right half of the lower jaw as seen from the inside. The drawing shows the arrangement of the teeth, their ankylosis, blood supply and shedding. The bone is 50 mm. in length, has seven sharp, cone-shaped teeth, separated by quite wide intervals, firmly ankylosed by a broad base to the upper ridge of the jaw bone. In the base of each tooth, Fig. 2 D, is seen the entering canal of the oral blood vessel, Fig. 20. Between the teeth are seen at intervals, the stumps of those teeth which are partly shed, Fig. 2 A, and in the bone of the jaw after the teeth have been completely shed, Fig. 2 E.

Fig. 3, is a drawing of a single tooth showing its parts. It is a hollow cone, straight when seen from the lingual side. It is composed of a translucent solid tip, Fig. 3 A, a shaft, Fig. 3 B. A base which is a mere shell, Fig. 3 C, ankylosed to the jaw bone, Fig. 3 E. In the center of the base is seen the entering vascular canal, Fig. 3 D.

Fig. 4, is a cross section of the jaw bone with a tooth in position and being veiwed from the side is curved.

Structure: The tooth is enclosed with a thin striated sheath presenting the appearance, in a fresh specimen, of a connective tissue formation Fig. 4 A. Underneath this is a narrow sheath of tooth substance marked off by fine radiating lines, Fig. 4 B. This sheath has the situation of enamel and is slightly yellowish in color. It is composed of some inorganic compound and with its short radial lines, has a slight resemblance to a thin enamel, but its position on the tooth rather than its distinguishable structure merely associates it with enamel. It would be very difficult to define enamel in such a way that it could always be recognized. The structure here presented, however, does not resemble the enamel prisms or rods sufficiently to be called enamel.

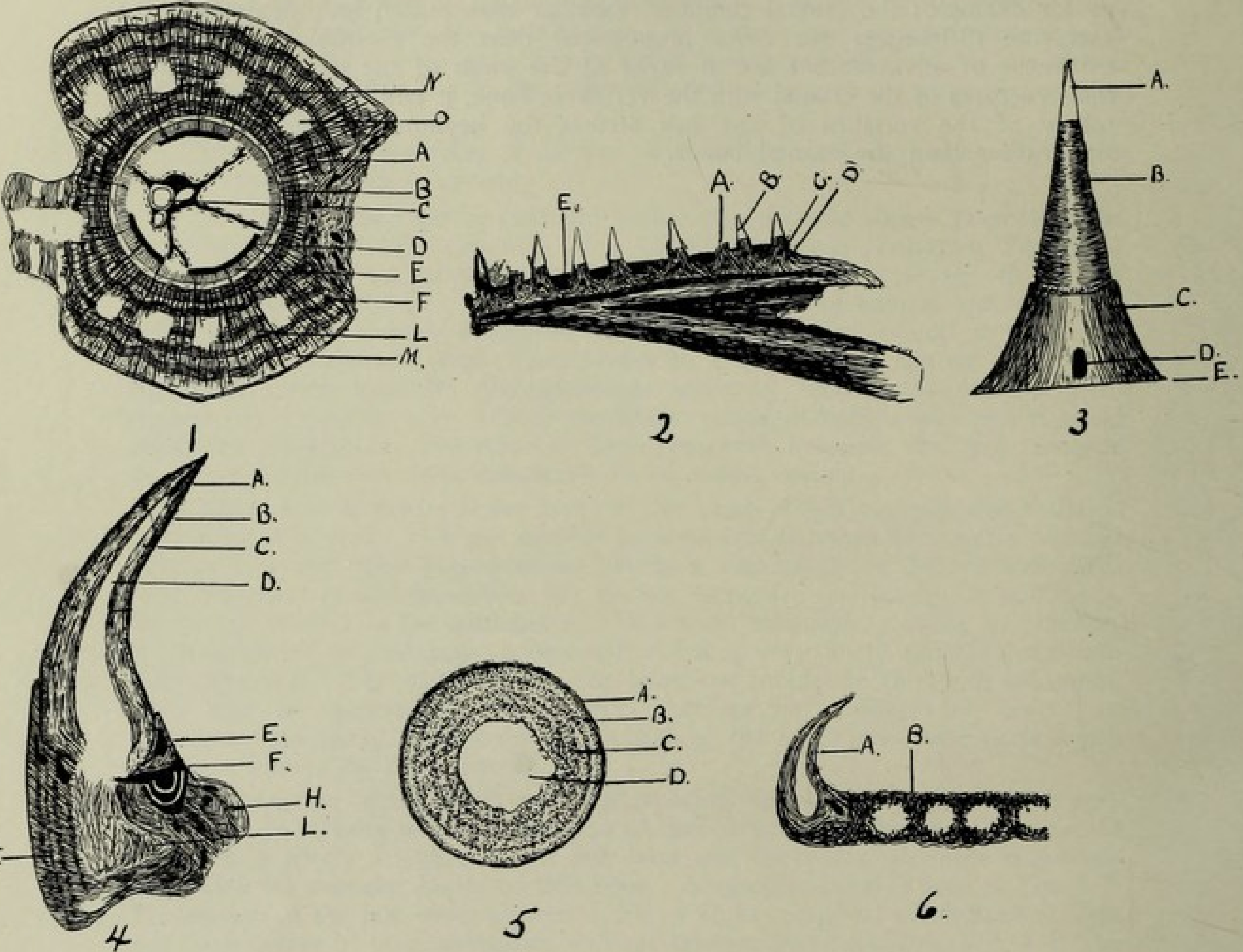
Within this structure is the body of the tooth which occupies the situation of dentine, Fig. 4 C. It is not dentine by structure although here again, dentine substance or any other homogeneous structure, can hardly be defined with sufficitne clearness to be identified. We do not recognize dentine by its substance, but by the tubules in the substances. This tooth substance, dentine by position, is composed of an inorganic compound which is very finely striated longitudinally, Fig. 4 C. The striations are fine lines, not tubules in the tooth substance. They may be incremental. There are therefore no evidences of enamel or dentine in this tooth, but merely the division of the tooth into those parts which later are known by those names.

In the center of the tooth is a large tapering chamber, extending to the very tip, Fig. 4 D. There was no indication of any structure within it. The base of the tooth is firmly attached to the jaw bone and its central chamber communicates with the vascular cavity of that bone. A vascular canal is seen at Fig. 4 F. The section of the jaw bone, as seen in Fig. 4 H, is composed of alternating light and dark layers of bone substance without lacunae and canaliculi, Fig. 4 I. The light and dark effects are produced by the different views of the fine vascular channels. This is the peculiar difference between the structure of the cranial bones and the vertebrae. The former has a channelled circulatory system without distinct lacunae and canaliculi; while the latter has additional lacunae, canaliculi and lamellation of the bone substance, in other words, is undergoing organization.

Fig. 5, is a cross section of the shaft of the tooth. A, is the border; B, the radial sheath; C, the tooth substance; and D, the central chamber. B and C present fine granular structures which are cross sections of the striations.

Fig. 6, is a longitudinal section of the anterior portion of the tongue, upon which are arranged fourteen teeth in the form of a hollow square, closed in front and open behind. These are sharp cone-shaped, curved teeth embedded pretty firmly in the keratoid tissue of the surface of the tongue. The tooth represented in the drawing is situated in the tip of the organ, Fig. 6 A. It has the same structure as that seen in the teeth of the jaw. The central chamber communicates with vascular cavities in the substance of the tongue in which the tooth is embedded. The lower half of the tongue is not represented in the drawing.

Comparing now, the tooth of the Lake Trout with the tooth of the Muscalonge, we notice certain resemblances, as for example: shape, ankylosis, blood supply from the oral membrane, the shedding; we also note certain differences, as for example: the central chamber, vascular distribution and structures. In fact, the differences are more pronounced than the resemblances and the evidences of advancement are in favor of the tooth of the trout. Comparing the structures of the cranial with the vertebrae bone, it will be seen that the histology of the vertebra of the fish strikes the keynote of bone differentiation rather than the cranial bones.



1. Cross section of a trunk vertebra of a Lake Trout—Salmo Ferox. A, Lamellar ring surrounding the central canal. B, A narrow clear ring crossed by radiating vascular canals. C, Blood vessel in central canal. D, Branch of C around the wall of the central canal. E, Small radiating branches from D. F, Concentric incremental lines. L, Radiating vascular channels from D. M, Bone substance.
2. Right half of the lower jaw of a Lake Trout as .seen from the inside A, Stump of a shed tooth. B, Shaft of tooth. C, Vascular canal. D, Base of tooth anchylosed to jaw bone. E, Concave depression of a shed tooth.
3. Tooth of the upper jaw of Lake Trout. A, Translucent tip. B, Cone-shaped shaft. C, Base of bone. D, Vascular canal. E, Edge of jaw bone.
4. Cross section of upper jaw of Lake Trout with tooth in position. A, Thin striated membrane. B, Narrow sheath of fine radiations. C, Body of tooth striated longtitudinally. D, Vascular chamber. E, Bone of jaw. F, Vascular canal. H, Jaw bone. L, Vascular cavity in the jaw bone.
5. Cross section of the shaft of a tooth of the upper jaw of a Lake Trout. A, Thin striated membrane. B, Narrow zone of granular radiations. C, Wider zone of oblique radiations. D, Vascular chamber.
5. Longitudinal section of the tip of the tongue of a Lake Trout with tooth in position. A, Tooth. B, Bony substance in surface of tongue.

A STUDY OF THE BONE AND TEETH OF THE GARPIKE—LEPIDOSTEUS.

THE BONE AND TEETH OF GAR-PIKE—LEPIDOSTEUS.

The Gar-pike is richly endowed with bone and teeth, having a cranio-vertebral axis of bone, external scaly covering of bone and fins of bone and having also an immense number of teeth of various sizes on the entire under surface of the upper jaw and on the lower mandibular ridges; in fact, the whole mouth is set with teeth excepting the floor between the diverging rami of the lower jaw.

Bone as found in the cranium, vertebra, scales and fins:

The cranium is extended forward into long, tapering jaws—50 mm. in length, 25 mm. wide at the cranial junction and 12 mm. wid at the tip. The frontal bone has no diploe and is composed of an inorganic, homogeneous base of bone substance in which is an immense number of multipolar, nucleated bone cells communicating by means of their slender dendrites and forming a fine circulatory reticulum as indicated in Fig. 4. Here and there are seen circular perforations; some are surrounded by incomplete lamellae resembling Volkmann's canals and others are without lamellae as though they were holes punched through the bone. In either case they appear to be vascular canals. Along the sides of blood vessels which are quite prominent, the bone substance is lamellated and the lamellae are frequently crossed by fine parallel narrow lacunae and many stellate pigmented cells. A short distance from the blood vessels the bone substance is clear and homogeneous and contains a reticulum of large multipolar bone cells which resemble multipolar nerve cells. These cells form the interesting feature of this bone. Were it not for the subjective feeling of hardness and the peculiar odor which are experienced during the grinding of bone the microscopic picture would fail to identify the structure as bone, Fig 4A, B. As we look at the section we are conscious of a universal cell unchanged in shape by a specific metabolism and developmental pressure—two great factors in cell morphology.

Fig. 3. This is a drawing of a cross section of a trunk vertebra; it is composed of a body of First Type bone with several blood vessels in cross section, A, two long transverse processes of the same type bone, enclosing long central spaces, and small groups of blood vessels at the extremities of the processes, B. Ventral to the body is a large circular canal surrounded by First Type bone, crossed by parallel vascular channels and containing blood vessels and supporting tissue, C. Ventral to this canal are two vascular extensions of bone forming a notch, D. The structure of the vertebra differs quite materially from that of the cranial bone; it has very few multipolar cells and has parallel lacunae indicating a later bone differentiation than that seen in cranial bone. The body of the vertebra does not transmit the spinal cord through its center.

In Fig. 15 is seen a section of two scales of the fish ground flat-wise. The section is composed of wide lamellar boundaries of bone crossed by radiating vascular channels, A, and central areas of bone substance with multipolar bone cells and containing two to four perforations, B, C. These are surrounded by lamellae also resembling Volkmann's canals. Pigment cells are seen along the line of union of the two scales and along their borders.

In Fig. 16 is seen a longitudinal section of a portion of the dorsal fin. It is composed of rays of bone, A, crossed at short intervals by blood vessels, B, which communicate with longitudinal blood vessels, C, situated in the flexible inter-ray intervals. The central portions of the rays are composed of bone substance with multipolar bone cells and the lateral portions, of lamellae crossed by fine, parallel vascular channels derived from the blood vessels, D. Numerous pigment cells are seen in the central portions and along the blood vessels.

Thus it may be seen that the bone of the Gar-pike presents a structural mixture of differentiations. The multipolar cells of the cranium, vertebra, scales and fins,—all suggest early differentiations which have not undergone developmental influences and hence display the original cell forms. In the transverse processes of the vertebra and in the bone surrounding the large vascular canals, the bone cells have undergone a developmental change indicative of a later organization. The difference between bone substance and bone lamellae, laminae or Haversian Systems furnishes the key to the degree of developmnt which characterizes the animal. It would certainly be illogical for us to conclude that a very early differentiation of bone would be accompanied by a very late differentiation of the teeth, since both are dependent upon the same inorganic metabolism, unless dentinal and enamel substances are produced in a complete form at the outset as a secretion might be. We could hardly suppose that the tooth of the fish might be produced in the bone of man or the reverse if the degree of differentiation means anything. The multipolar bone cell is not found in man, but is common in the fish. The two differentiations are widely separated and it would seem practically impossible for them to form one and the same product by their metabolism. Differentiation implies time and progressive cellular changes directed toward an objective point or level which is possible by virtue of a similar phylogenetic history. We would be hopelessly confused if the earliest and latest vertebrates were found to have the same degree of structural differentiation or stage of development. As a matter of fact they do not, but each vertebrae conforms to the differentiation and development of its class. We would be greatly surprised if we found human teeth in the fish. Not expecting this, we look for those structures which lead up to the human tooth by projective power operating in variations. It is unreasonable to assume that inorganic tissues of the body have little or no connection with each other or that they may arise independently of each other. It disrupts our ideas of harmonious organization. If we can separate bone and teeth, we can just as well separate other tissues and give to them an independent uncorrelated development or growth, which is the foundation of tumors rather than of physiological unity. If we could put the bone of the fish into the skeleton of man without upsetting physiological values, we could also make the same transfer of other tissues and thereby reduce fish and man to one common substance, which is absurd.

The Gar-pike is an animal in which calcium metabolism is pre-eminently a dominant factor of development. It is a bone animal and in this suggests certain fundamental metabolic variations which occur throughout the vertebrate series and which account for successes and failures in bone and tooth values.

Teeth: The Gar-pike has an immense number of teeth. In Fig. 1, A, is seen a side view of the two jaws with the small external and large cone-shaped curved internal teeth situated on the outer ridges of the jaw bones. On each lateral jaw bone there are 19 or 20 ankylosed teeth and 16 depressions in the bone from which teeth have been removed by shedding. There are no hinged teeth present—the fish differing in this respect from the Great Northern Pike. The upper projects over the lower jaw in front where the teeth are larger than elsewhere. Fig. 1, B, shows the oral surface of the upper jaw which is practically all teeth as indicated by dots. They could not be satisfactorily counted. In Fig. 2 is shown the under jaw as seen from above. There are two rows of external teeth, A and C, and a bank of small teeth just within at B. The floor of the mouth is the only portion from which teeth are absent.

Fig. 5, is a cross section of the upper jaw with the teeth in position. (The section is upside down.) The jawbone A is a first type bone with narrow parallel lacunae, containing bone cells instead of multipolar bone cells in bone substance as were found in the cranial bone; it is therefore a later differentiation. Several large vascular canals, V, extend lengthwise of the bone and provide locations for blood vessels which supply the teeth. E, a large tooth in position and F, F, F, small teeth in position. These teeth are supplied by underlying blood vessels as D. The teeth are firmly ankylosed to the jaw bone by a spreading base.

Fig. 6, is a cross section of the lower jaw with the teeth in position. The type of bone is the same as that of the upper jaw which would be expected, since both are tooth producing bones and must be the same in the degree of differentiation in order to produce the same differentiation of the teeth. We would naturally expect that if one jaw had an earlier differentiation than the other, the teeth of that jaw would present a corresponding early differentiation, unless, as was seen in the early elasmobranch fishes, enamel and dentine are produced in a complete form at the beginning of vertebrate history. A, is a first type bone with large vascular canals like that seen in Fig. 5, A. B, is a large and C, C, C, are small teeth supplied by blood vessels as at D. The methods of blood supply and tooth shedding seem to differ in different fish. In the Gar-pike the blood supply is derived from vessels within the jaw bone and the shedding occurs at the line of ankylosis with the jaw bone; while in other fish, as in the Great Northern Pike, Trout, Cat-fish, the blood supply is derived from oral vessels external to the teeth and the shedding occurs at the junction of the shaft with the base.

In Fig. 7, is shown a large curved cone-shaped tooth from the lower jaw. At A is seen a yellowish, nearly homogeneous tip which corresponds to enamel in position. It has an irregular attachment to the shaft, B, to insure rigidity and receive from it a few tubular extensions. At C, is seen the corrugated base which is firmly ankylosed to the jaw bone at D.

Fig. 8, is a longitudinal section of a similar tooth showing the blood supply and general structure. At A, is a small tooth, the enamel tip is seen at T, a narrow structureless border at B, the shaft at E, an internal view of the corrugated base at C, the blood supply at F, arising from the vessel in the jaw bone D. The general structure is as follows: The vessel, D, sends off branches upward into the tooth which then gradually converge as they reach the shaft. The arrangement is like the lodge poles of a wigwam. Around each vessel is formed the dentinal structures. On reaching the shaft the converging vessels are brought close together in the dental chamber and the surrounding dentinal substance is continued on to the enamel tip.

Fig. 9, shows one of these teeth which has been pushed over from its bone attachment. It is a hollow tapering cone; at A, is seen the central cavity, at B, one of the corrugations.

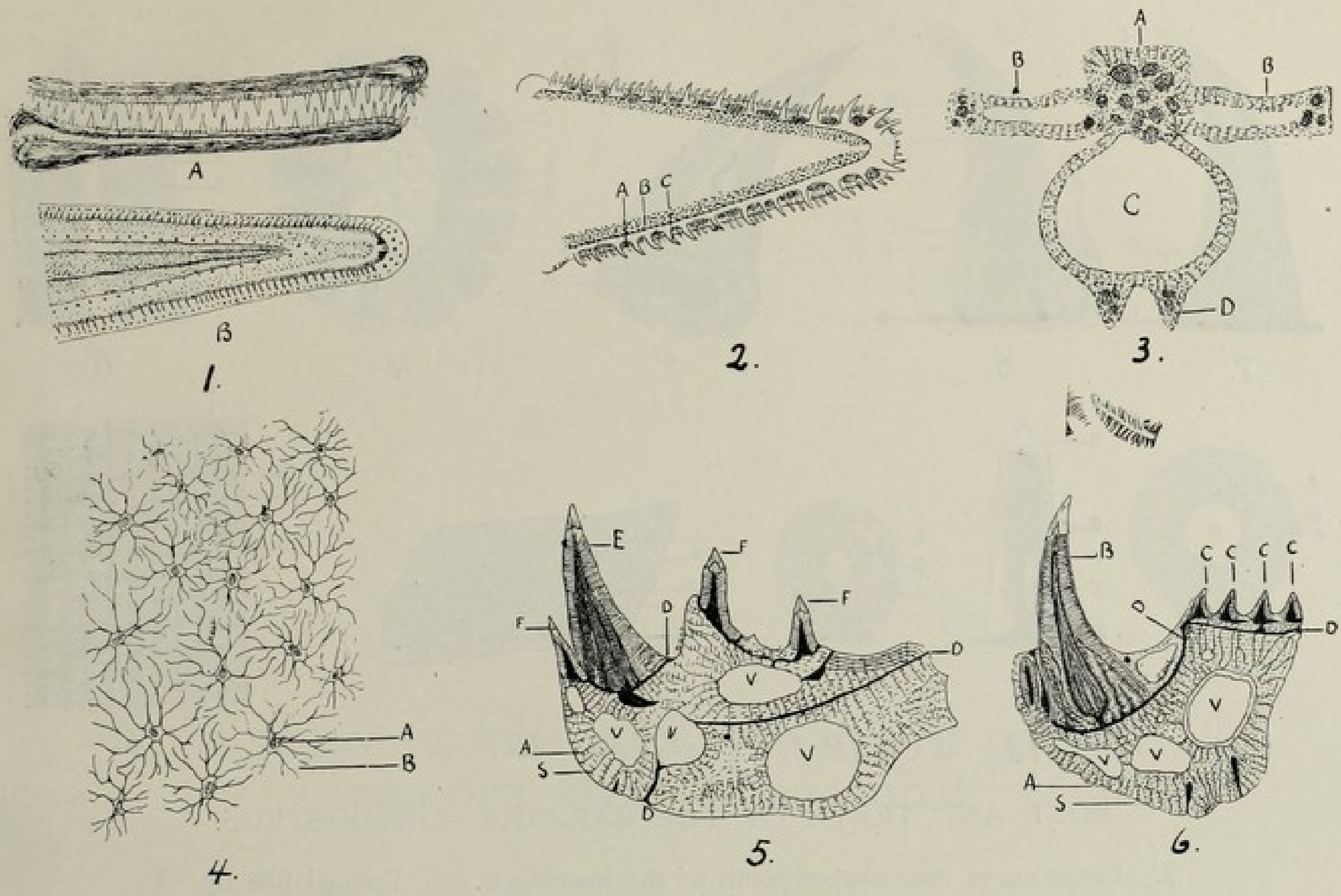
Fig. 10, is a cross section of the corrugated base of one of these lower teeth. The section shows a regular series of corrugations surrounding a central chamber which contains blood vessels supported by a delicate connective tissue. The description of one of these corrugations will answer for all as they all have the same structure. Each corrugation-lodge pole of the wigwam—is surrounded by a narrow granular border C, which shows a tendency towards radial striations. Underneath this is a wide band of dentinal substance, B. This is composed of an inorganic, homogeneous substance corresponding in location with that of dentine. In this inorganic substance are seen tubules arising from the central vascular chamber and ending in the terminal branches at the granular border. The tubules are the outward extensions of the blood vessels of the central chamber as indicated in Fig. 10, a. The relation of the circulatory system to the dentine seems to be one of cause and effect.

In Fig. 11, is seen a longtiudinal section of the shaft as indicated in Fig. 7, at B. At A, is seen the thin homogeneous border which becomes slightly striated over the tip C. This is merely a suggestion of a differentiating enamel. D, is the dentinal substance, the tubules are prominent, take a slightly curved outward direction from the central chamber and profusely branch at their extremities just beneath the external border. The ground substance, F, is homogeneous. The dentinal substance is more advanced in differentiation and resembles the dentine of later teeth.

Fig. 12. is a cross section of the shaft of this tooth in which the same structures are recognizable.

Fig. 13, is a longitudinal section of a small lower tooth. The blood supply is seen at A, the enamel cap at D, the shaft at B, there being no corrugated base, and the dentinal tubules branching off from the central vascular chamber at C.

Fig. 14, is a cross section of a similar tooth and shows the same structure.



THE BONE AND TEETH OF THE GAR-PIKE—LEPIDOSTEUS.

1. A, Showing side view of the jaws, 50 mm. in length, showing the small external and large cone-shaped internal teeth. B, Under surface of the upper jaw, showing the great number of small teeth indicated by dots.

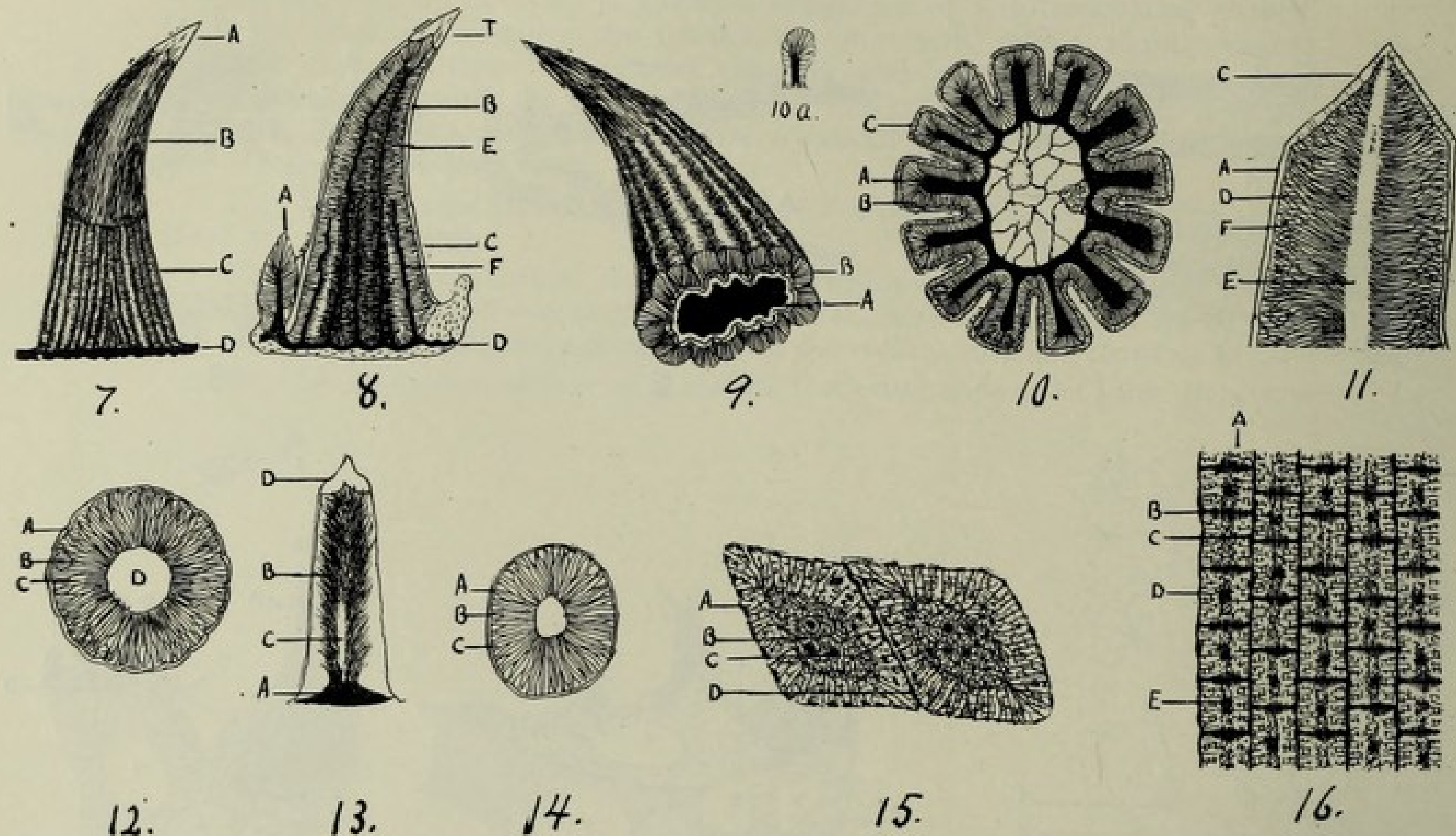
2. The lower jaw, showing the two rows of external teeth and a large number of small internal teeth indicated by dots. A, Small external; C, Large; B, Bank of small teeth.

3. Cross section of a trunk vertebra. A, Body of First Type Bone with several blood vessels. B, Transverse processes with long central spaces and blood vessels at the extremities. C, Large canal surrounded by First Type Bone and containing large blood vessel and nerve. Two ventral vascular extensions of bone, D, forming a notch.

4. Section of the frontal cranial bone ground flat-wise showing mulitpolar bone cells. A, Cell. Bone substance, B.

5. Cross section of upper jaw with teeth in position (section should be reversed). A, First Type Bone with large vascular canals, V, and many small vascular channels, S. D, Blood vessel. E, Large; F, F, F, Small teeth.

6. Cross section of lower jaw with teeth in position. A, First Type Bone with large vascular canals, V. Small vascular channels, S. B, Large; C, C, C, Small teeth. D, Blood vessel supplying the teeth.



BONE AND TEETH OF THE GAR-PIKE—LEPIDOSTEUS.

7. Large curve cone-shaped tooth of the lower jaw. A, Enamel like tip. B, shaft. C, Corrugated base. D, Attachments to jaw bone.
8. Longitudinal section of same showing blood supply and corrugations. A, Small tooth. Tip, T. Border, B. Shaft, E. Corrugated base, C. Blood supply, F. Jaw bone, D.
9. A large lower tooth pushed over showing central cavity and corrugations. A, Cavity
10. Cross section of the corrugated base of Fig. 9, showing relation of blood supply, A, to dentine.
11. Longitudinal section of shaft, Fig. 7, showing the structure. A, Thin border. C, Striated tip. D, Dentinal tubules. F, Dentinal substance. E, Central vascular chamber.
12. Cross section of Fig. 11. A, Structureless border. B. Dentinal tubules. C, Dentinal substance. D, Central chamber.
13. Longitudinal section of small lower tooth. A, Blood supply. B, Tubules. C, Cavity.
14. Cross section of Fig. 13. A, Border. B, Dentinal tubules. C, Dentinal substance.
15. Section of two scales ground flat-wise. A, External lamellar bone with radiating vascular channels. B, Central areas of multipolar bone cells. C, Perforating canals.
16. Longitudinal section of the dorsal fin ground flat-wise. A, Rays of First Type Bone crossed at short intervals by blood vessels, B, which communicate with longitudinal blood vessels, C. The central portions of the rays are composed of bone cells and the lateral of lamellae crossed by vascular channels, D. E, Pigment cells.

A STUDY OF THE BONE AND TEETH OF THE CHANNEL CATFISH—SILURIDAE.

BONE AND TEETH OF THE CHANNEL CAT-FISH—SILURIDAE.

The bone and teeth of the cat-fish are especially interesting on account of the early differentiations of bone and teeth they present. The bone sections are taken from the vertebrae, from the osseous oral membrane of the upper jaw, from the lower jaw, and from the dorsal and pectoral spines of the fins. The teeth are taken from the lower jaw, from the osseous membrane and from the dorsal and pectoral fins.

In Fig. 1, the lines A and B, show the situations of the following sections: 2-5.

Trunk Vertebra—Fig. 2, is a cross section of a trunk vertebra through B. Around the central canal are a number of concentric lamellae of bone, separated by concentric vascular canals, Fig. 2, A. At intervals the canals widen into lacunar shaped spaces with canaliculi passing out to neighboring lacunae, Fig. 2, F. The lamellae have a uniform thickness and the vascular canals between do not communicate except by canaliculi. In all cases the lacunae are seen within the canals and not within the lamellae. The bone substance of the lamellae is finely striated circularly. The lamellae extend out into the ribs, Fig. 2, R. In Fig. 2, the spaces C and D, are produced by cross sections of the conical identations around the circumference of the body of the vertebra. The sections 3, 4 and 5, are taken from B, E, R and D, Fig. 2, and represent the early differentiation of bone.

Fig. 3, shows lamellae between the dotted lines B, and the lacunae with long canaliculi are seen extending in parallel rows as at A. The bone substance, F, is homogeneous. On the left side of the drawing may be seen the early and on the right side the late differentiations D. The section being made through N. This variation may be due to the pressure of development.

In Fig. 4, which was taken from B, Fig. 2, are seen the homogeneous lamellae A. Between the dotted lines and a delicate retiform circulation composed of the lacunae and their united canaliculi, B, C. The lacunae are occupied by bone cells and the canaliculi by their processes and the bone substance of the lamellae is the only visible product of the bone cells. It is difficult to associate the two together as a cause and result and yet no other conclusion presents itself in the absence of any other histological element.

In Fig. 5, taken from another portion of Fig. 2, shows a homogeneous bone substance, undifferentiated into lamellae, in which are long irregularly shaped lacunae, with long, delicate canaliculi. These elements may be seen at A, B and C. The section is situated at Fig. 20. It does not resemble a section of bone as closely as it does a section of nervous tissue with certain multipolar cells. It suggests bone in the making, that is, cells and their product. In these sections, the relation of bone to the circulatory system, is very striking.

Bone of the Fin Spines—Fig. 6, is a drawing of the anterior osseous spine of the dorsal fin. It is composed of bone A, differentiated into a form of teeth at B.

Fig. 7, is a longitudinal section of the spine shown in Fig. 6. It is composed of lamellae of bone A, thrown up into wave-like crests, B, which are teeth. The lamellae come together like the rafters of a roof. At their apices are numerous multipolar bone cells. This is a simple mechanical arrangement of early bone elements, to form an organ of greater resistance than would be possible with parallel lamellae. In the center E, is a longitudinal vascular canal, in which is seen a blood vessel, C, which sends off branches to the tooth elevations. The posterior wall D is composed of lamellated bone, with vascular canals at intervals.

Fig. 8, is the cross section of the spine shown in Fig. 6. The section was made at A. It is composed of arched, concentric laminae, B, separated into several radial divisions, C, by radial blood vessels, D, and all enclose a central, vascular canal, E. In the anterior and posterior wall, A, F, are seen radial vascular channels.

The section is interesting as it exhibits a peripheral incremental growth of bone, similar in appearance to the growth of a tree trunk. The laminae are composed of many lamellae of bone substance, with long, narrow lacunae and straight canaliculi. It is much later bone differentiation than that seen in the vertebra of the same animal.

Fig. 9, is a drawing of the osseous spine of the pectoral fin of the same cat-fish. The spine is broader than the dorsal spine and has larger teeth.

Fig. 10, is a longitudinal section of spine made at B. It is composed of a superior and inferior wall, enclosing a central canal. The teeth are situated in the inferior wall and are extensions of the bone lamellae of that wall. They are composed of bone substance with long, narrow lacunae and straight canaliculi extended and curved into teeth, B. There is no evidence of any other structure. The bone cells are irregular in shape, with short branching canaliculi. Beneath the teeth in the wall of the bone are seen the bone lamellae which form the teeth and which contain many blood vessels extending into the bases of the teeth as at B. The central canal, C, contains blood vessels supported by a delicate connective tissue. The remaining wall is composed of bone lamellae with blood vessels, D.

Fig. 11, is a cross section of this spine. It is composed of arched, concentric laminae, D, separated into several radiating divisions, B, by radial blood vessels, C, all enclosing a central, vascular canal, E. The general structure is similar to that seen in the dorsal spine. The particular interest in these spines is, that they are composed of a much later differentiation of bone than is seen in the vertebrae or in any other bone in the fish. This fact suggests a more specialized purpose of toothed bones than is found elsewhere. The bone of the lower jaw and osseous oral membrane, will be taken up with the teeth.

TEETH AND BONE OF THE MOUTH REGION.

The teeth of the cat-fish are very numerous, several hundred in number. On the lower jaw and ankylosed to the bone is a horse shoe shaped area, of small cone shaped, hollow teeth, 50 mm. long, 4 mm. wide, Fig. 12 B. On the upper jaw and not joined to the bone by bony attachments, but to an osseous oral membrane, is a slight curved tooth, 30 mm. wide, Fig. 12 A. The teeth are attached either to the bone of the jaw or to the bone structure of the oral membrane.

Fig. 13 is a cross section of the lower jaw, with two teeth enclosed in a bone extension, F, derived from the jaw in position. The teeth are 1.5 mm. long and 0.5 mm. in diameter. The tooth is composed of a yellow, homogeneous tip, A, fastened by an irregular base to the shaft, D. Tubules from the shaft extend into it. The shaft is surrounded by a thin sheath, B, which has a membraneous structure. Underneath this is a transverse, thin striated border, C, composed of inorganic substance, in which are short, granular, transverse striae. Beneath this is a dentine-like substance, forming the body of the shaft, D, composed of a homogeneous base, in which are seen many tubules extending from the central chamber to the striated border, where they become continuous with the granular striae. Extending from the base of the tooth to the tip is the central chamber, E. It has very little, if any, contents visible in the ground section. The shaft appears to be separated from the base at H. This line of separation indicates the shedding line of the tooth. The shaft is united to the base by the dentine-like extension, excepting at this one entering canal, through which the section was made. Under the shaft is seen the base, composed of striated bone containing loops of blood vessels. The shaft is a developmental extension from this vascularized bone. The tooth as a whole, is a hollow cone springing from this bone, which is derived from the bone of the jaw and which is differentiated into tooth-like structure as it emerges from its bed. Underneath the teeth is seen a cross section of the jaw bone, composed of channelled bone, L, of cross striated laminae, M, and of lamellated bone at I. These various bone units are more distinct in architecture, than they are as completed structures. Many large vascular canals in cross section are seen, from some of which vessels extend into the base of the tooth, K. This bone resembles quite closely a similar bone of the muscalonge.

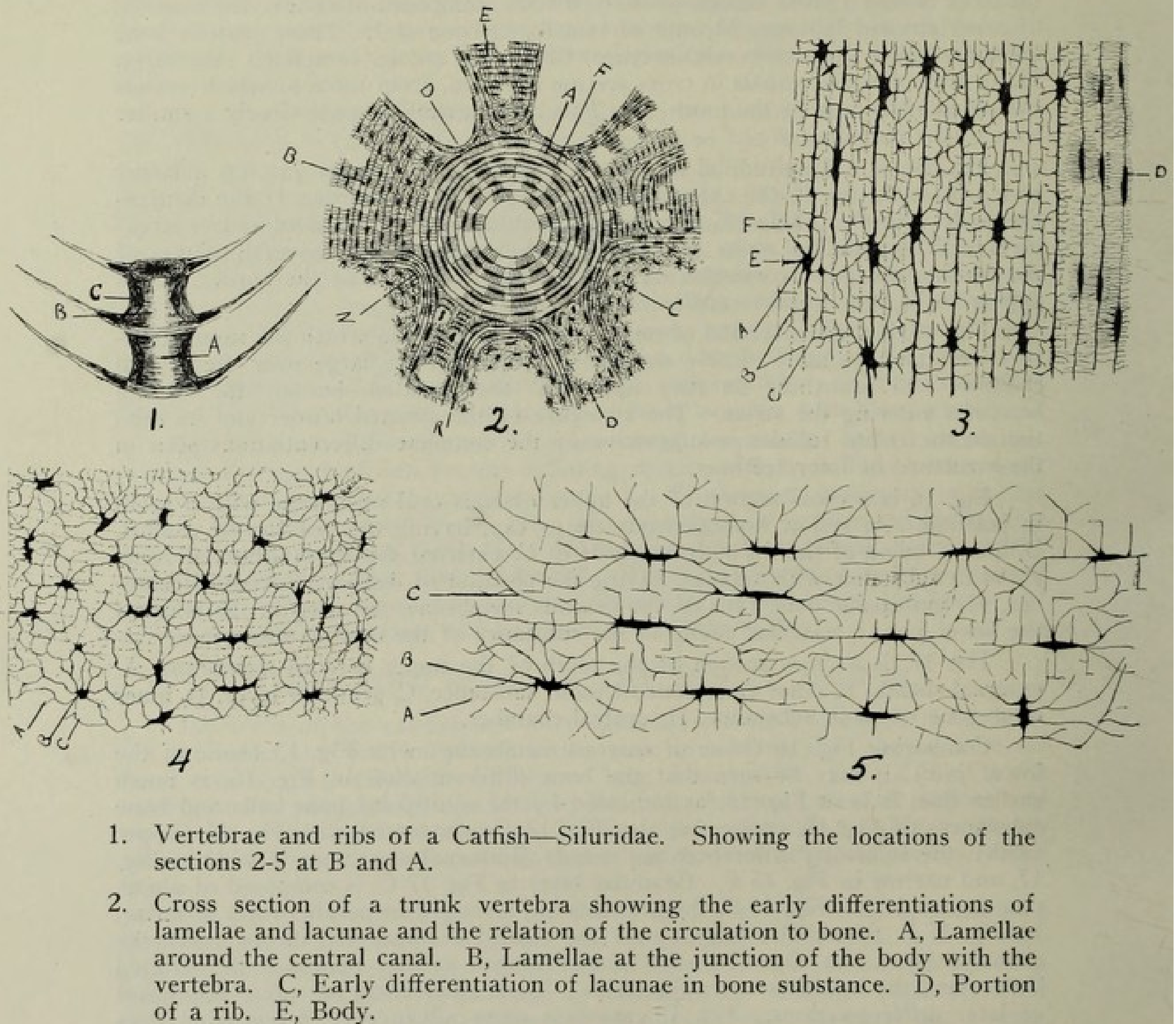
Fig. 14, is a longitudinal section of a tooth of the lower jaw on a larger scale. A, is the tip, B, the external sheath, C, the striated border, D, the dentine-like body with the tubules, E, the central chamber, and H, the dentine-like structures with longitudinal striae seen in the background. The transverse tubules of the dentine substance communicate directly with the striae of the border, which appear to be very minute canals.

Fig. 15, is a cross section of one of the lower teeth in which the same structures are perhaps more clearly shown. The tubules are large near the central chamber and branching as they approach the striated border, the minute branches entering the striae. The structure of the striated border and its relation to the radial tubules is suggestive of the complete differentiations seen in the structure of later teeth.

Fig. 16 is a cross section of the upper osseous oral membrane with a tooth in position. A, yellow homogeneous tip or cap, having the position of enamel, B, line of union of the tip with the shaft E, C, external sheath, D, granular zone, E, tooth substance with tubules, having the position of dentine, F, central chamber, H, multipolar bone cells of the osseous membrane, not seen in the bone of the lower jaw, I, vascular cavity in the substance of the osseous membrane.

Fig. 17, is a cross section of the tooth of the upper osseous membrane. A, external sheath, B, outer clear zone of tooth substance, C, granular layer, D, inner clear zone of tooth substance, H, central chamber.

Comparing Fig. 16 (bone of osseous membrane) with Fig. 13 (bone of the lower jaw), it may be seen that the bone differentiation in Fig. 16, is much earlier than it is in Fig. 13, as indicated by the multipolar bone cells and bone substances of Fig. 16, comparing also Fig. 17 (lower tooth) with Fig. 15 (upper tooth), the following differences are noted: External clear zone is wide in Fig. 17, and narrow in Fig. 15 F. Granular layer in Fig. 17 C, is composed of amorphous granules, in Fig. 15 B, the granules are arranged in parallel rows or striae. In Fig. 17 E, the tubules branch near the central chamber and do not reach the granular layer. In Fig. 15 C, the tubules branch as they approach the striated border and the branches enter the striae. These differences are quite significant of later differentiations. Fig. 15, shows a more advanced differentiation than Fig. 17. Thus the bone and teeth of the catfish present the following points of interest in bone and tooth histology: (1) The early differentiation of bone in the vertebrae and osseus membrane. (2) The later differentiation of bone in the specialized tooth or barbed spines of the dorsal and pectoral fins than elsewhere. (3) The formation of these teeth by a mechanical arrangement of the bone lamellae. (4) Early and later bone differentiations of the upper osseous membrane and lower jaw of the same animal. (5) Yellow homogeneous tips or caps of the tooth, corresponding to enamel, the homogeneous tooth substance with tubules extending from central chamber to striated border, corresponding to dentine, the ankylosis of the tooth to the underlying bone, the shedding line, the communication of the central chamber of the teeth with vascular canals or cavities in the bone, to which they are ankylosed. (6) The different developments of the granular layers and striated borders.

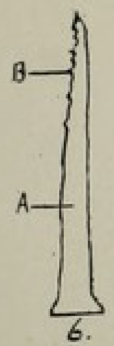


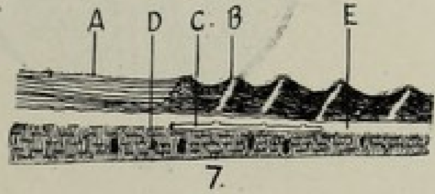
1. Vertebrae and ribs of a Catfish—Siluridae. Showing the locations of the sections 2-5 at B and A.

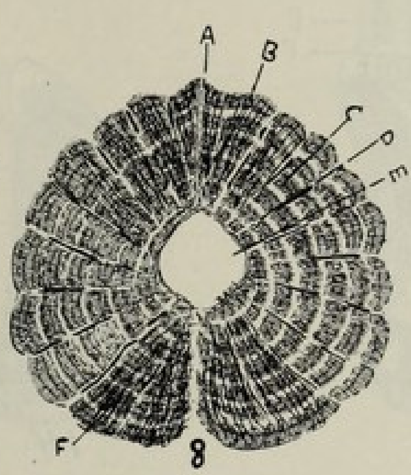
2. Cross section of a trunk vertebra showing the early differentiations of lamellae and lacunae and the relation of the circulation to bone. A, Lamellae around the central canal. B, Lamellae at the junction of the body with the vertebra. C, Early differentiation of lacunae in bone substance. D, Portion of a rib. E, Body.

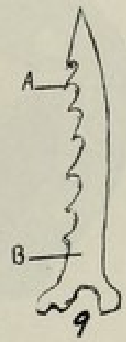
3. Lacunae and canaliculi in different degrees of differentiation. A, Lacunae. B, Lamella. C, Canaliculi. D, Late; E, Early differentiations of lacunae.

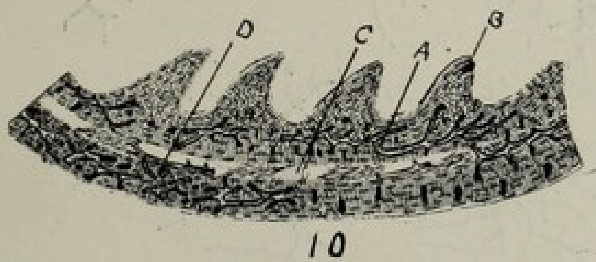
4.-5. Lacunae and canaliculi forming the circulatory system of the bone substance. A, Lamella or bone substance. B, Lacunae. C, Canaliculi.

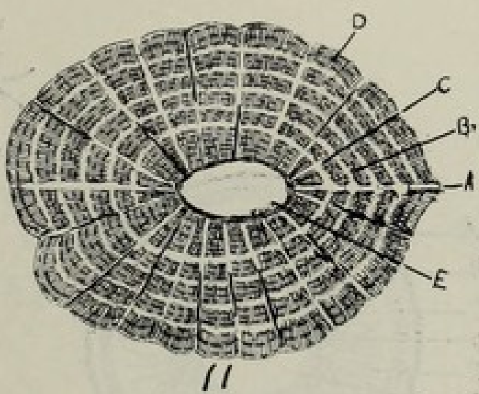


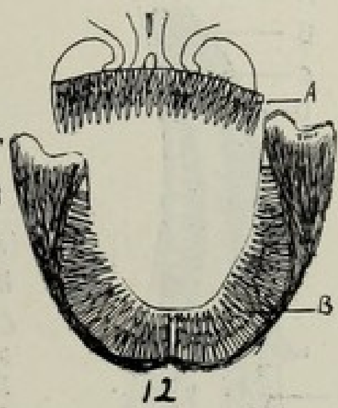












6. Anterior osseous spine of the dorsal fin of a catfish—Siluroid. A, Shaft. B, Teeth.

7. Longitudinal section of Fig. 6. A, Shaft of bone lamellae. B, Crest of lamellae or tooth. C, Blood vessel. D, Lamella of bone with blood vessels. E, Central vascular canal.

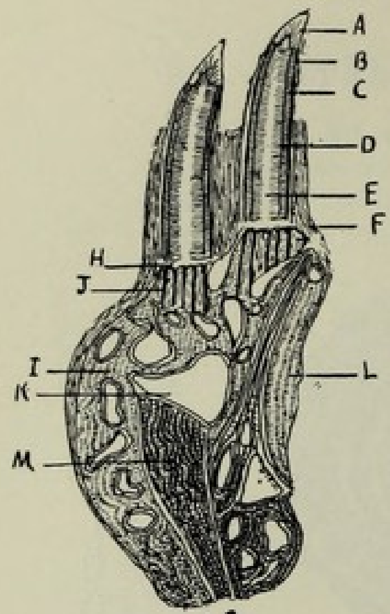
8. Cross section of Fig. 6. A, Anterior border. B. A fluted concentric lamina of bone. C, One of the radial divisions. D, Radial vascular canal. E, Central canal. F, Radial vascular channels.

9. Osseous spine of the pectoral fin of a catfish. A, Teeth. B, Shaft.

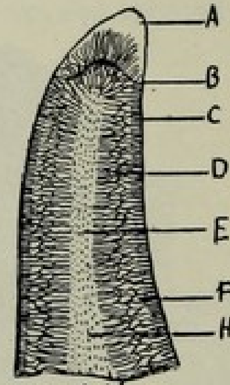
10. Longitudinal section of Fig. 9. A, Lamellae of bone with blood vessels. B, Tooth composed of bone. C, Central vascular canal. D, Blood vessel in bone.

11. Cross section of Fig. 9. A, Superior border. B, One of the radial divisions. C, Radial vascular canal. D, A fluted lamina of bone. E, Central vascular canal.

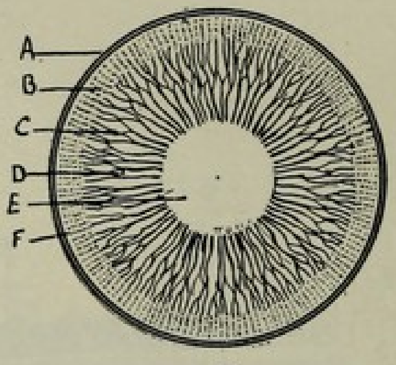
12. Teeth of the upper and lower jaws of the Catfish. A, Upper; B, lower jaw.



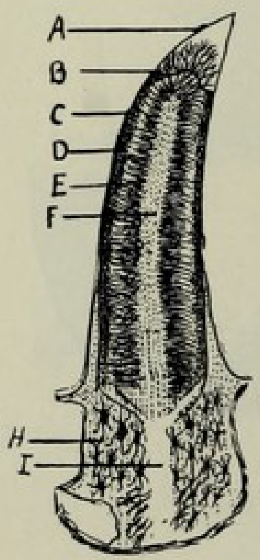
13



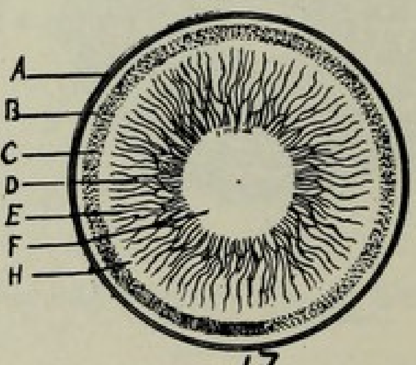
14



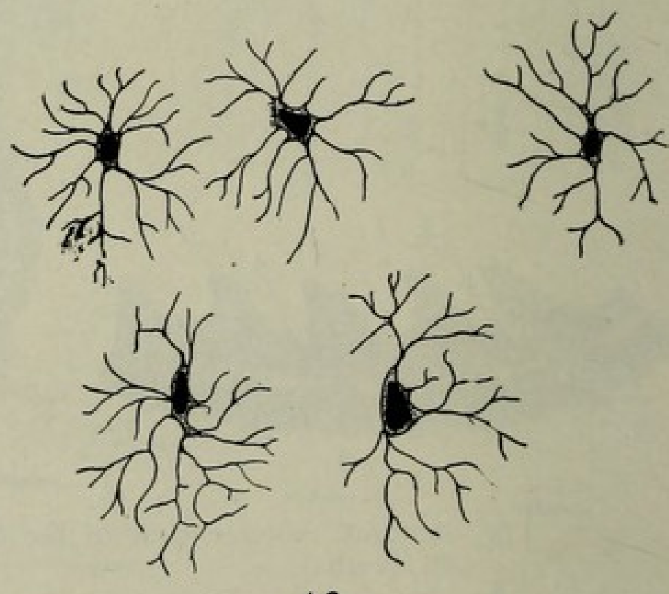
15



16



17



18

13. Cross section of lower jaw—with two teeth in position—of a Catfish. A, Yellow tip of the tooth. B, External membraneous sheath. C, Transversely striated border. D, Body of tooth with tubules. E, Central cavity. F, Extension of jaw bone. H, Junction of shaft with bone. I, Jaw bone. J, Vascular loops and bone under tooth. K, Vascular canal in the jaw bone. L, Channelled bone. M, Bone laminae.
14. Longitudinal section of a tooth of the lower jaw of Catfish. A, Yellow tip. B, External sheath. C, Striated border. D, Body of the tooth with tubules. E, Tubules. F, Dentinal substance. H, Central cavity.
15. Cross section of Fig. 14. A, External sheath. B. Striated border. C, Tubules from central cavity to striated border. D, Tooth substance or dentinal substance. E, central cavity. F, Clear zone.
16. Cross section of upper osseous membrane with tooth in position. A, Yellow tip. B, Line between tip and shaft. C, External sheath. D, Granular border. E, Tooth substance with tubules. F, Central cavity. H, Bone cells and bone substance under the tooth. I, Cavity in substance the membrane.
17. Cross section of upper tooth of a Catfish. A, External sheath. B, Clear zone. C, Granular layer. D, Tooth substance. E, Tubules. F, Central cavity. H, Clear zone.
18. Multipolar Bone cells from the superior maxilla of a Catfish.

A STUDY OF THE BONE AND TEETH OF THE MASCALONGE—ESOX.

THE TEETH AND BONE OF THE MASCALONGE—ESOX OF WISCONSIN WATERS.

The gross and microscopic characters of the teeth, the microscopic structure of the circulation in bone have been studied in the mandible and cranial bones of a mascalogne, weighing 25 pounds, caught in Lake Barker, Wisconsin.

Character of the Teeth: The teeth of the lower jaw—twenty-eight in number—are arranged in a single row along the upper border of the jaw bone and are curved inwards. In the anterior and posterior portions, they are small, while in the middle portion they are long and widely separated, Fig. 1. They are all sharp-pointed teeth, varying in length from 2 mm. in the anterior to 15 mm. in the middle portions, and are firmly ankylosed to the bone. Between the teeth may be seen the sites of the shed teeth, Fig. 1 B. A large muscle occupying the central canal of the jaw bone is seen at A. The teeth are prehensile, destructive of prey, and are teeth by appearance and situation rather than by definition. In addition to the teeth of the lower jaw, there are a large number of small, curved, sharp-pointed teeth on the lingual bone, situated in the floor of the mouth. This bone separates into two diverging branches at its posterior extremity and these branches are thickly set with teeth curving inwards and backwards. Between these branches and the anterior extremity of the bone are four isolated patches of teeth. The teeth of the lower jaw are shed, at least once, and the new teeth are established by the sides of the old ones in the following manner: A loose vascular membrane is attached to the inner and upper surfaces of the jaw bone, and is perforated by the old teeth, Fig. 2 D. This is a tooth forming membrane—the jaw bone taking no part in the formation of the teeth. It is composed of an inner and outer layer enclosing a trough-like cavity, Fig. 2 E.

Fibrous, vascular buds, Fig. 2 A, or extensions arising from the inner layer produce new flattened, cone-shaped, hollow teeth which remain firmly attached to these extensions, Fig. 2 B. Slitting open the membrane lengthwise, the new, white teeth may be seen lying flat-wise in the bottom of the cavity, as at Fig. 2 B. Gradual transformation of the connective tissue extensions by an ossifying process, from their distal ends, Fig. 2 K, brings the new teeth to a vertical position by the sides of the old teeth. These new teeth become the shafts of the second teeth, Fig. 2 C, 3. The fibrous extensions being transformed into osteodentin or some inorganic compound, are then ankylosed to the jaw bone and become the bases of the second teeth, Fig. 2 F, 3. The blood vessels of the fibrous extensions become enclosed as the osteo-dentin is formed and remain as the blood vessels of the second teeth. Following the ankylosis of the new teeth —which have pierced the outer layer of the teeth—forming membrane—the shafts of the old teeth separate from their bases, which then degenerate, become granular and wear away down below the surface of the jaw bone, where they may be seen as concave, granular depressions, Fig. 1 B, 2-H. This is the shedding of the old teeth.

Thus, there are three processes involved in the production of the second teeth, viz., (1) the formation of the shafts on the tips of the connective tissue extensions; (2) the transformation of these extensions into inorganic substance and their fixation—by ankylosis—to the jaw bone; and (3) the shedding of the old teeth. In the production of these—the earliest teeth in tooth history among vertebrates—the three essentially different processes in operation in the production of the second teeth of man. In the production of human teeth there is (1) a downward dip of the oral epidermal epithelium, (2) an upward extension of the connective tissue of the jaw—called the papilla. (The epithelial layer is applied—cap-like—to the papilla and becomes the enamel, while the papilla gives rise to the dentin), and (3) the shedding of the old teeth. Thus the shedding of the teeth among vertebrates began in the fish.

Structure of a New Tooth: Fig. 4, is a cross section of a new tooth of the lower jaw before the base is formed and ankylosis has occurred. The central body of the teeth is composed of a perfectly clear white substance—called by some, vaso-dentin—traversed longitudinally by many vascular canals, Fig. 4 A. Very minute branches are sent off from these canals in all directions dividing the vaso-dentin substance into small cell-like looking bodies, Fig. 4 B. There is a central cone-shaped canal occupied by the vascular extensions from which the new tooth originated, Fig. 4 C. The canal gradually disappears from the apex toward the base, as the vaso-dentin substance is formed. Around the border of the body of the tooth is a large vessel which sends off numerous straight, small branches toward the external boundary of the section, Fig. 4 D. At this stage of development there is no indication of enamel. A slightly yellowish layer is seen around the outer portion of the body, but cannot be distinguished from it by any line of demarcation, Fig. 4 E. The line shown in the diagram merely indicates the position of this enamel-like layer. The small vascular branches from the peripheral vessel extend to the outer border of the enamel-like layer, but disappear as differentiation advances. Around the enamel layer is a thin, structureless, colorless membrane-like enclosure, Fig. 4 F.

Structure of an Ankylosed Tooth of the Lower Jaw: In Fig. 5, is shown a section taken from the middle portion of the left half of the lower jaw and is a cross section of the jaw bone and a longitudinal section of a tooth in its natural position. A line drawn through the middle of the section from the tip of the tooth to the lower border of the bone is an arc of a circle having a diameter of 30 mm. The length of this line is 32 mm.—the tooth having a length of 15 mm. and the jaw bone a width of 17 mm.—that is, the tooth is about equal in length to the width of the jaw bone. The anterior portion of the jaw bone is an arc of a circle with a diameter of 240 mm. In the center of the jaw bone is a large canal extending lengthwise and diminishes in its diameters as it passes forward. This canal contains a large striped muscle, which—with its companion—moves the jaws with great force—and is found inside the bone instead of outside, Figs. 1 A, 2, 5. The circular characters of the jaw bone, as seen in its two measurements, gives a mechanical value of great importance to the muscular force applied whenever contraction occurs. Beneath the muscular canal is a smaller vascular canal, Fig. 5. The tooth is a stout cone shaped, curved tooth with a sharp tip, a glistening, tapering shaft and a dull bone-like base, having a thickness equal to that of the jaw bone to which it is firmly ankylosed, Fig. 5. The tooth is buttressed on the outside by a wall of bone extending upward from the jaw. Just above the lower border of the base of the tooth, and midway between the lateral boundaries of the base is a round hole 1 mm. in diameter, which is the site of the entering blood vessel on its way from the tooth, forming membrane to the tooth, Figs. 5, 3, that is, the ankylosed tooth receives its blood supply from the oral membrane and not from the jaw bone. This may be seen in Fig. 5, where there is no vascular connection between the tooth and the bone.

Structure of the Shaft and the Tip: The shaft of the ankylosed teeth—as seen in cross section Fig. 6—differs considerably in structure from that of the new tooth described under Fig. 4. The shaft of the ankylosed tooth is the new tooth under completed differentiation. The points of difference are the following: The new tooth has a central canal, vessels extending to the outside border of the enamel-like envelope, and an enclosing membrane-like covering. The ankylosed tooth has no central canal, has enamel-like envelope without vessels and is without a special enclosing membrane, Fig. 6.

Enamel: The external glistening envelope is called enamel, more on account of its situation and color than on account of its structure. It seems to be merely a modification of the vaso-dentin substance and derived from the same source, Figs. 4, 5.

The tip of the tooth is sharp, circular or knife blade in shape and composed entirely of the enamel substance, Figs. 4, 5.

Structure of the Base of the Tooth: Fig. 7, is a longitudinal section of the base of an ankylosed tooth. It is composed of parallel, longitudinal, ossified connective tissue fibers or rods, enclosing many vascular canals, containing blood vessels, Fig. 7 A-B. There is a small amount of the base (1 mm.) below the entering vascular canal. The artery, after passing into the base, divides into a vertical plexus, which embraces the ossified rods and extends outwards into the shaft. At the junction of the base and jaw bone are found several vascular canals in cross section.

Cross Section of the Base: Fig. 8, is a cross section of the base. It is composed of cross sections of the ossified rods—seen in the longitudinal section —arranged in the form of a framework enclosing the vascular canals. The rods are round or angular in shape. Some of them are cut obliquely and appear as striated bodies. In a cross section of a rod there is seen a center and lines radiating from it in all directions.

The Teeth of the Upper Jaw: These teeth—1,000 or more—are small and large, sharp pointed, curved or straight, and are arranged in rows on the two palatine bones and central vomer. Directly above the teeth of the diverging branches of the lingual bone is a large area of small teeth occupying the central portion of the roof of the mouth. These teeth are also curved backwards. They remind one of the filliform papillae of the tongue (ossified) which are seen in herbivorous animals. The teeth along the inner borders of the palatine bones are larger and longer than those along the outer borders; while the teeth of the central vomer are large in front and decrease markedly in size as they extend backwards. The teeth of the palatine bones are curved inwards and backwards, while those of the vomer curve backwards. On the anterior portion of these bones and near the entrance to the mouth are six or eight large, straight, sharp-pointed teeth. The small teeth are hinged and the large, ankylosed.

Besides these, there is a row of very small curved teeth along the outer lip of the upper jaw, and a patch of small curved teeth—25 mm. long and 12 mm. wide—on the lingual bone. Such an extensive tooth array as this provides a most formidable prehensile character to the mouth of the fish. Fig. 9, is a cross section of the vomer, showing the hinged teeth and the circulation underneath. The hinged and ankylosed teeth differ very materially in their methods of blood supply. In the hinged teeth the blood supply is derived from the jaw bone, in the ankylosed from the oral membrane.

Fig. 10, shows a hinged tooth and an ankylosed tooth drawn on a larger scale than that in Fig. 9, for the purpose of comparison. The hinged* tooth is seen at A, and the anklosed at B. The interesting differences between the two teeth are to be found in the plan of circulation and in the pulp rather than in structure.

In Fig. 10 A, is seen the circulation in the form of a dense plexus of blood vessels situated in the bone, directly undereneath the tooth and derived from the jaw bone.

In the ankylosed tooth (Fig. 10 B) the circulation is seen to be in the tooth and is independent of the jaw bone.

---

* For a descriotion of hinged teeth, see Tome's Dental Anatomy, 7th Ed.

Fig. 11, is a drawing of a plexus of blood vessels as it was seen in a cross section of a palatine bone. The plexus was underneath a hinged tooth.

On account of the hinged feature and dense circulatory plexus, the hinged tooth is more highly organized than the ankylosed and consequently the formation of new, and shedding of the old teeth, would involve complex embryological differentiations not adapted to the situation. A hinged tooth has a cone-shaped pulp, while the ankylosed has not, Fig. 10. By tipping the hinged tooth laterally a small central core or pulp may be pulled out, leaving a cone-shaped cavity. Fig. 12 is a cross section of a hinged tooth. Comparing this with Fig. 6, which is a cross section of an ankylosed tooth, the marked increase in the number of vascular canals is obvious, as well as the variations in the character of the pulp.

It is not easy to understand why the teeth of this fish require such an extensive blood supply. They are organs of capture and not of mastication, and are called teeth more from their location than from their function. The mascalonge* captures a variety of living animals.

Comparing the tooth of the fish with the tooth of man, there are some points of resemblance in their methods of formation and in their structure. They are millions of years apart historically and the resemblance is more of the nature of a common force calling out of undifferentiated bone substance the differentiated forms of a definite and permanent value in the various functions which the teeth will possess.

In the tooth formation of the fish there are: 1, Shaft; 2, Base, (Enamel, Vaso-Dentin, Osteo-Dentin); 3, Ankloysis; 4, Shedding of old teeth.

In the tooth formation of man there are: 1, Enamel; 2, Dentin and pulp; 3, Cementum; 4, Shedding of teeth.

Bone: From an extended study of over 1,000 sections of the femoral and other bones of different animals, from amphibian to man (inclusive), it has been determined, by the writer, that bone is not uniform in structure, but varies in structural type in the various classes, species, individuals and in the grade of development of the individual. Even kittens of the same litter may not have the same bone structure. There are three structural bone units which—singly or in combination—enter into the construction of bone, viz.: the lamella, lamina and Haversian System, Fig. 12½. Some units extend from the amphibian, through the reptile, bird and mammal into Man, as the lamellae and early differentiations of the Haversian System; some, from the reptile to man, as the laminae, and some from the late mammals-ungulates into man, as the late differentiations of the Haversian System; that is, lamellae, laminae, and Haversian Systems did not appear in an equal degree of differentiation at the same time in vertebrate history, but at different times, and in the order above mentioned. The most completely differentiated unit is the Haversian System and this is found as the sole unit of structure in only a few mammals and in some men, but not in all.

Variation in bone structure is the rule and not the exception, and occurs most extensively in the mammals. It is generally true that the lower the grade of development of the animal, the lower the type of bone structure will be, and conversely the higher* the grade the higher the bone type. We do not find an

* Those who have caught these fish have found the following animals in their stomachs at different times: Wood duck, rice birds, garter snake, black bass, minnows, crawfish, frogs, sucker or "red horse," wall-eyed pike.

* The terms lower and higher grade of animal refer more especially to cerebral than to physical levels and low and high bone type, to the earliest unit—lamella—and to the latest—Haversian System.

amphibian bone composed of completely differentiated Haversian Systems, and do not find human bone composed of lamellae alone; but the lamella characterizes the amphibian and the Haversian System, man. It seems to be a fact that those animals possessed of the highest degree of intelligence have the highest type bone, and those with the lowest degree have the lowest type bone. Taking the degree of intelligence as the basis of valuation, we would expect to find a low bone type in the fish and in this we are not disappointed.

As the fish is the earliest vertebrate which has bone, it is interesting to compare its bone type with that which is found in the amphibian (next in order above) and the higher mammals.

The bone structure of the mascalogne presents some interesting peculiarities.* In bone construction the visible result is evidence of an operating force which produced it. The peculiarities of bone type of the fish are seen (1) in the differentiation of bone substance leading to a constructive unit, (2) in the plan of the circulation and (3) in the relation of one to the other.

Referring to Fig. 5, again, a cross section of the lower jaw bone with a tooth in position may be seen. The differentiation of bone substance in this section presents an earlier or lower degree than that seen in the amphibian. The bone substance is lamellated, but the lacunae and canaliculi which are present in the amphibian are not found in the bone of the fish. In this bone, minute objects are seen in the bone substance which appear—at first sight—to be lacunae, but which on further investigation are found to be short segments of minute vessels.

No canaliculi extending from one lacunae to another have been found in any of these sections as in amphibian and later bone sections, and therefore, no lacunae with their osteoblasts are possible, unless the short segments of the minute vessels, referred to above, are earlier forms of lacunae than those seen in the amphibian and the endothelial cells of the vessels are early forms of osteoblasts. Extending in a curved direction from about the middle of the base of the tooth, around the central, vascular canal, to the lower border of the jaw bone, are four or five curved, cross striated strands arranged closely together, Fig. 5 D. These strands resemble the bone differentiations seen in some amphibians and reptiles. One of these strands, usually the middle one, has several perforations which seem to lead into a hollow center of a tube, but in a cross section of the strand, no tube is evident. This striated structure is quite distinct from the rest of the bone and is always present as a considerable number of sections show. With the high power objective the cross striations are seen to be single or branched slits or clefts in the bone substance and extending between them are extremely minute parallel slits or clefts. The clefts are believed to be circulatory channels forming an early plan of circulation and one that extends into some of the later animals—as the amphibians, reptiles and some mammals. Segmenting the striations with their minute communicating clefts would form the lacunae and canaliculi of later differentiations. Fig. 13, is a cross section of a palatine bone with an ankylosed tooth in position. In this section the bone exhibits a differentiation similar to that seen in the strands of Fig. 5 D. This may be seen around the external border of the section where there are eight or ten strands partly or completely crossed by vascular clefts, Fig. 13 A. This has also been observed in Testudo sophyrus—a reptile.

In Fig. 14 is shown a cross section of the right half of the lower jaw through the fourth small tooth from the front, Fig. 1 C.

* In a monograph entitled "The Comparative Histology of the Femur" referred to in a former foot note, the comparative histology of bone was considered from amphibian to and including man and in this connection the bone of the fish, which antedated historically the amphibian, becomes interesting by way of comparison.

In this section, while the differentiation of bone is early, the plan of architecture is a finished plan.

It preceded and devised structural units to work out its needs as more and more complex functions arose. In the upper half of the sections, is seen a cone-shaped vascular bone structure terminating above in the small tooth, below near the central canal, and is distinctly separated from the rest of the bone, Fig. 14 A. The strands, mentioned above, are seen at the right of a small central canal, Fig. 14 B. A great many vascular canals equivalent to the earliest form of Haversian Systems are seen in various parts of the section. These canals are found in the bone of all classes of animals, including man. They are surrounded by clear areas of bone substance and their great number indicates a very vascular condition in bone, Fig. 14 C. The architecture of this section is very complicated and defeats an explanation when the position of the bone and its purposes are taken into consideration. The bone substance is lamellated and non-lamellated, but no lacunae or canaliculi are recognizable.

Circulation: In Fig. 15, is seen a tangential section of the lower jaw, showing the circulation. The vessels are of different diameters and are parallel with each other. They extend lengthwise of the bone, and are practically independent of the teeth. Between the blood vessels and along the lower side is seen the lamellated bone without lacunae or canaliculi.

In Fig. 16, is seen a small portion of a cross section of the lower jaw. The bone substance is differentiated into lamellae. There is no visible evidence of lacunae or canaliculi. The lamellae are composed of a clear, homogeneous bone substance and are made distinctly visible under the microscope by the granular cement substance which holds them together. That these are distinct units is shown by the fact that in senile conditions, the changes that are found occur in one lamella after another. The lamella, the first differentiation of bone substance, is found to extend through all classes of animals from the fish into man, and is therefore fundamental. The interpretation which it has in one class remains in all classes, as long as the lamella remains the same. This occurrence in the fish makes it one of the oldest units of construction in bone history.

Fig. 17, shows some of these vessels. Their connective tissue coats have a circular or spiral arrangement which gives a physical value to the blood stream. Some are very small, others large. Here and there one is seen to branch. Around the outside of one of them is is seen a vine-like clinging distribution of a nerve plexus.

In Fig. 18, is seen a tangential section of a cranial suture and adjacent bone. The structure of the cranial bones differ somewhat from that of the lower jaw bone. It does not have the same complicated architecture. The bone substance is a clear white homogenous substance, not lamellated, in which are numerous minute objects arranged in rows radiating from the suture. Some of them resemble short segments of minute blood vessels and others cross sections of capillaries or channels which are made to appear crescentric by a dark, thick wall on one side and a thin, almost invisible wall on the other. They have no canaliculi, do not in any way resemble the lacunae of the later bone and seem to be segments of minute vessels. It is obvious that without canaliculi they could not contain bone cells. From the suture, minute clefts or channels radiate into the adjacent bone substance and these small objects are isolated segments of these channels.

Relation of the Circulation to Bone Differentiation.

Comparing the bone of the fish, the earliest in bone history, with the bone of the amphibian and later animals, the most important difference between them is to be found in the relation of the circulation to bone differentiation. In the bone of the fish there are found no lacunae or canaliculi; and bone substance, homogeneous or lamellated, is produced by the blood vessels. In the amphibians and the later animals, lacunae with their canaliculi, are always present and the special bone cells or osteoblasts which occupy the lacunae, produce bone substance. In the amphibian and later bone there is a flow of blood plasma from the blood vessels through canaliculi to the lacunae containing bone-forming cells and also through canaliculi from one lacuna to another, the whole system forming a complete circulation, while in the fish bone the circulation is confined to the vessels and to clefts and channels in the bone substance.

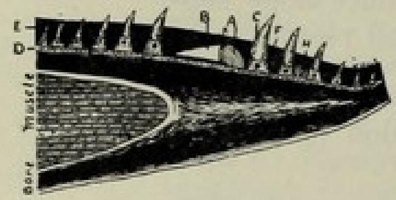


Figure 1.

Portion of lower jaw showing ankylosed teeth. Striped muscle, A; sites of shed teeth, B.

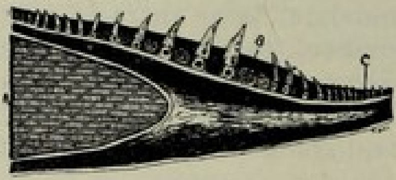


Figure 2.

Formation of a new ankylosed tooth of lower jaw. A, fibrous extension; B, tooth.

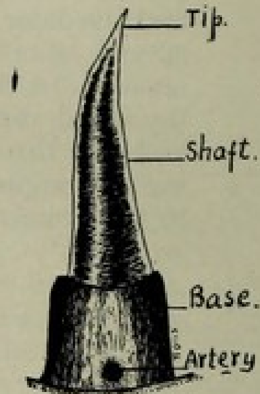


Figure 3.
Ankylosed tooth of the lower j

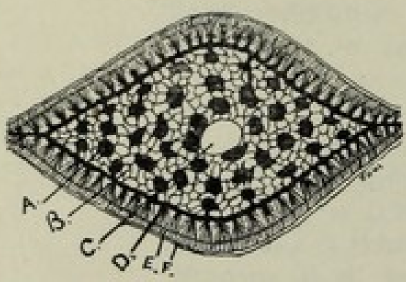


Figure 4.

Cross section of a new tooth of lower jaw of a mascalonge before it was ankylosed to the bone.

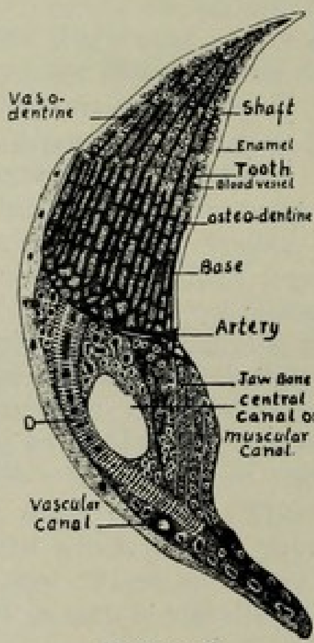


Figure 5.

Cross section of the lower jaw of a mascalonge with ankylosed tooth in position.

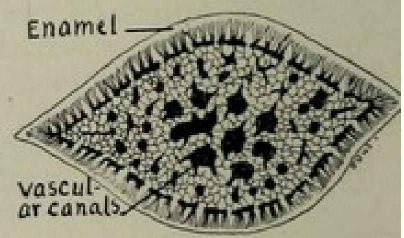


Figure 6.

Cross section of ankylosed tooth the lower jaw.

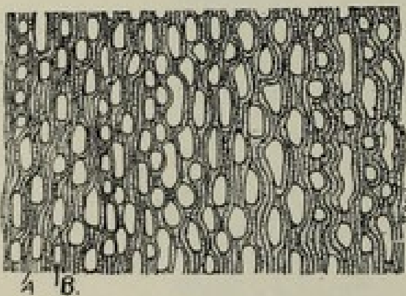


Figure 7.

Longitudinal section of base of tooth of lower jaw. A, ossified rods; B, vascular canals.

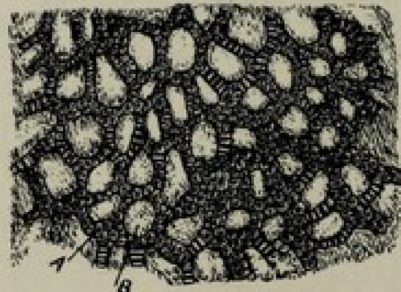


Figure 8.

Cross section of the base of an ankylosed tooth of the mascalonge. A, ossified rods; B, vascular canals.

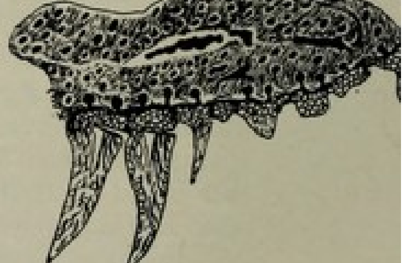
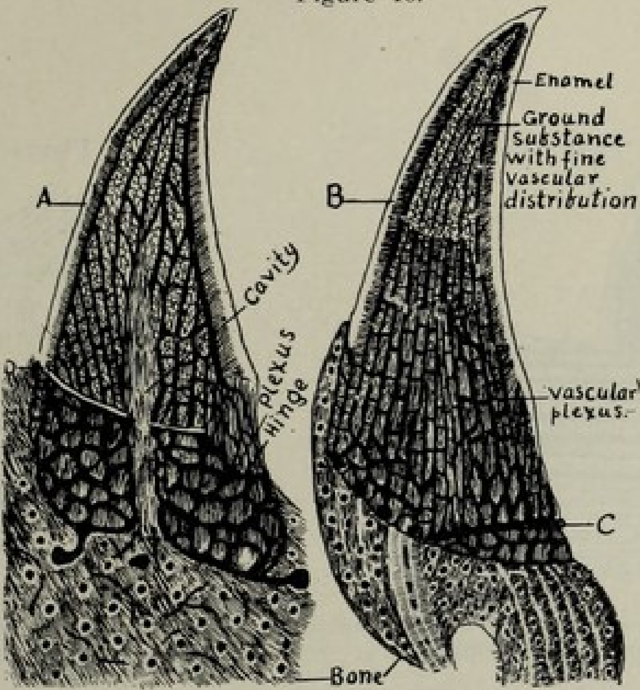


Figure 9.

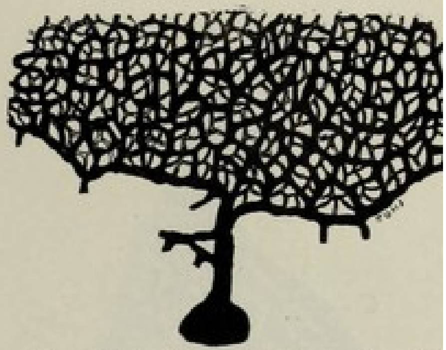
Cross section of vomer of a m calonge, showing hinged teeth a the circulation underneath.

Figure 10.



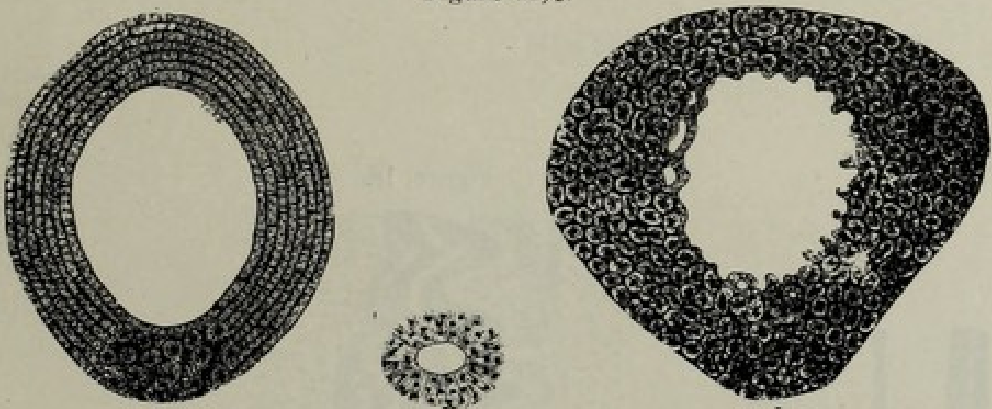
Hinged tooth (A) of the vomer, and ankylosed tooth (B) of the lower jaw of the mascalonge.

Figure 11.



Circulation beneath the teeth of tl palatine bone of the mascalonge, seen in a cross section.

Figure 12½.

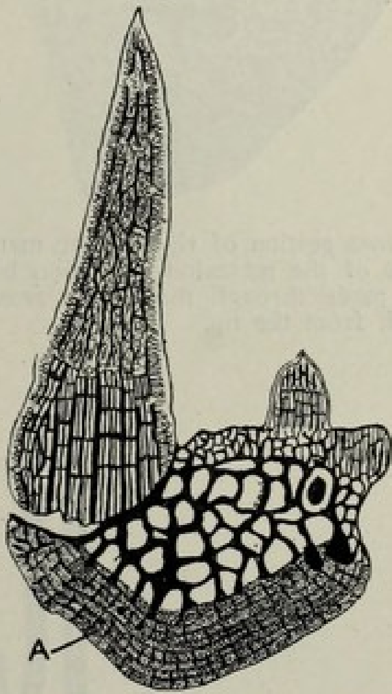


2. Second type bone, Laminae-Eland.

1 First type bone, Lamallae-Frog.

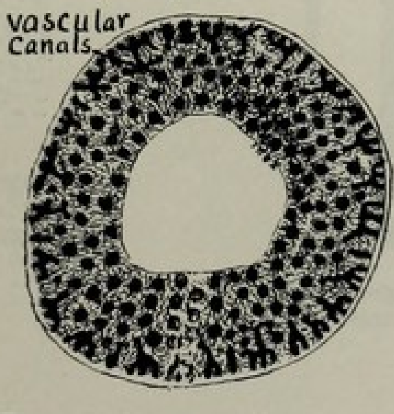
3. Third type bone, Haversian System—Man.

Figure 13.



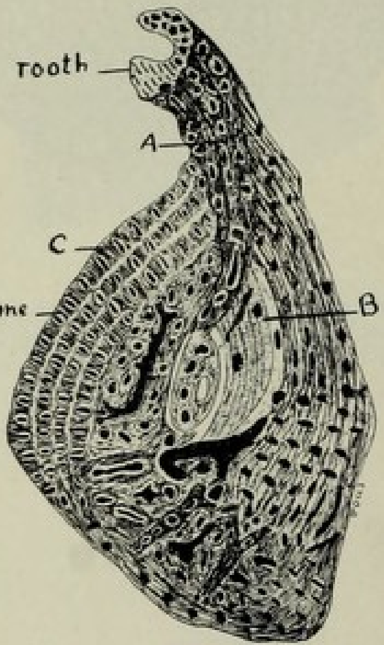
Cross section of right palati bone, with tooth in position, of ma calonge.

Figure 12.



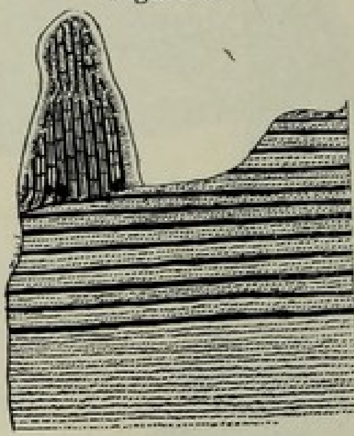
Cross section of a hinged tooth of the palatine bone of a mascalonge.

Figure 14.



Cross section of right lower mandible of the mascalonge, section being made through the fourth small tooth from the tip.

Figure 15.

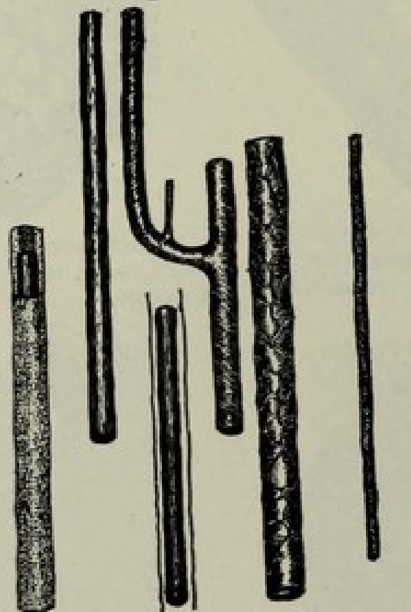


Tangential section of the lower jaw and mouth of a mascalonge.

Figure 16.

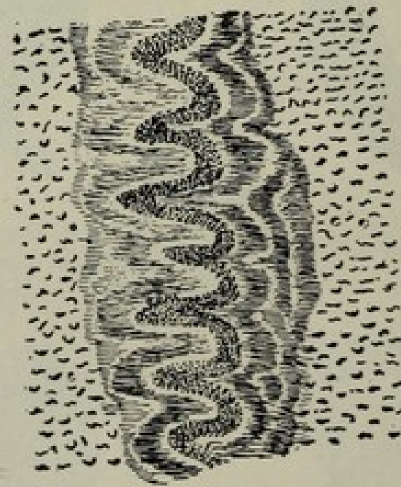
Cross section of lower jaw of ma calonge, showing lamellated bo without lacunae or canaliculi.

Figure 17.



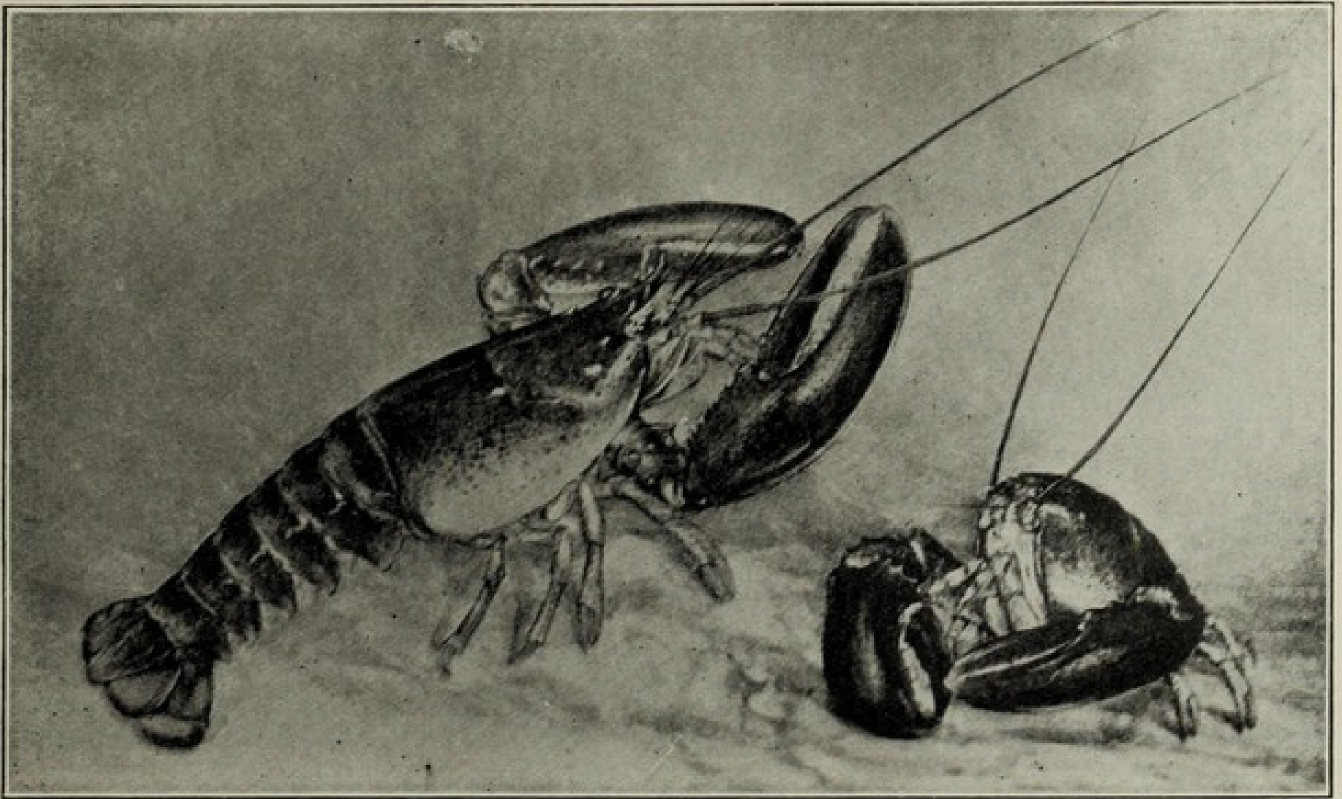
Blood vessels in a tangential section of lower jaw of a mascalonge.

Figure 18.



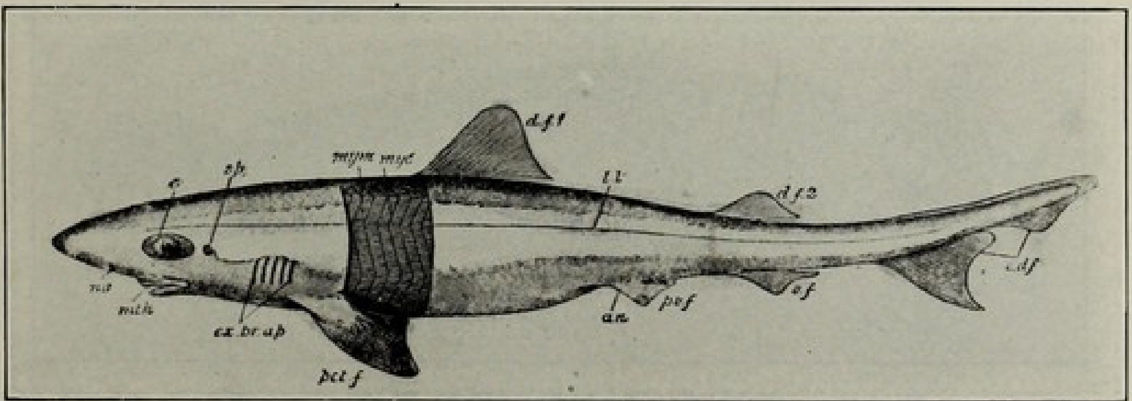
Tangential section of a cranial suture and adjacent bone of a mascalonge.

FISHES DESCRIBED.

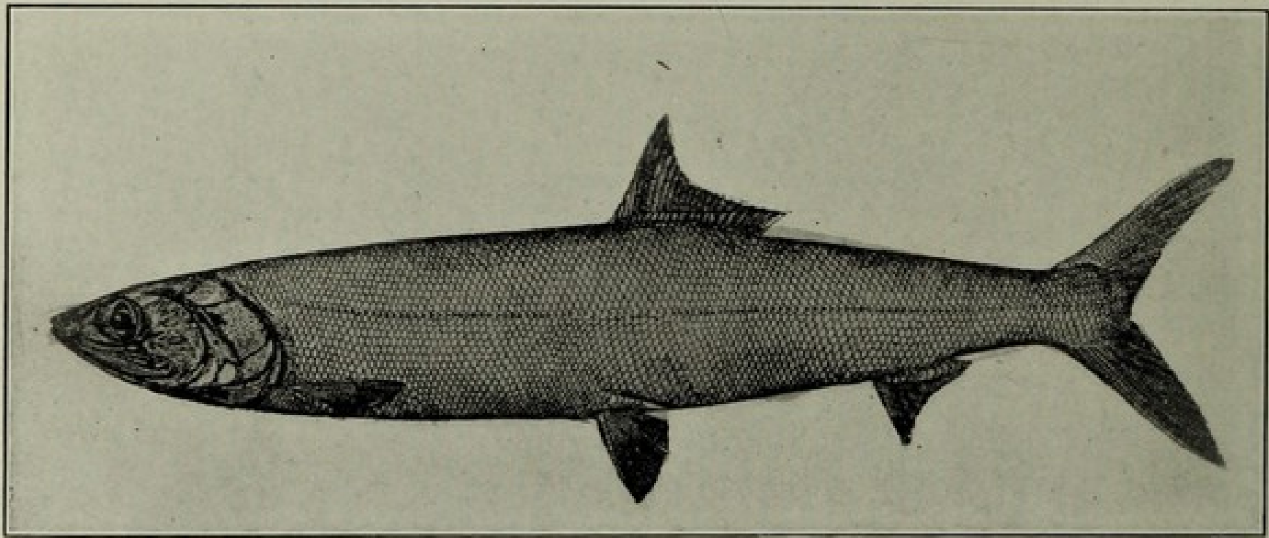


AMERICAN LOBSTER—
(Homarus Americanus)

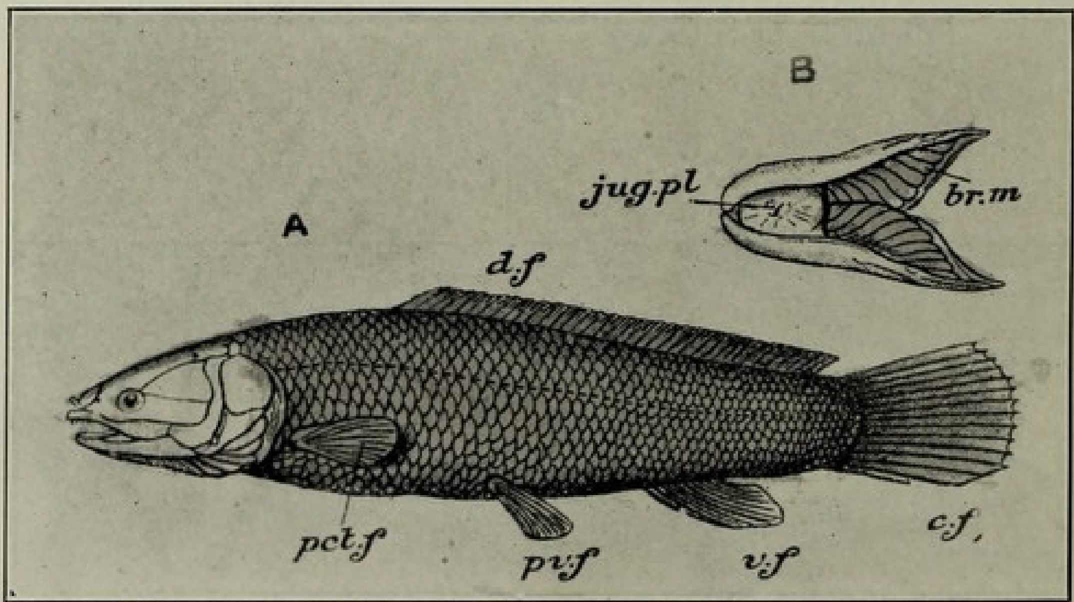
National Geographic Society
Hashime Murayama



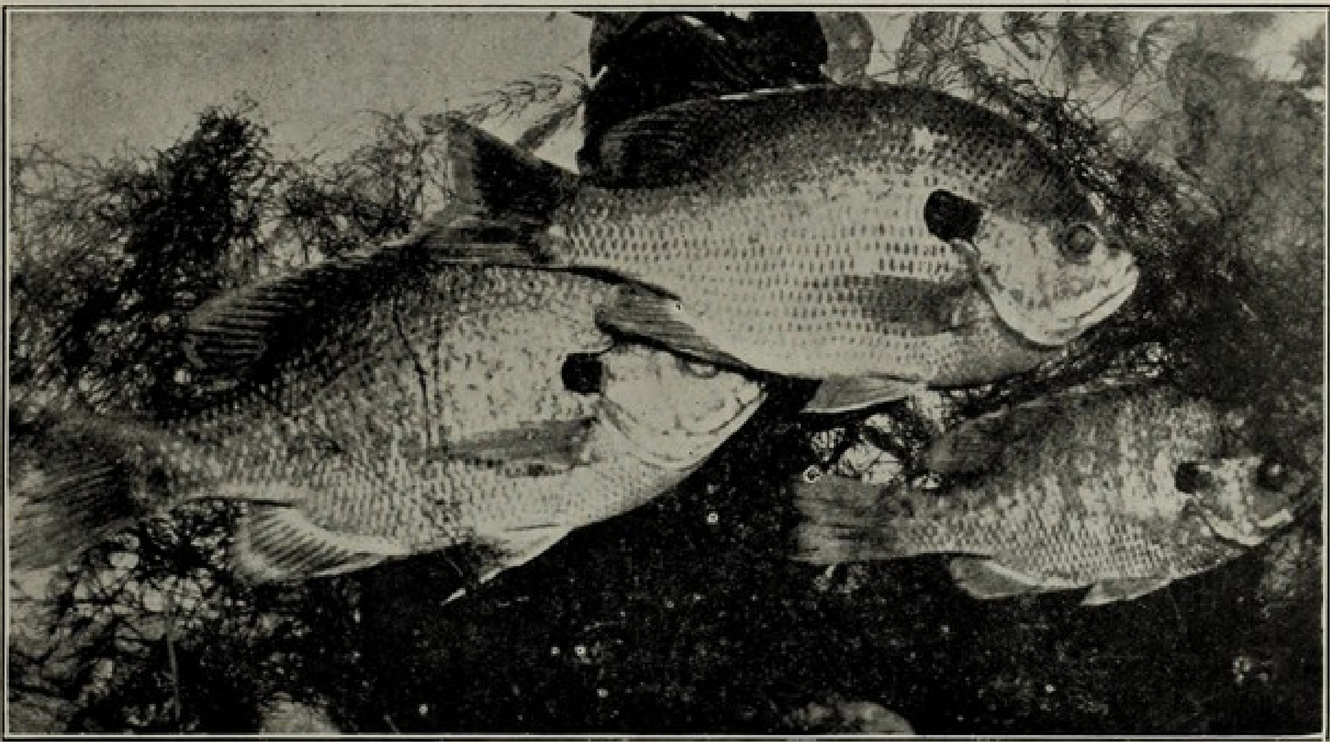
DOG FISH—(Mustelus Antarctics)
Parker & Haswell



BONY FISH: TEN-POUNDER—(Elops Saurus)
Jordan & Evermann

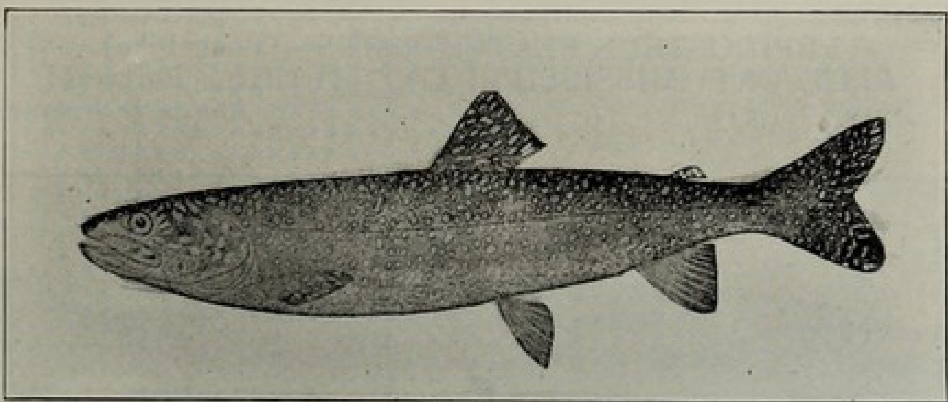


AMIA CALVA—(Bow-Fin)
Parker & Haswell



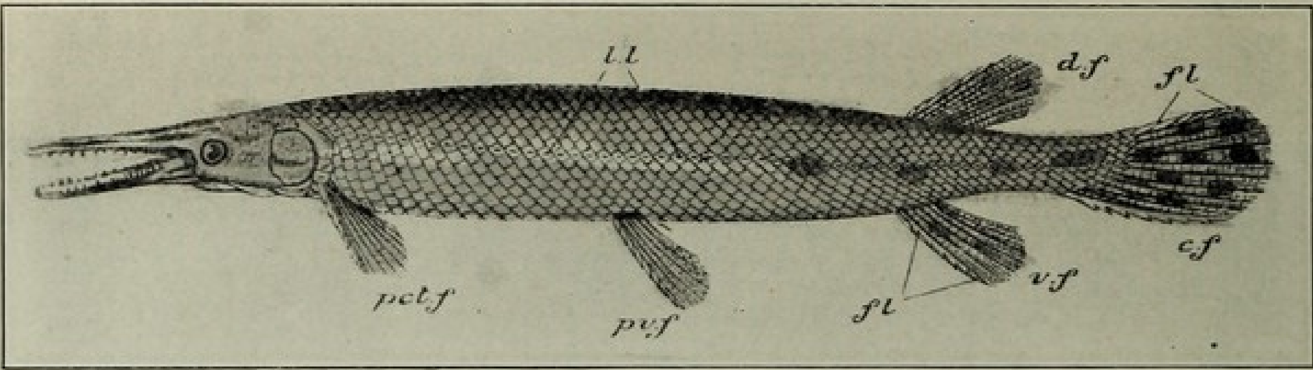
LEPOMIS PALLIDUS

Jordan & Evermann

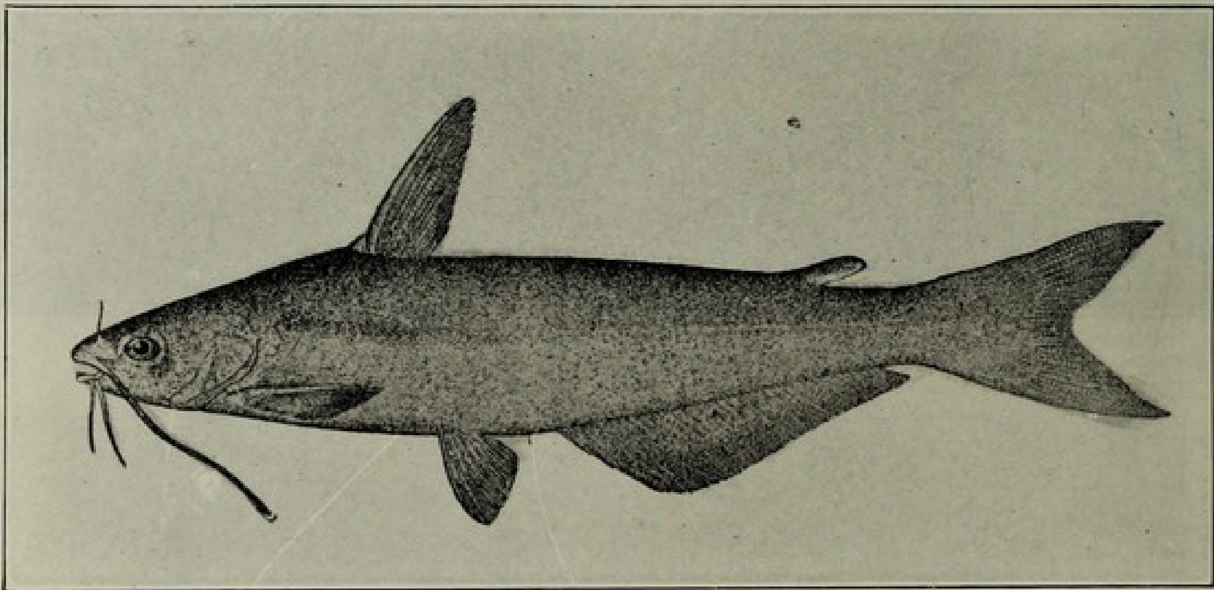


GREAT LAKE TROUT: MACKINAW TROUT
(Cristvomer Namaycush)—Walbaum

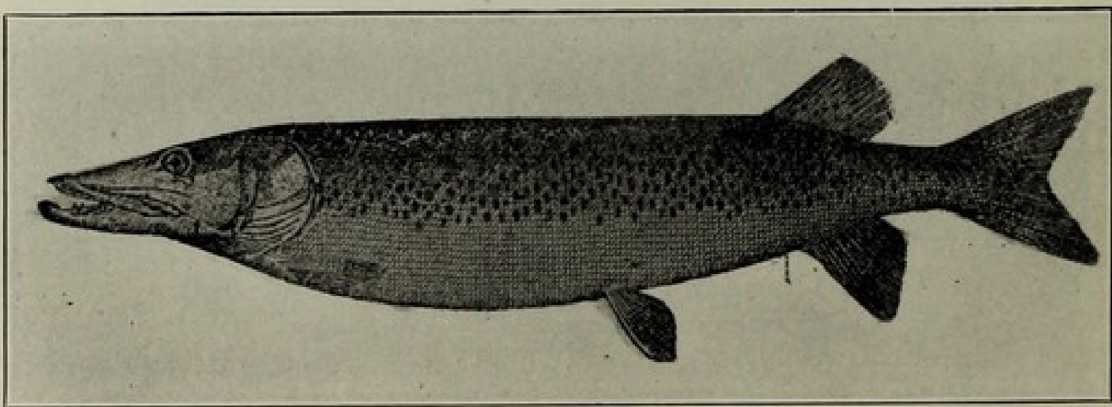
Jordan & Evermann



BONY PIKE—(Lepidosteus Platystomus)
c. f., Caudal fin; d. f., Dorsal fin; fl., Fulera; l. l., Lateral line; pct. f., Pectoral fin; pv. f., Pelvic fin; v. f., Ventral fin. (After Cuvier.)
Parker & Haswell



LEPIDOSTEUS PLATYSTOMUS—(Bony Pike)
BLUE CAT: MISSISSIPPI CAT—(Ictalarus Furcatus)
Jordan & Evermann



MUSKALLUNGE—(Esox Masquinongy)
Jordan & Evermann

WHEN AND HOW WE ACQUIRED OUR TEETH—BASED UPON THE COMPARATIVE HISTOLOGY OF BONE AND TEETH.

BY

J. S. Foote, A. B., M. D., LL. D.

Research Professor in the Dental Department of Creighton University, Omaha, Neb.

This investigation was undertaken in behalf of the Scientific Foundation and Research Commission of the American Dental Association.

PART II.

AMPHIBIANS.

CONTENTS

life of that vertebrate. The lower jaw and teeth fit into a groove between the upper teeth. The long tight joint between the jaws, the two rows of upper teeth and intervening groove, the lower jaw and teeth adapted to the groove, make a prehensile arrangement of unusual strength and value to the animal. Section of upper teeth and bone. Semi sockets. Tooth grasping. Sections of upper jaw and teeth and lower jaw and teeth. Low differentiation of bone. Keratinized and calcified tissue extension. Sections of vertebra and femur. First type bone. Comparison of bone of tailed and tailless amphibian. The toad, frog, hellbender. Variations in the number of teeth in the water and land amphibians. Variations in the relations of bone to teeth. Advance in bone type due to a biological cause operating through the vertebrate series and forcing the acquatic to assume the atmospheric life. Life began in water.....................Page 31

V. *A Study of the Bone and Teeth of Hyla versicolor—tree frog.* Genus includes tree frogs and toads. One hundred and fifty species of Hylinae. Tree frog more appropriate name than tree toad on account of the resemblance of the teeth of the tree frog to the bull frog. The toes terminate in round sucking discs. Under surface of the skull showing the upper jaw with about 60 microscopic teeth in a single row. Jaw bone cartilage and calcified cartilage. Longer jaw and eversible tongue. No teeth on the lower jaw. The Hyla versicolor conforms to the Rana catesbeiana in the arrangement of teeth instead of the Bufo americana and hence the appropriate name Tree-frog...Page 39

VI. *A Study of the Bone and Teeth of Scaphiosus holbrooki.* The amphibians illustrate the change in animal life from aquatic to air breathing. General classification of amphibians. Difference in bone type between the amphibians and their successors, the reptilian lizards is very slight. Line of histological bone demarcation not defined. Other differences. Amphibians could be extended to the alligators as far as bone type is concerned. First important advance in bone type found in the alligator. Under surface of the skull of Scaphiosus showing 100 small teeth of the upper jaw in a single row. Lower jaw composed of several strands of first type bone united by connective tissue. Eversible tongue. Lower jaw flexible. Sections of vertebra and cranial bones showing very little bone differentiation. Section of the femur shows an early differentiation of the first type bone. Origin of dentinal tubules from the cells and blood vessels of the central tooth chamber. Relation of dentinal tubules to circulatory system ....Page 42

VII. *A Study of the Bone and Teeth of Rana catesbeiana—Bull frog.* Amphibians lead dual lives. Change from water to air signifies change in organization. Gills to lungs, fins to limbs and important change in metabolism. From the Silurian to the Carboniferous Age the fish was raised to a higher level from which life on land became visible. Differences in bone types of 39 amphibians. An advance is seen in the lamina and early Haversian Systems. The majority of amphibians true to the lamellar bone type. The advance is biological, not functional. Biological advances are slow, but real and follow a fixed law. Reversion of that law is not possible as applied to living things. Bone and teeth tell the story of the progress of life. If they had remained fixed there would be no visible evidences of advance. A fixed, stationary living tissue or organ is not possible. Life implies a constant change. From bone substance to Haversian System by perceptible gradations is the rule in development. Under jaw of large bull frog showing maxillary and vomerine teeth. More than 200 of the maxillary with eight of the vomerine teeth make up the tooth array of this frog. Prehension made possible by double curve of both jaws. Tooth shedding. Lower jaws without teeth. Eversible tongue. Sections of vertebra and urostyle. First type bone. Section of the lower jaw showing a better development than the upper. Sections of the femora of three bull frogs—large, medium sized and small, showing different developments. Section of the last rib showing cancellous bone.

INDEX OF AMPHIBIANS

AMPHIBIANS.

The Amphibians are divided into general classes, viz., the Urodels or tailed amphibians as the sirens, amblystoma, newts, salamanders, cryptobranchus and the Anura or tailless amphibians, as the frogs and toads.

URODELA
OR
TAILED AMPHIBIANS.

A STUDY OF THE BONE AND TEETH OF SIREN LACERTINA

SIREN LACERTINA—AN EEL-LIKE AMPHIBIAN.

The Siren is an eel-like amphibian having fore legs with four fingers on each leg and no hind legs; the head is triangular in shape with a small mouth.

1. Drawing of the under surface of the skull showing the upper jaw and teeth: A, tip of the jaw with small irregularly shaped teeth, B, jaw, C, small teeth covering the whole under surface of the skull or roof of the mouth and extending backward beyond the articulation with the low jaw, D, articulation with the lower jaw, E, circular group of small teeth; the teeth are conical in shape in the anterior portion and resemble the tooth-like scales of certain fish in the posterior portion. The teeth of the two jaws have no particular relation to each other thereby indicating only a prehensile function.

2. Drawing of the lower jaw with teeth and tongue; A, jaw, B, teeth, C, tongue, D, articulation with the upper jaw, E, floor of the mouth. The teeth recall those of the fish in their occlusive relations; there are three or four rows of microscopic teeth along the inside of the jaw, while there are no teeth in the corresponding locations of the upper jaw, there are no teeth on the tip of the lower jaw, while there is a group of teeth on the tip of the upper jaw.

3. Tooth of the lower jaw, the tooth is slightly conical in shape terminating in a clear pointed cap corresponding in location and appearance to enamel; A, cap; B, shaft.

4. Longitudinal section of the lower jaw; A, outer surafce, B, B, B, strands of first type bone, C, C, C, blood vessels, D, D, cross section, E, bone.

5. Longitudinal sections of a tooth of the upper jaw; A, cap, B, shaft, C, bone.

Thus, the arrangement of the teeth in Siren lacertina suggest no particular function unless it is one of prehension and in this it indicates a similar function observed in the foregoing fish and appears to be not far removed from that class of vertebrate and only slightly elevated above the level of that class. The absolute identification or recognition of biological levels is not as easy as it would seem to be. Enamel, dentine and bone are closely related and are indicated by their positions, by obscure rods, tubules, canaliculi and lacunae which, excepting the rods, are not dentine or bone, but merely canals and spaces in an inorganic base. Enamel substance, dentinal substance and bone substance are clear inorganic compounds of protoplasm of different inorganic densities and, for convenience, we call them by names just as though we really understood their differences. The early vertebrate teeth are single cones and, perhaps, the best forms of teeth to serve the purpose of prehension; at least, it seems best, in the light of the fish and amphibian developments, to conclude that the foundation of the conical tooth has been laid and it only remains to multiply and fuse together these cones to prepare them for the more specialized functions of mastication of the later vertebrates. Furthermore, we are able to see in this the establishment of the cone tooth which may appear by extension or biological projection at any time in later vertebrates by virtue of its prehensile impress which was the first fundamental office of the tooth.

Another peculiar character established in the tooth history of amphibians is seen in the biological condition of tooth losses; in the tailed amphibians, as the Siren and Cryptobranchus, there is a multiplicity of teeth which seem to be beyond the apparent needs of the animals, in the tailless amphibians, as the frogs, there are many teeth on the upper jaw and none on the lower jaw, in the toads there are no teeth on either jaw. These tooth losses are difficult to account for except on the basis of biology and hence may be expected to recur at any time thereafter in vertebrate history and for a similar reason. Phylogenesis evidently does not lose its bearing at any time in biological history and the gains and losses of the developmental forms of life may be considered as having their causes somewhere in phylogenetic history. Life, at the amphibian level, has not gone beyond the single cone stage of the tooth, nor the first type of bone excepting in the Bufo americana in which the second type bone was indicated by the presence of a single second type bone or lamina.[1] It is somewhat unexpected that the first evidence of an elevation in bone type level should be accompanied by a complete loss of teeth as is shown by the fact that the Bufo americana has a bone elevation and no teeth.

When the amphibian lost its tail, it began to lose its teeth; thus, the tailed amphibians—siren lacertina, amblystoma tigrinum, necturus maculatus, crytobranchus alleghaniensis—all have teeth on both jaws. The tailless amphibians—rana catesbeiana, hyla versicolor, scaphiosus holbrookii—have teeth on the upper jaw and none on the low jaw; while the Bufo americana has not teeth on either jaw. This latter tailless vertebrate occupies the position of an exception to the rule in vertebrate history. This exception, however, might have little or no effect upon the rule, since it occurs in the small percentage of vertebrates. It is possible for a portion of a species to form an exception without changing the rule. Teeth in vertebrate history is the rule and a specialized small portion of it may form an exception and not change the rule. Following the amphibians, the general rule may again be reinstated with the recurring possibility of tooth loss at any time in the future by virute of the impresses in phylogenetic history.

TEETH AND TAILS IN EARLY VERTEBRATE LIFE.

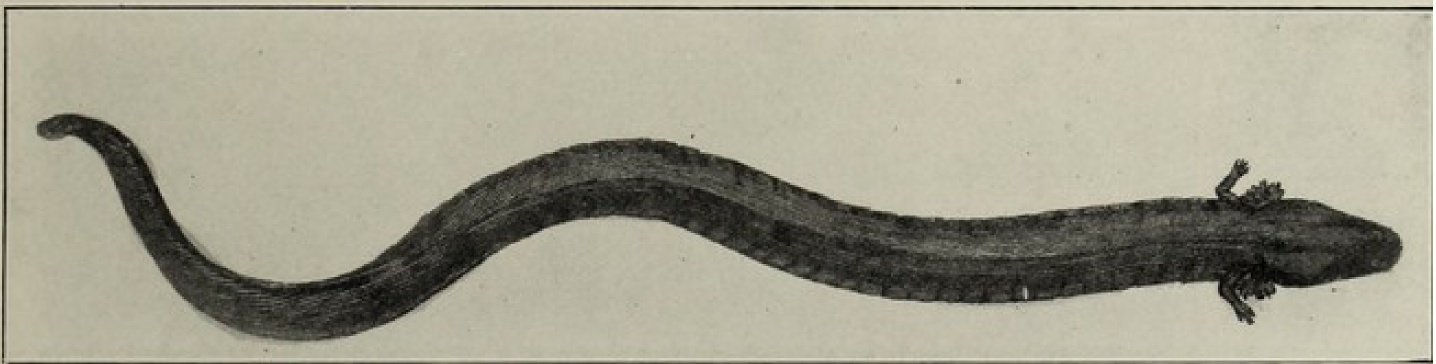
Tailed Amphibians.

Siren lacertina—teeth on both jaws.
Amblystoma tigrinum—teeth on both jaws.
Necturus maculatus—teeth on both jaws.
Cryptobrachus alleghaniensis—teeth on both jaws.

Tailless Amphibians.

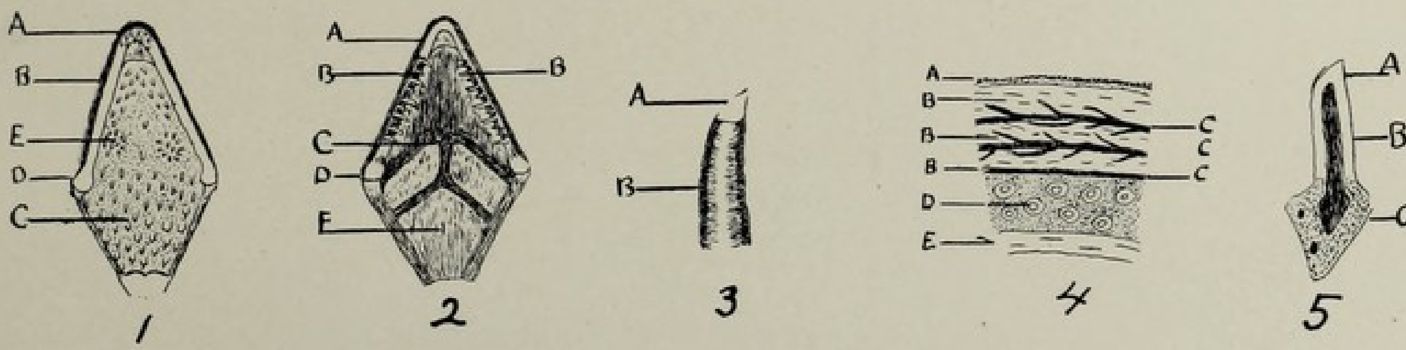
Rana catesbeiana—teeth on upper jaw, none on lower.
Hyla versicolor—teeth on upper jaw, none on the lower.
Scaphiosus holbrookii—teeth on upper jaw, none on lower.
Bufo americana—no teeth on either jaw.

While there may be no relation of the loss of the tail to the loss of teeth, yet the above amphibian list of vertebrates is interesting. It is possible that the loss of an important, functional portion of the backbone and its circulatory system may have some biological bearing upon all of the inorganic structures of the body and especially upon the teeth if there is a genetic relation between bone and teeth. In biological history the bone and the teeth began at about the same time, the bone somewhat antedating teeth, and both were dependent upon the blood for their origin and characters. A reduction of the total amount of bone and its circulatory system, by removal of the tail, might have some important bearing upon the teeth and they would suffer a loss for the same reason. The loss of the tail is as difficult to understand as the loss of teeth and seems to have a similar cause; why should the vertebrate ever had a tail if it did not expect to need it and keep it? Evidently it did not, for it began to lose it in amphibian life. The survival and extinction of important organs of the vertebrates can hardly be explained on the basis of function, there seems to be a biological factor in the cause which is capable of extension throughout the vertebrate series.



SIREN LACERTINA (From Mivart.)

Zoology *Parker & Haswell.*



TEETH OF SIREN LACERTINA.

1. Drawing of the roof of the mouth showing the teeth.
2. Drawing of the lower jaw and floor of the mouth.
3. Drawing of a tooth of the lower jaw.
4. Longitudinal section of a portion of the upper jaw.
5. Longitudinal section of a tooth of the upper jaw.

A STUDY OF THE BONE AND TEETH
AMBLYSTOMA TIGRINUM

BONE AND TEETH OF AMBLYSTOMA TIGRINUM.

The Amblystoma tigrinum is said to be the lowest of existing Amphibia and, the most primitive form. It is interesting on account of its early position among amphibians and also on account of its unique larva—called the Axolotl. The first vertebrate, the fish, depended chiefly upon the tail for its power of locomotion and when the amphibian stage of development was reached, the tail was still retained in its original capacity in the water, while the fins were transformed to limbs for use on land. The Urodeles or tailed amphibians introduced, therefore, the primitive land vertebrates. In the vertebrate series, the tail is the rule and not the exception. It may be said that while Nature began this great series with a visible, function tail, she has ended it without one. The amblystoma also has an unique larval stage as seen in the Axolotl which may or may not exhibit metamorphosis depending upon environmental circumstances. In some instances the larval gills disappear, the gill slits close and a terrestrial animal appears; in other instances the larva exhibits no change, but breeds in its larval stage, reproduces its kind and reaches its adult stage as an Axolotl. In this early stage of vertebrate development of land animals we may expect to find interesting bone and tooth differentiations.

1. A drawing of the under surface of the skull showing the upper jaw and the two rows of teeth across the anterior end: A, external row of teeth, B, groove, C, internal row of teeth, D, sphenethmoid bone, E, articulation with the lower jaw. The two rows of teeth are not parallel, but are more widely separated at the outer angles of the jaw than they are in the middle.

2. A drawing of the lower jaw and teeth. The teeth are arranged in oblique rows passing from the external to the internal borders; in this, the jaw differs from that of the Necturus maculatus, which has only one row of teeth and that along the middle of the jaw bone: A, external row of teeth extending around the outer border of the jaw, B, groove, C, oblique row extending from the outer to the inner borders of the jaw, D. D, articulation with the lower jaw.

3. Flat, longitudinal section of a portion of the upper jaw: A, dentinal tip of a tooth, B, shaft with short faint dentinal tubules, C, central chamber, D, jaw bone from which the tooth arises; there is no line of demarcation between the bone and the tooth, but the tooth is an extension and differentiation of the bone substance, E, blood vessel extending along underneath this layer of bone, F, bone of higher type, as indicated by the long narrow lacunae and a network of canaliculi; two types of bone differentiation appear, an early type, D, which gives origin to the teeth, and F, a higher type as a foundation of the early type.

4. Longitudinal section of a single tooth of the upper jaw: A, dentinal tip, B, shaft with short, dentinal tubules coming off from the central chamber, D, vascular cavity of bone in connection with the central chamber.

5. Longitudinal section of a tooth of the lower jaw in position; the tooth is more pointed than one of the upper jaw: A, dentinal tip, B, clear portion of the shaft, C, portion of shaft with dentinal tubules, D, central chamber, E, early bone type, F, later bone type. As the section is not made exactly in the longitudinal center of the tooth, the central chamber does not show connection with a vascular cavity of the jaw bone.

6. Flat longitudinal section of the superior cranial bone: A, large irregular, branching bone cells, B, numerous longitudinal striations, generally parallel with each other; in a way the striations remind one of the osteogenetic fibers of cranial bone development of the embryo.

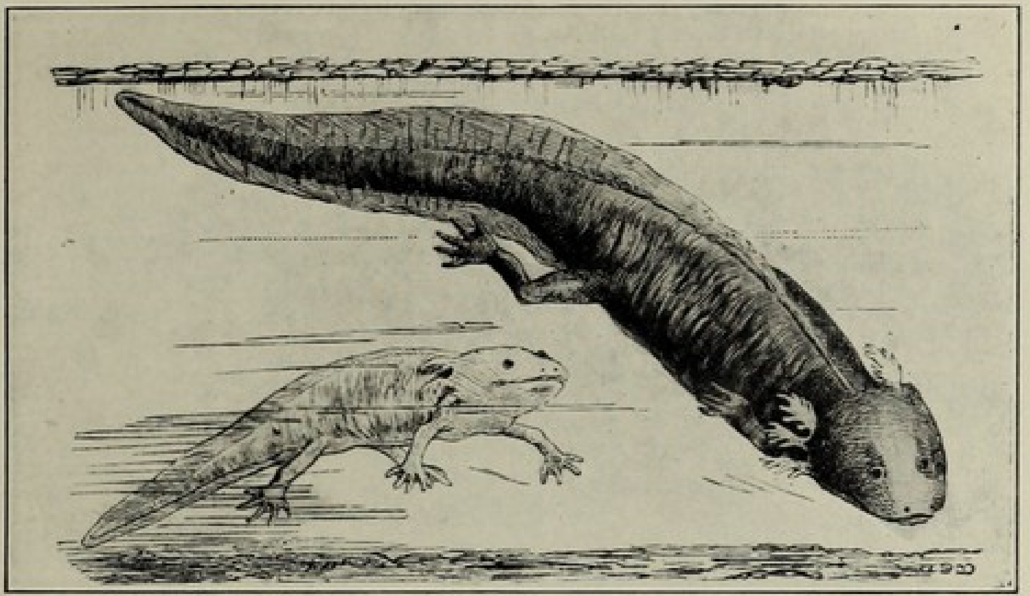
7. Cross section of a vertebra: A, neural canal, B, blood vessal along which is a zone of calcified cartilage, C, canal of the notochord. The whole section is

otherwise composed of bone substance in which are oval lacunae visible canaliculi.

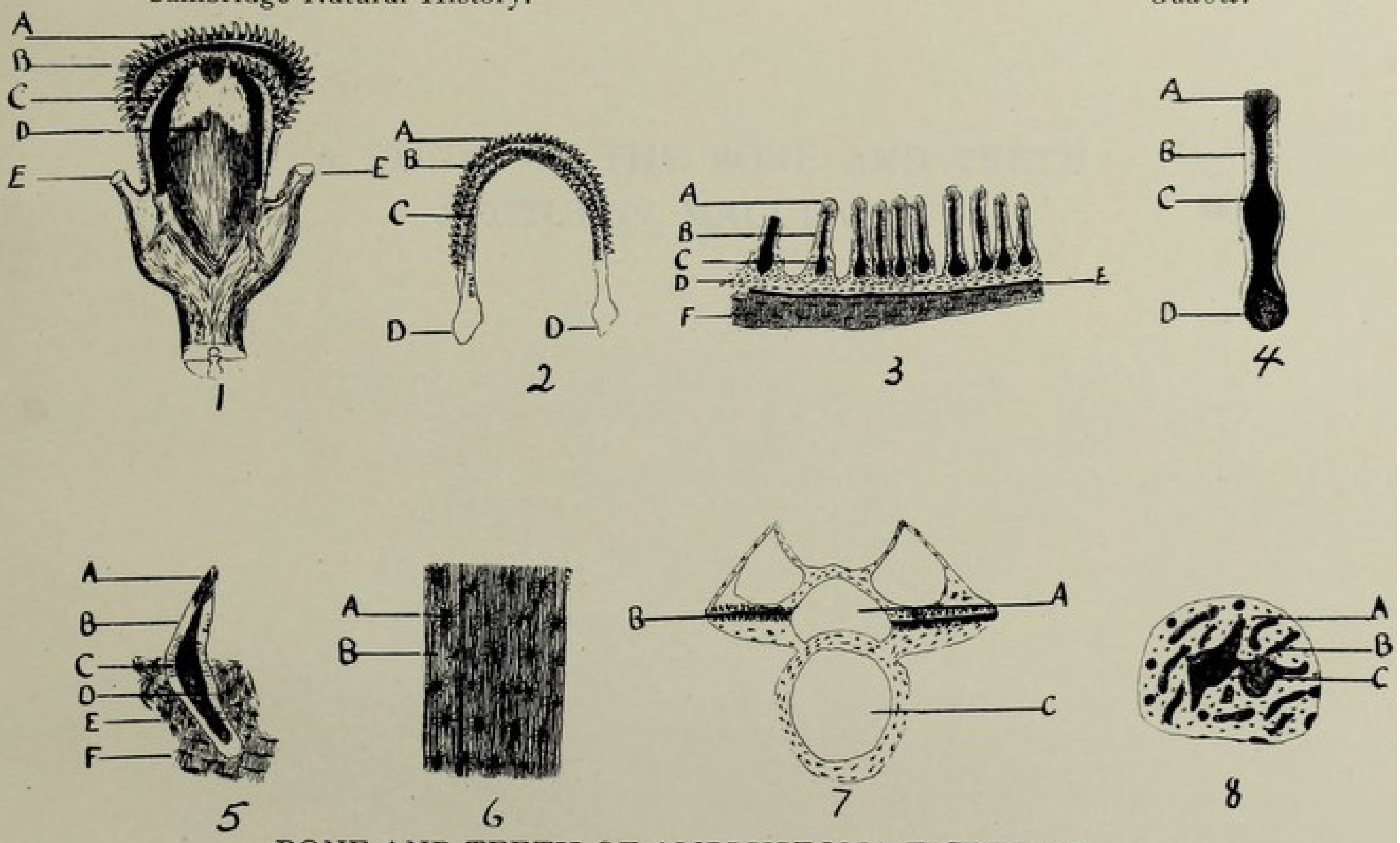
8. Cross section of the left femur at its midline: A, bone substance with oval lacunae, B, vascular canals, C, medullary canal. The bone is a low type bone.

Comparing the bone and teeth of the Amblystoma tigrinum with the bone and teeth of the Nectarus maculatus, there is found very little difference in the degree of differentiation in the two animals; they both belong to a very early stage of amphibian development. Geological time was required to establish permanent and specific variations which could be recognized as sufficiently distinctive to distinguish one class of vertebrate from another. The bone of the Necturus maculatus shows a slightly earlier type of differentiation than that of the Amblystoma tigrinum while the teeth of the two animals do not vary very much from a common type. Evidently they both belong to the devlepoment of about the same geological age and we would not expect to find any marked variation peculiar to either one.

A peculiar and significant feature in connection with the teeth of this early amphibian is the irregularly arranged double row of teeth on the anterior portion of the upper jaw and the oblique arrangement of two or three rows of teeth on the lower jaw. Known function does not account for this peculiar variation. Such an irregular occurrence of teeth in early tooth history makes possible a recurrence of a similar arrangement, in part at least, in later teeth by virtue of an extension of the original cause and the lasting impress of the formative period of tooth history. Whatever has happened in tooth history may happen again and for the same reason that it happened in the first place and, furthermore, whatever happens now in later developments, happens because it has happened before. This may be offered as an explanation of the very irregular tooth arrangement frequently observed in man. Cases have been seen by dentists, of two incomplete rows of teeth, in the maxillary region, separated by a groove into which the teeth of the lower are applied.



AXOLOTL OR LARVAE OF AMBLYSTOMA TIGRINUM.
Cambridge Natural History. *Gadow.*



BONE AND TEETH OF AMBLYSTOMA TIGRINUM.

1. Drawing of the undersurface of the skull showing the upper jaw.
2. Drawing of the lower jaw and teeth.
3. Flat, longitudinal section of a portion of the upper jaw.
4. Longitudinal section of a single tooth of the upper jaw.
5. Longitudinal section of a tooth of the lower jaw in position.
6. Flat, longitudinal section of the superior cranial bones.
7. Cross section of a vertebra.
8. Cross section of the left femur.

A STUDY OF THE BONE AND TEETH
NECTURUS MACULATUS

TEETH AND BONE OF A TAILED AMPHIBIAN—NECTURUS MACULATUS.

The head is triangular in shape and flattened. The upper jaw articulates with the lower 20 mm. from the front by a slanting joint. The upper jaw has two rows of teeth, an external row of six teeth at the apex of the triangular mouth, and internal row of 25 teeth parallel with the external row and separated from it by a groove. The plan is that of Amblystoma plan in miniature. The lower jaw has 52 teeth and fits into the groove between the two upper rows of teeth.

1. Under surface of the skull showing the upper jaw with its two rows of teeth: A, external row of seven teeth projecting from the anterior apex of the triangular under surface of the skull. The teeth are small, curved and pointed. B, grove between the external and interal rows of teeth. C, internal row of 25 similar teeth which is parallel with the external row. D, joint of articulation with the lower jaw 20 mm. from the anterior apex. E, inferior bony surface of the skull. The few projecting external teeth remind one of the protruding central incisors sometimes seen in later mammals.

2. Lower jaw with 52 teeth like those of the upper jaw. A, jaw bone with teeth, B, joint of articulation with the upper jaw.

3. Cross section of the upper jaw showing the two rows of teeth and the immediate groove. A, A, teeth of the internal row, B, B, teeth of the external row, C, bone of the internal row from which the teeth arise, D, bone of the external row from which the teeth arise, E, joint of the two bones, F, check of the join, H, connective tissue between the two bones holding them in place, I, joint in the bone of the external row giving slight motion to the two parts of the bone, J, vascular cavity between the two bones. The joint between the two bones gives motion to the two rows of teeth enabling them to approach each other with a check stop seen at F.

4. Flat, longitudinal section of the internal row of teeth and bone. A dentinal tip, B, shaft of tooth with homogeneous walls, C, central chamber with blood vessels and irregularly shaped cells along the outer border, D, base of the tooth fitting into a depression in the jaw bone, E, jaw bone composed of a clear matrix in which are numerous oval cells with very short canaliculi. Between the bases of the teeth are seen extensions of the jaw bone from which the cells of the shafts seem to arise. The only dentinal structure found was in the tips of the shafts, the remainder was homogeneous. The whole structure shows a low degree of differentiation.

5. Longitudinal section of a single tooth and its bone attachment of the internal row. A dentinal tip, B, homogenous shaft, C, central chamber with blood vessels and cells, D, union of shaft and bone, E, jaw bone composed of a clear matrix in which are many bone cells with numerous canaliculi. The central chamber dips down into the bone a considerable distance. At the junction of the shaft with the bone is a small vessel extending at right angles to the long axis of the tooth.

6. Longitudinal section of a tooth and its bone attachment of the external row of the upper jaw. A, dentinal tip, B, homogeneous shaft, C, central chamber with blood vessels and cells, D, union of shaft with bone, E, extension of the central chamber into a depression of the jaw bone, F, jaw bone composed of granular matrix in which are numerous irregularly shaped bone cells with short canaliculi. There seems to be no transitional structure between the shaft of the tooth and the bone, but there is an abrupt change from the bone to the homogeneous shaft of the tooth.

7. Drawing of a tooth of the internal row as seen from the outside. A, dentinal tip, B, shaft, C, union of shaft with bone.

8. Flat, longitudinal section of the teeth and bone of the lower jaw. A, dentinal tip, B, homogeneous shaft, C, central chamber, with blood vessels and irregularly shaped cells, extending down into a depression of similar shape in the jaw bone, D, bone elevation between the teeth from which the shaft of the tooth arises, E, jaw bone composed of a clear homogeneous matrix in which are oval bone cells without apparent canaliculi.

9. Cross section of a vertebra. The whole bone structure is composed of homogeneous matrix in which are oval bone cells occupying lacunae without canaliculi. A, A, bone, B, Neural canal, C, canal of the notochord.

10. Cross section of the right femur at its mid-line; the bone is composed of a very clear, homogenous bone substance in which are a few branching bone cells.

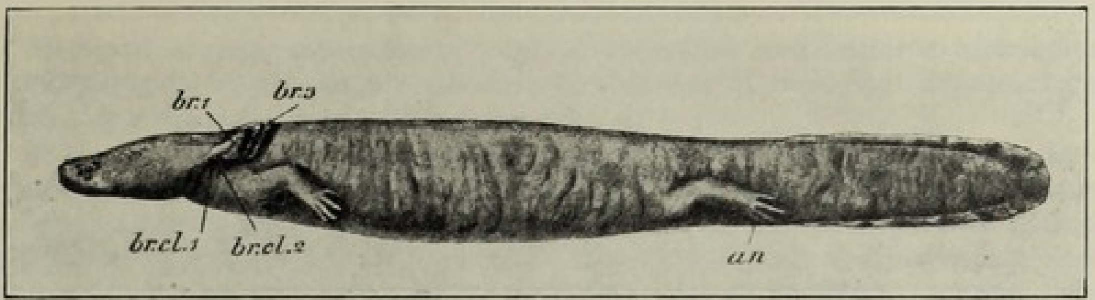
11. Flat section of the superior cranial bones. A, several parallel rows of large branching bone cells in a granular matrix forming the central bones of the skull, B, granular bone substance in which are large, irregularly shaped, branching bone cells.

Thus, the bone and teeth of the Necturus maculatus show a low degree of differentiation; the bone is merely a clear bone substance in which is a varying proportion of bone cells of variable developments; in the vertebra the bone cells occupy lacunae with no perceptible, or at least, with very short canaliculi. There is no indication of lamellation, which is the index of advancement in early bone differentiations. The vertebra, therefore, marks the grade of bone advancement and as we have seen, of general advancement. In the femur, there is a clear bone substance with a few branching bone cells, in the cranial bones, there is a granular bone substance in which are many branching, irregularly shaped bone cells.

In a vertebrate of such a low degree of bone differentiation, we would not expect to find a high stage of tooth development and in this we are not disappointed. The only dentine found in the short dentinal tips of the teeth; the shafts are homogeneous in structure and appear to arise from the jaw bone; the central chambers are relatively very large and occupied by blood vessels and irregularly shaped cells, there was not found an enamel cap over the dentinal tip of each tooth, but the short dentinal tubules reached the apical surfaces.

A comparison of the Necturus maculatus with the Cryptobranchus alleghaniensis in the point of time of its first appearance or departure from the class of fishes, indicates that the Necturus preceded the Cryptobranchus, for the reason that it has an earlier bone and tooth development. There is another indication seen in the gross variations in the two rows of teeth of the upper jaws. In the Necturus there are seven teeth in the external row and 25 in the internal row; in the Cryptobranchus there are 110 teeth in the external, 55 in the internal row; in that is, there is a difference of 103 external and 30 internal teeth in these two tailed amphibians. The question now arises, whether or not this difference is due to a reduction of the larger number to the smaller or to an increase of the smaller number to the larger; that which decided the point is the difference in the types of bone and teeth found in the two cases; the bone and tooth types of differentiation of the Necturus belong to an earlier period of development than those of the Cryptobranchus and, therefore, the Necturus preceded the Cryptobranchus in point of time of first appearance or the departure from the class of fishes.

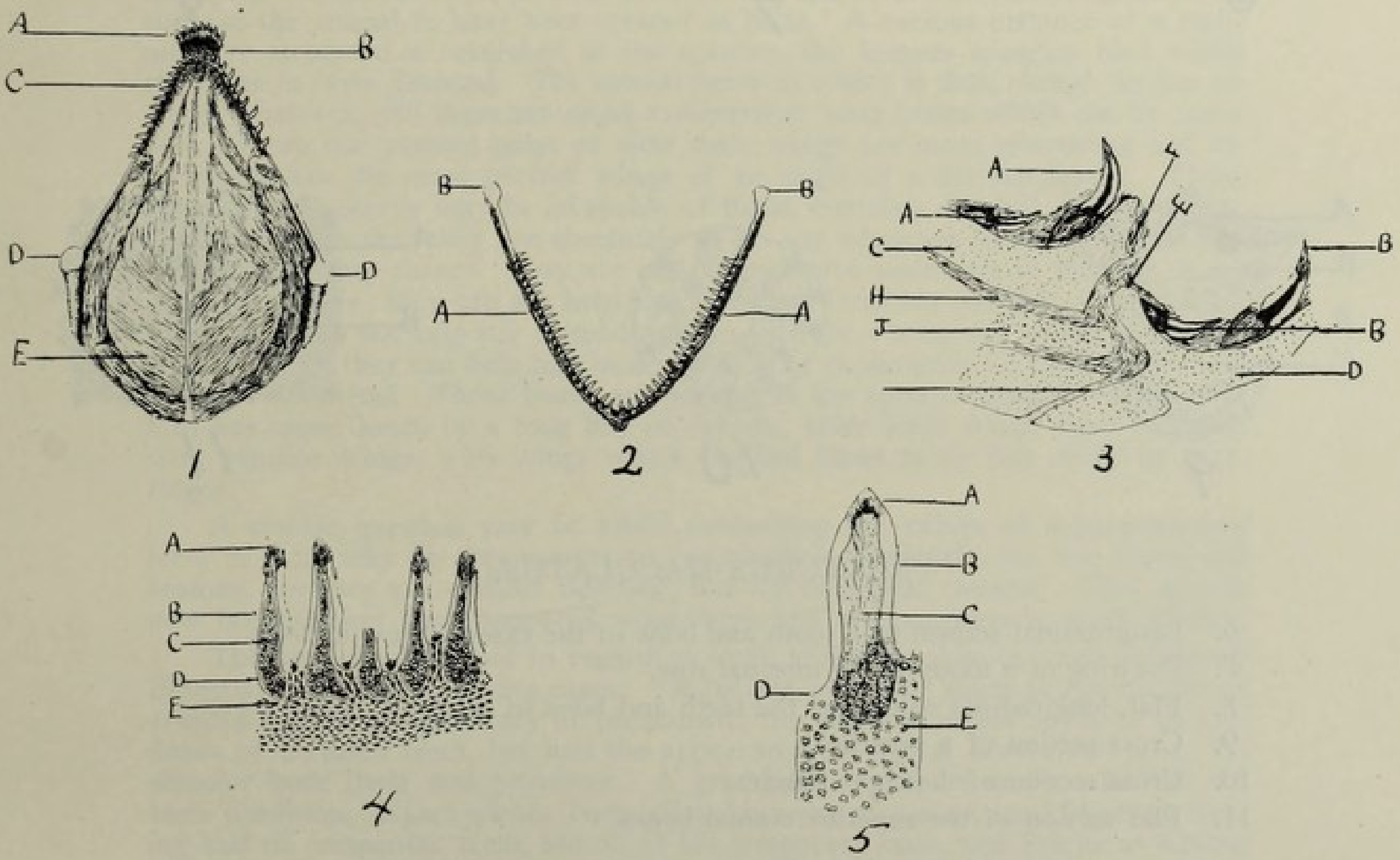
The significance of the tooth irregularities in Fig. 1 may be realized in some premaxillary disturbance in man who has not seen the enormously protruding upper central incisors in man and wondered at the cause.



NECTURUS MACULATUS.

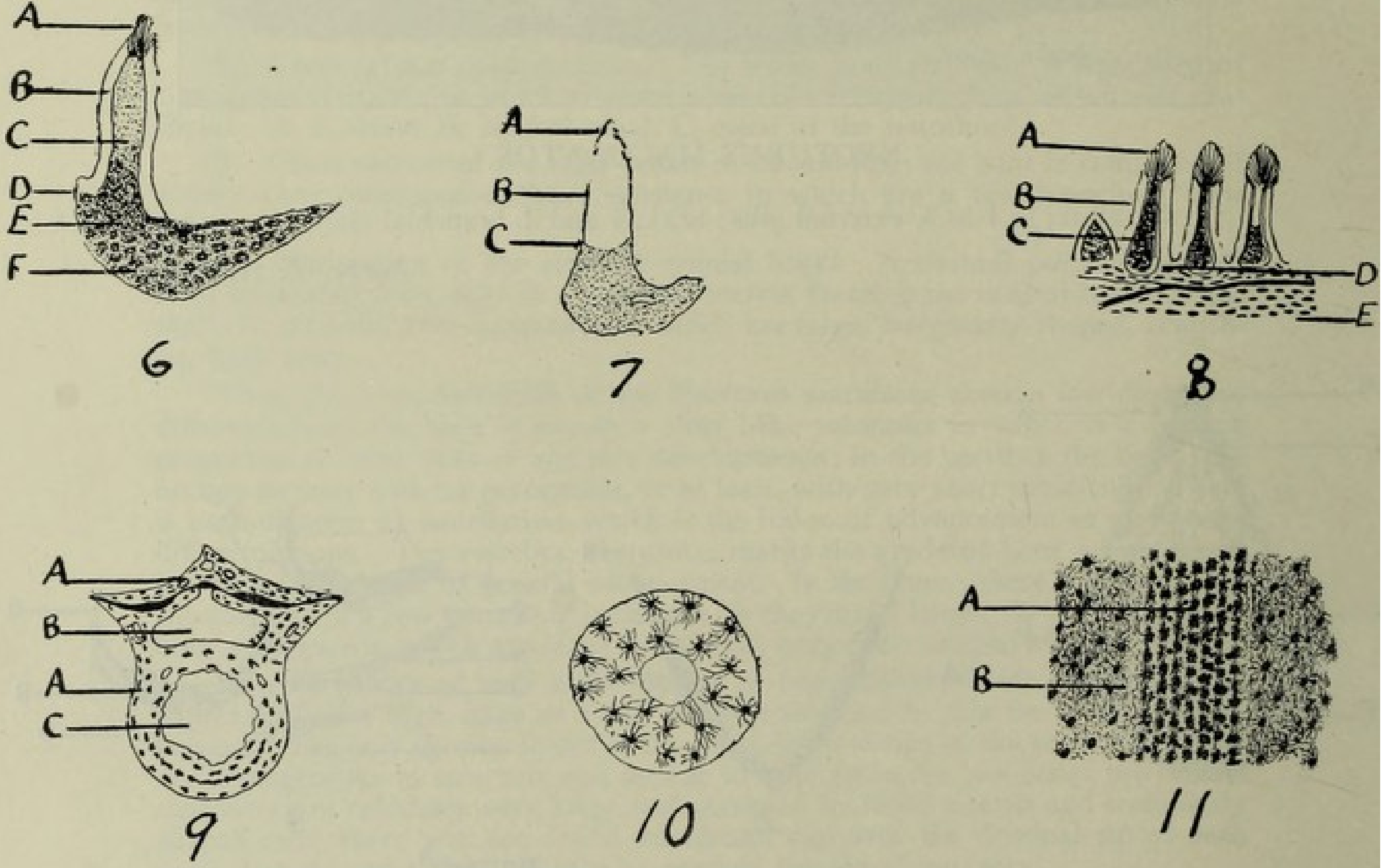
an., anus; br.1-br.3, external gills; br.cl., 1 and 2, branchial clefts.

Zology. *Parker & Haswell.*



NECTURUS MACULATUS.

1. Under surface of the skull showing the upper jaw.
2. Lower jaw.
3. Cross section of the upper jaw showing the two rows of teeth.
4. Flat, longitudinal section of the internal row of teeth and bone.
5. Longitudinal section of a single tooth and its bone attachment.



NECTURUS MACULATUS.

6. Longitudinal section of a tooth and bone of the external row of teeth.
7. Drawing of a tooth of the internal row.
8. Flat, longitudinal section of the teeth and bone of the lower jaw.
9. Cross section of a vertebra.
10. Cross section of the right femur.
11. Flat section of the superior cranial bones.

THE SIGNIFICANCE OF VESTIGIAL ORGANS IN VERTEBRATES.

Vestigial organs, supernumery organs, anomalies and extreme histological or embryological variations are significant evidences of biological impresses extended along the bone stem which unites all vertebrates.

It is not reasonable to suppose, for example, that the femora of the snake—Python—the small wing bones of the flightless bird—Apteryx—of New Zealand, the supernumerary teeth of man, the toothless jaws of man were created as such without regard to ancestral or hereditary influences—remote and immediate—and especially when an investigation of vertebrate, biological history reveals those organs in a useful capacity at some time in the past. That organ which exists today in a functionless state in vertebrate life had its origin in the original functional plan according to which the phylum, to which it belonged, was constructed and this may have been the early geological ages of the world.

Sir Robert Ball, in his book on "The Earth's Beginning," refers to rudimentary organs in the following article: "It not unfrequently happens that an animal has in its organization some rudiments of a structure which is obviously of no use to the animal in its present mode of life and would be unintelligible if we suppose the animal to have been created as he is. A curious instance of a rudimentary structure is furnished in the apteryx, the famous wingless bird which still lives in New Zealand. The special point to notice is that, though he has no wings whatever, still there are small rudimentary wing bones which can be easily seen. From our present point of view these wings are more interesting and instructive than the most perfect wings of an eagle or a carrier-pigeon. Those wings in the apteryx may be incapable of flight, but they are full of instruction. As it is certain that they are absolutely of no use whatever to the bird, we may ask, why are they there? They are not there to give assistance to the bird in his struggle for life; they can not help him to escape from his enemies or to procure food; they can not help her to tend and nurture the young one which is hatched from the egg; they can help him in no way. The explanation of those ineffectual wings is historical. Those bones are present in the apteryx simply because that bird has come down, by a long line of descent, from birds which were endowed with genuine wings, with wings which enabled them to fly like rooks or partridges."

A similar question may be asked concerning the values of supernumerary teeth in man, why do they appear so frequently? Evidently, not for functional reasons, for they are without function, but for biological reasons. They appear now because they have appeared somewhere and at some time in tooth history.

The same may be said in regard to tooth absences. Under tooth deficiency Blanchard cites the following cases: "A patient over fifty years of age had never erupted any teeth, temporary or permanent; the alveolar arches revealed no evidence of enclosed teeth, but had the appearance of typical edentulous jaws, the alveolar bone itself was primitive. A grandparent and an uncle exhibited the same condition. Kjaer quotes Tueswell as knowing of a man, aged 54 years, having had no permanent teeth, but all of his temporary ones, and Fricke as having three cases of retention of temporary teeth until 16, 18 and 20 years respectively, and Linderer as having a case of a lady, aged 60 years, who had not had any teeth and a case of his own in which the temporary teeth were lost from time to time, but no permanent successors appeared and none could be detected by skiagraphy."

If we look over our record in this investigation we find that there are vertebrates which have no teeth whatever as the toad, there are vertebrates which have teeth on the upper, but not on the lower jaws, as the frog, there are vertebrates which have two parallel rows of teeth on the upper and one row on on the lower jaws as the hellbender, there are vertebrates which have six external teeth projecting from a complete internal row of upper teeth as the Necturus maculatus; in fact, there is hardly a tooth anomaly in man which has not its counterpart somewhere in teeth history.

Supernumeray Teeth: In Dental Pathology and Therapeutics by Blanchard and Inglis is the following article on supernumerary teeth:

"Any teeth in excess of the normal number of teeth belonging to any one class, although clearly cases of reversion of type (A. H. Thompson; American System of Dentistry, vol. 3, and American Text-Book of Operative Dentistry) are included in the category of supernumeray teeth.

"Supernumerary teeth appear as single unmodified cones or as combinations of cones resembling the forms of teeth. The conical form is most common. Cases where these peg-like teeth appear around the third molars, singly or in number, are numerous. Their appearance in any situation is evidence that the normal number of dental cords has been exceeded.

"They are, perhaps, all to be regarded as cases of long reversion, not alone because they increase the number of the dental series, but because they have primitive forms—a modification of the forms found among the reptiles and fishes."

Those teeth which we now call supernumerary teeth had a function in the stage of development which they represent. This conclusion coincides with that which necessarily arises from the preceding study of the teeth of fishes and amphibians. From this it may be seen that in the latest vertebrate-man, two tooth formations are in progress, the one, true to the type of the class of vertebrate to which man belongs at the present time and the other, true to the early type of vertebrates from which man sprang. A tissue disharmony is the result of an attempt to operate together a primitive and late development under one and the same physiological command. We may believe, then, that the present cases of tooth variation have had their origin in a remote type in tooth history and are not unexpected in the course of later tooth developments. Whatever appears now as an extraordinary example of tooth variation either in structure, location or relation has an explanation in the biological history of vertebrate teeth. The occurrence of peg-like teeth around the third molars of man today is a visible evidence of the extension of a primitive impress along the bone stem from the earliest to the latest vertebrate, otherwise there is no adequate explanation of these remarkable disturbances in tooth production.

The extension of an operating, biological force toward an objective along a material bond of union is not the same as the reversion from a higher to a lower level of development when that objective is reached. Reversion of a higher to a lower type of structure implies degeneration. Having once had the higher type of tooth which belong to a man, we could not expect that tooth to revert to a lower type without the violation of a biological law, but we could and do expect that the original, projecting force which caused the single cone tooth in the amphibian or reptile to produce that type of tooth in any succeeding class of vertebrate, including man whenever a corresponding type of bone is present; that is, a primitive bone and single cone tooth may be expected to appear together. It is the survival of a developmental force and the establishment of the original product of that force. Man has the peg-like tooth as the original tooth and the modified cusped tooth of his later development, each one representing the peculiar characters of its developmental level.

Furthermore, there is no reason for supposing that the tooth alone represents this dual, biological disharmony in man, but rather that the entire individual in these dual impresses made during the race for supremacy of position and the tooth, by virtue of its organic structure, is the only organ which withstands its own decomposition. The peg-tooth man is an example of the survival and extension of the original tooth forming force beyond its proper stage of vertebrate development. When these two developments, activated by a common cause, are established in a highly organized individual, the unsuccessful partnership results in a pathological condition of the primitive member of the firm.

A STUDY OF THE BONE AND TEETH OF CRYPTOBRANCHUS ALLEGHANIENSIS—THE HELLBENDER

IV.

A STUDY OF THE BONE AND TEETH OF CRYPTOBRANCHUS ALLEGHANIENSIS—THE HELLBENDER.

The head is broad and flat and connected with the lower jaw by a long, heavy-set joint.

1. Drawing of the upper jaw as seen from the under surface, showing two parallel, curved rows of teeth. A, external row of 110 small, rather stout curved teeth, B, internal row of 55 similar teeth set on a much shorter arc, C, deep groove between the two rows of teeth, D, vomer-palatine bone. This aggregation of 165 teeth in parallel rows forms a prehensile plan of great importance in the upper jaw of this vertebrate quite unlike that of any other hitherto examined.

2. Drawing of the lower jaw, showing the long joint and teeth. The lower jaw is relatively smaller than the upper as it takes a position in the groove between the upper rows of teeth, when the jaws are closed, thus forming an additional prehensile arrangement of great strength and especially in conjunction with the long tight joint at the angle of the two jaws. A, joint, B, jaw bone with teeth.

3. Drawing of a cross section of the two upper rows of teeth and the intervening groove, showing their separate bone attachments and the joint relations between them. A, skin, B, bone of the external row of teeth, C, one of the teeth, D, groove between the teeth, E, bone of the internal row of teeth, F, one of the teeth, H, joint between the bones with a check at I, J, vascular canal between the two bones, K, joint in the upper bone, I, base of the tooth fitting into a concavity of the upper bone and enclosed by calcified connective tissue as seen at N; the same is true of the internal tooth F, and its base fitting into a concavity in the lower bone and enclosed by calcified connective tissue as seen at O. While these teeth are external to the bones, yet, they are enclosed by properly fitting bone concavities and connective tissue-forming semi-sockets.

The two bones with their teeth united by a loose joint and provided with muscles make it possible for the teeth to grasp the lower jaw when it is in the groove, thereby increasing the prehensile power of jaw system. The teeth are small and quite easily broken off at the junctions of the shafts with their bases, but the marginal shapes of the jaws, the two parallel rows of teeth on the upper and one on the lower jaw fitting into the groove between the upper teeth form a mechanical arrangement which does not require heavy teeth—the work of prehension being done mainly by the mechanism of the jaws.

4. The Longitudinal section of a tooth of the upper external row: A, enamel, B, dentine, C, central cavity extending down into the base, D, junction of the shaft with the base, E, base of tooth. The tooth fits into the concave under surface of the external bone of the jaw as may be seen in 3 C and P.

5. Teeth and bone of the external row ground flatwist, showing the teeth in longitudinal section and a new tooth coming up from the bone of the jaw. A, enamel, B, dentine, C, cavity of tooth extending into the base, D, base, E, cement between the bases, F, jaw bone, H, junction of the shafts with their bases, I, new tooth arising from the jaw bone and displacing the tooth above it, J.

6. Longitudinal section of a tooth of the external row (enlarged) showing its relation to bone and the circulatory system. A, enamel, B, dentine with branching tubules on one side and S shaped tubules on the other, C, central cavity occupied by a rich plexus of blood vessels, D, junction of shaft with the base, E, base of tooth composed of a very finely striated bone substance, F, plexus of blood ves-

sels in the cavity of the base, H, laminated bone diagonally abutting the base of the tooth.

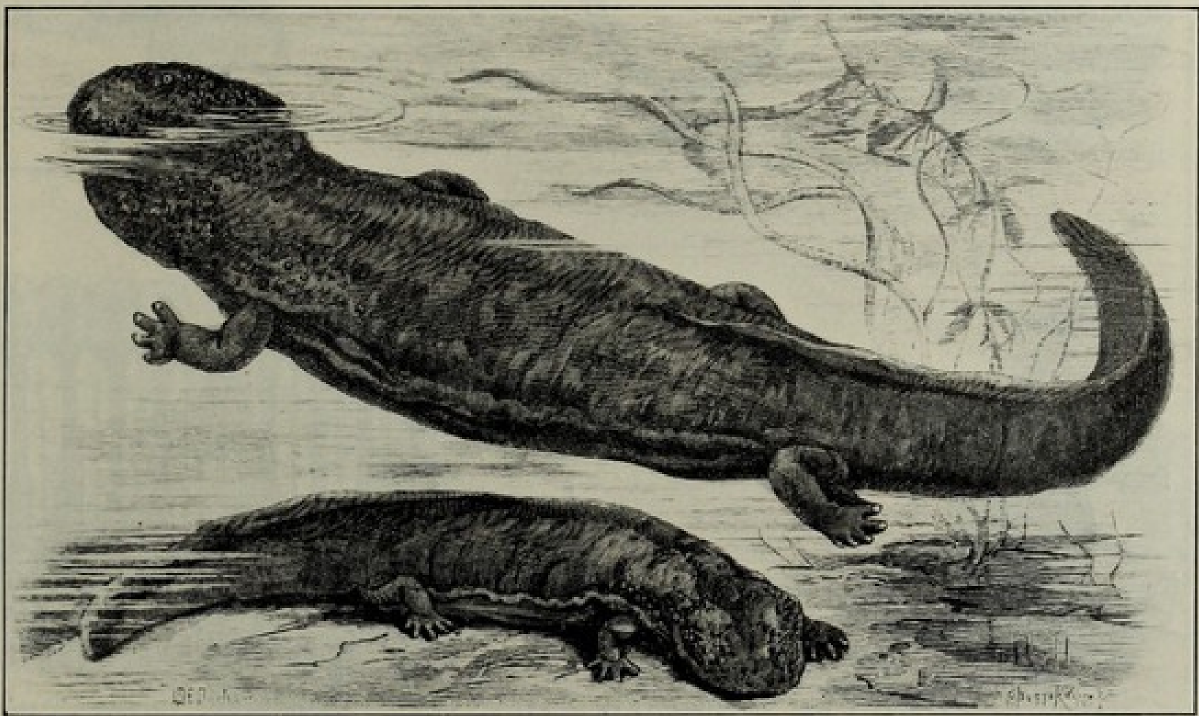
Cross section of the lower jaw with a tooth in position. A, tooth, B, concavity or socket in which the tooth is held, C, keratinized extension from the oral membrane, D, bone of the jaw showing the First Type differentiation, E, keratinized and calcified tissue extension from the oral membrane, F, new tooth arising from the cavity of the jaw bone.

8. Cross section of a vertebra and short extensions into the ribs. A, dorsal portion composed of a fairly well differentiated First Type bone, B, neural canal, C, small portion of the rib, D, canal of the notochord, E, body of the vertebra.

9. Cross section of the left femur at the mid-line. A, internal circumferential lamellae surrounding the medullary canal which is full of marrow, B, wall of the bone composed of oval lacunæ with branching canaliculi in bone substance forming a First Type bone of intermediate differentiation.

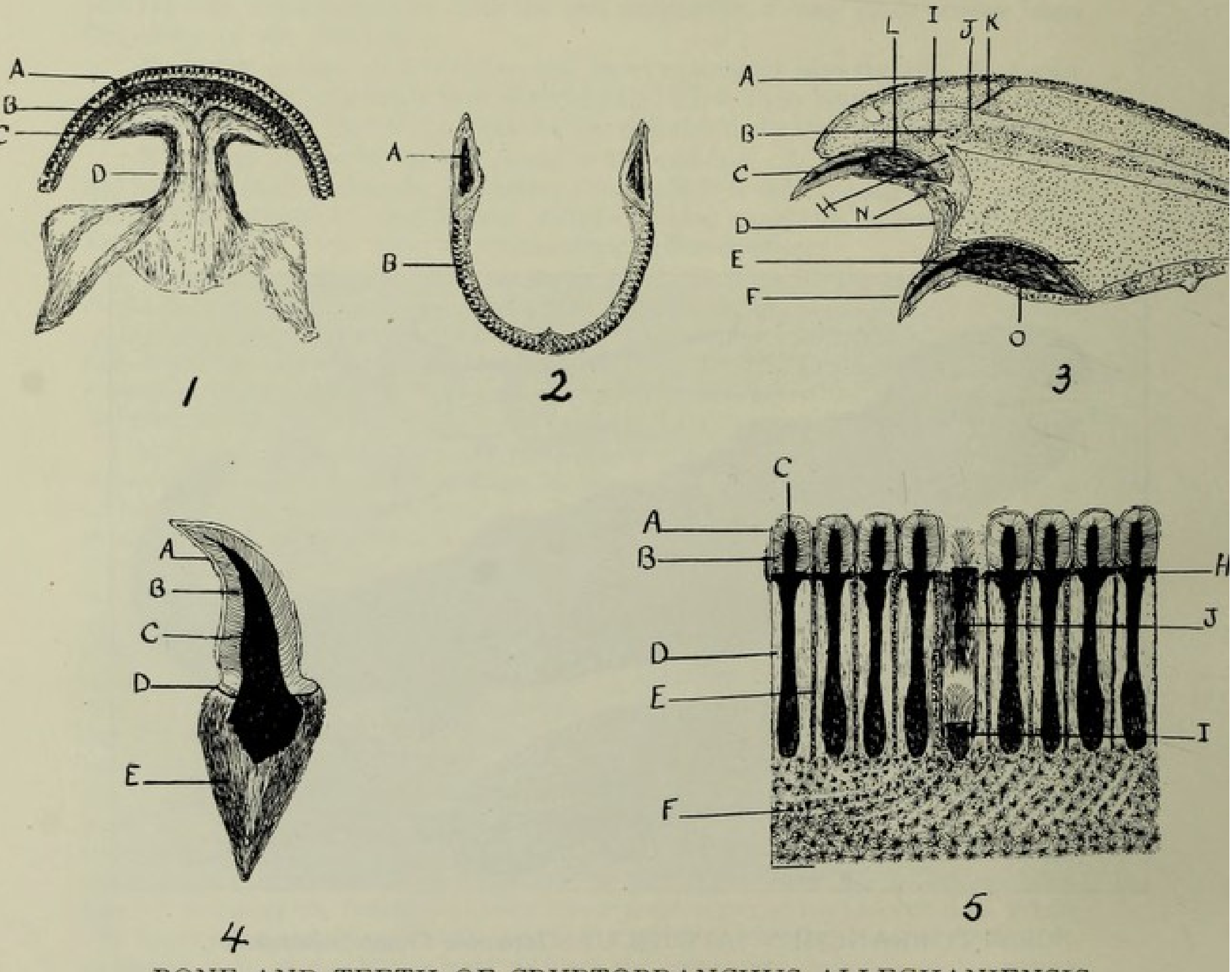
Thus, it may be seen by a comparison of the bone of the tailed with that of the tailless amphibian or the bone of the cryptobranchus alleghaniensis with that of the rana catesbeiana or bufo americana, that no marked variation in bone type has occurred, although the life histories of these veretebrates differ greatly. The cryptobranchus and rana catesbeiana are much more water than land animals and the bufo americana is much more of a land than water animal.

Of the three vertebrates above mentioned, the amphibian toad or land animal shows the most evidence of advance in bone type, since the early differentiation of the Third Type bone unit or Haversian System has made its appearance and in considerable numbers; while these units were not found in the rana catesbeiana or cryptobranchus alleghaniensis. On the other hand (and perhaps contrary to expectations on the basis of inorganic kinship) the toad (Bufo) with the highest type of bone has no teeth, while the frog (Rana) and hellbender (Cryptobranchus) with a much lower type of bone have a great many teeth; the hellbender, primarily a water animal with a lamellar bone type has 165 teeth on the two jaws, the frog, primarily a water and secondarily a land animal with a lamellar bone, has 200 teeth on the upper and no teeth on the lower jaw; the toad primarily a land animal with a lamellar and early Haversian System bone has no teeth on the lower jaw. This unexpected relation of teeth to bone suggests that the advance in bone type was due to a biological cause operating through the verebrate series toward an objective, on account of which the animal was forced to leave the aquatic and assume the atmospheric life, or that atmospheric life raised the bone type by changing the function of bone levers from water to land locomotion. While life began in water, it evidently reached a point in development when aquatic oxidation was on too low a level to meet the increasing demands of advancing developments and the change from water to air or from oyxgen in solution in water to oxygen (free) in air cast the die of a new and different model of life.



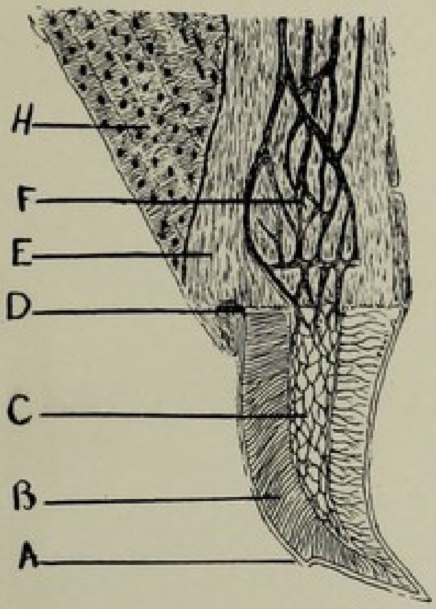
CRYPTOBRANCHUS JAPONICUS—Japanese Giant Salamander.

Cambridge Natural History. *Gadow.*

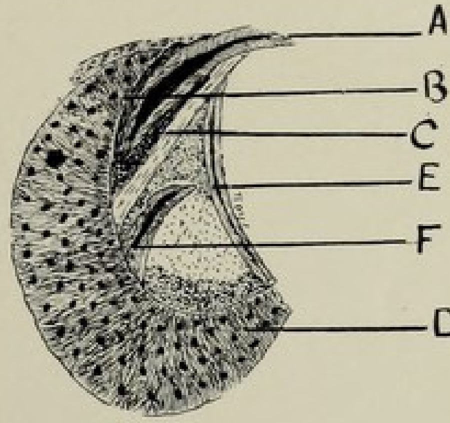


BONE AND TEETH OF CRYPTOBRANCHUS ALLEGHANIENSIS

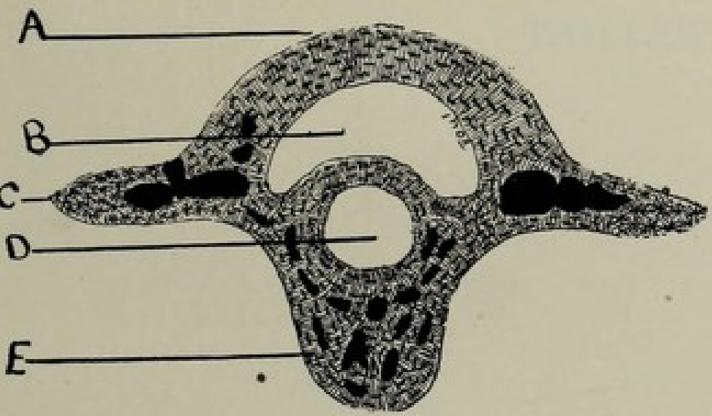
1. Drawing of the upper jaw as seen from the under surface showing two parallel rows of teeth.
2. Drawing of the lower jaw showing the long joint and teeth.
3. Drawing of a cross section of the two upper rows of teeth and intervening groove.
4. Longitudinal section of a tooth of the upper external row.
5. Teeth and bone of the external row ground flatwise.



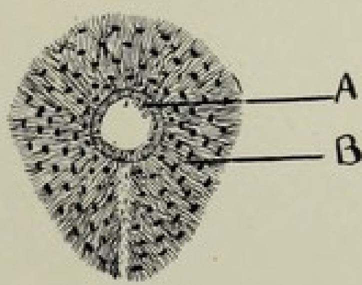
6.



7.



8.



9.

BONE AND TEETH OF THE CRYPTOBRANCHUS ALLEGHANIENSIS
(Continued.)

6. Longitudinal section of a tooth of the external row.
7. Cross section of the lower jaw with a tooth in position.
8. Cross section of a vertebra and short extensions into the ribs.
9. Cross section of the left femur at the mid-line.

ANURA
OR
TAILLESS AMPHIBIANS

A STUDY OF THE BONE AND TEETH OF HYLA VERSICOLOR —TREE FROG

V.

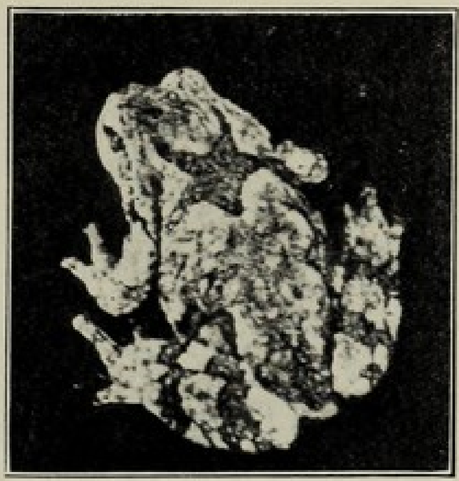
HYLA VERSICOLOR—TREE FROG.

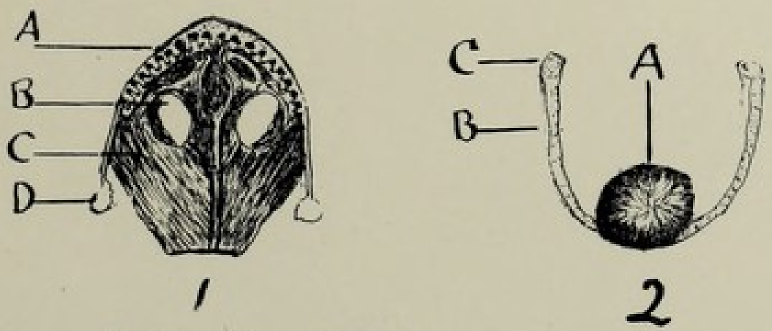
There are said to be 150 species of Hylina of which the Hyla versicolor is one; the genus includes the tree-frogs and toads and belongs to the order Anura. As far as the teeth are concerned as a standard in comparison, the name, tree-frog, is more approriate than tree-toad, as may be seen from the structure. The toes terminate in round sucking discs by which the animals are able to hold their positions on the branches and leaves of trees. The color of the skin is rendered protective by changing pigments. (The specimen is small and difficult to work out).

1. Drawing of the under surface of the skull showing the upper jaw with its microscopic teeth. A, upper jaw with about 60 small teeth tipped with black pigment; they are flexible and attached to a flexible jaw. The jaw is composed of cartilage which is calcified in certain areas and connective tissue. B, eye cavity, C, under surface of the skull, D, articulation with the lower jaw.

2. Drawing of the lower jaw and eversible tongue which appears spherical. A, tongue attached to the front of the jaw, B, very small jaw composed of strands of interlacing connective tissue, enclosing blood vessels; C, articulation with the upper jaw. No teeth present.

It is interesting to note that the Hyla, tree-frog, conforms to the Rana, ordinary frog, in the arrangements of its teeth, instead of the Bufo, ordinary toad. The round sucking discs on the ends of the toes are special adaptations to a different environment, while the arrangement of the teeth remains true to type. The very minute teeth prevent ground sections.





TEETH OF HYLA VERSICOLOR.

1. Drawing of undersurface of the skull.
2. Drawing of the lower jaw.

BONE AND TEETH
SCAPHIOSUS HOLBROOKI

VI.

BONE AND TEETH OF SCAPHIOSUS HOLBROOKII.

The Amphibians are a large class of vertebrates comprising a mixed group of animals which illustrates the very important change in animal life from aquatic to air breathing. The class is subdivided as follows: Urodels or tailed amphibians, Anura or tailless amphibians, Gymnophiona or snake-like amphibians having no limbs or distinct tail, Stegocephala or the extinct tailed amphibian of great size.

The difference in bone type between the amphibians and their biological successors—the reptiles—is very slight and more especially between the amphibians and the first portion of the reptilian group, the lizards. Just where the amphibians leave off and the reptiles begin is not easy to determine by histological bone structures; the skin of the amphibian is soft, while that of the reptiles is scaly; the skin of the amphibians is respiratory, while that of the reptiles is protective.

As far as the type of bone is concerned the amphibians could be extended to the aligator among reptiles (including lizards and snakes) for the reason that the first great change in bone type occurred in the alligator where the second type bone appeared and introduced a new and advanced level in development.

The Scaphiosus holbrookii belongs to the amphibian group of Anura. The animal is small and the bone and teeth are hard to grind down to satisfactory thinness for microscopical purposes.

1. Drawing of the under surface of the skull showing the small teeth of the upper jaw. A, teeth, B, jaw bone, C, eye socket, D, sphenethmoid bone. The specimen is nearly semicircular, the eye sockets are proportionately large, the teeth (100 in number, 0.5 mm. long) are very fragile.

2. Drawing of the lower jaw; it is composed of several strands of first type bone held together by connective tissue. It has no teeth. A, attachment of the eversible tongue to the anterior portion, B, jaw bone, C, articulation with the skull. The under jaw is very small and flexible, made so by the small alternating strands of bone and connective tissue.

3. Cross section of a vertebra. A, anterior spinous process, B, neural canal, C, rib, D, canal of the notochord. The bone is a simple first type bone with small, oval lacunae and scarcely visible canaliculi. The bone substance is clear showing little or no differentiation.

4. Flat, longitudinal section of the superior cranial bone of the skull. A, first type bone with very numerous small, oval lacunae and faintly visible canaliculi, B, connective tissue base, C, pigment cells of the skin; the section is flexible and tough.

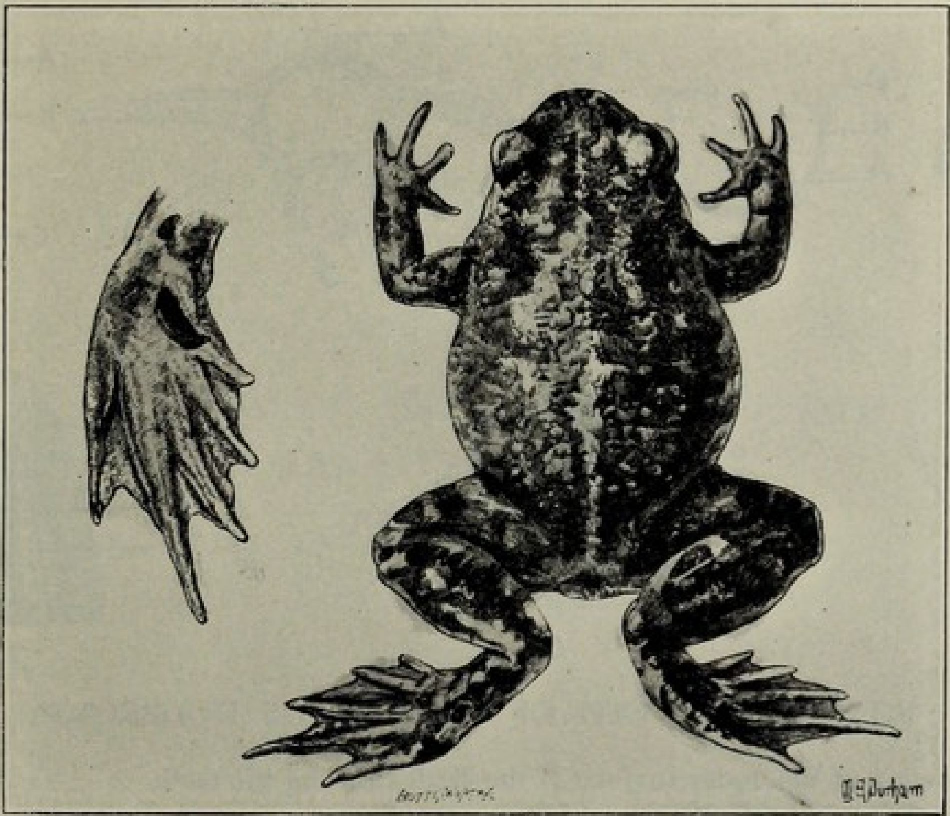
5. Cross section of the left femur. A, bone substance with very small lacunae, their canaliculi are scarely visible, B, medullary canal. The section at the midline is circular, above, it gradually becomes pyramidal depending upon the development of the posterior ridge. The bone shows an early differentiation of the first type.

6. Flat, longitudinal section of a portion of the upper jaw showing two teeth and their connection in the jaw bone. A, structureless tip penetrated by extensions of anterior blood vessels of the central chamber, B, clear structureless shaft of the tooth, C, blood vessels of the central chamber extended from vessels of the jaw bone, D, central chamber, E, vessels from the jaw bone, F, first type bone of the jaw. This fine branching, extensions of the blood vessels of the chamber, becomes dentinal tubules of the tip after producing a layer of irregularly shaped

cells along the inner border of the tip which then extend their minute dendrites into the tubules of the tip.

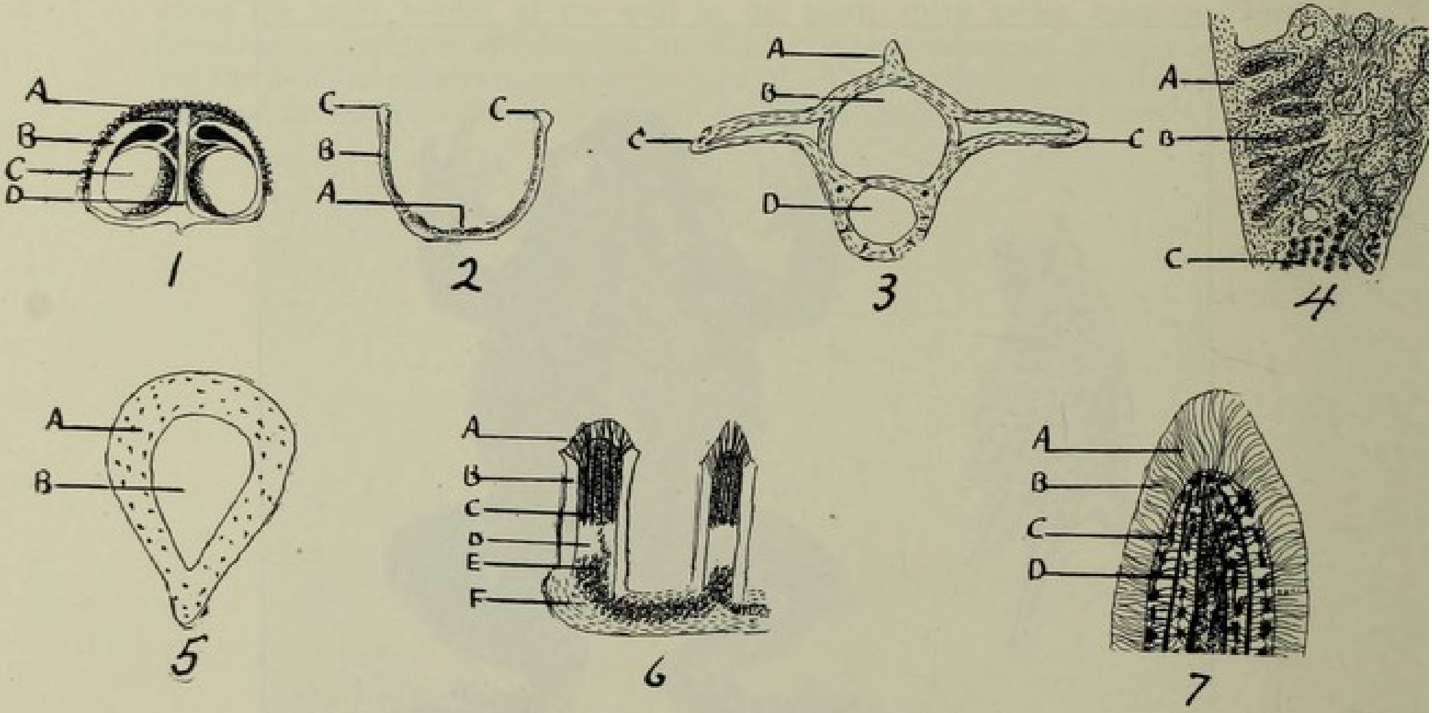
7. Tip of tooth enlarged to show the origin of the dentinal tubules from the cells and blood vessels of the central chamber. A, wall of the tooth, B, dentinal tubules, C, branching cells in the central chamber coming off from the blood vessels and giving origin to the dendrites which occupy the dentinal tubules, D, blood vessel in the central chamber arising from the blood vessel of the jaw bone.

The specimen is especially interesting as it shows the relation of the dentinal tubules and their contents to the circulatory system. From the blood vessels of the central chamber, D, there arises a network of branching cells, C. From those along the inner border of the wall of the tooth, there arises numerous small branches or dendrites which enter the clear inorganic substance of the wall forming the dentinal tubules and their contents, B. These cells represent the formative stage of the odontoblasts which in turn are derived from the blood vessels.



PELOBATES CULTRIPES—Spade-foot Toad.
(x 1, and under surface of left foot.)

Cambridge Natural History. *Gadow.*



BONE AND TEETH OF SCAPHIOSUS HOLBROKII.

1. Drawing of the under surface of the skull showing the teeth.
2. Drawing of the lower jaw.
3. Cross section of a vertebra.
4. Flat section of the superior cranial bones.
5. Cross section of the left femur.
6. Flat, longitudinal section of a portion of the upper jaw showing two teeth.
7. Tip of a tooth enlarged to show the origin of dentinal tubules.

A STUDY OF THE BONE AND TEETH OF RANA CATESBEIANA—BULL FROG

VII.

A STUDY OF THE BONE AND TEETH OF RANA CATESBEIANA—BULL FROG.

The amphibians lead dual lives. They live in water and on land as the name implies. This could not have occurred if the histology and physiology of the preceding vertebrate had not been changed and this, perhaps, marked the most important transformation in the history of vertebrates.

Obedient to the inexorable biological law of differentiation and development in operation in the fishes or first vertebrates, the amphibians reached a point in the constitution of their organizations when they left the water and the organs of locomotion which had, for ages, been sufficient for a change of location in water, acquired an especial adaptive change to meet the requirements of locomotion on land.

By a rearrangement of the constituent parts of the anterior and posterior fins, these organs have been transformed into anterior and posterior limbs as these vertebrates successfully emerged from an aquatic to an atmospheric life.

This remarkable change in biological level was further made possible by a corresponding change in tissue metabolism.

Obviously, the fish could not breathe the air nor move about on land in search of food. A reorganization of the whole animal on a higher plane was necessary. The amphibians, therefore, were the first vertebrates equipped with levers of bone and respiratory organs to meet the new conditions which prevailed on land—the permanent abode of advancing vertebrates. A new value was given to bone when vertebrates began to walk. From the Silurian to the Carboniferous Age of the world involved an immense stretch of time and it was during this period that the fish was raised to a higher level from which it claimed both air and water as its domain.

In the foregoing chapter on the bone and teeth of the primitive fishes, we saw three bone types of differentiation, viz., lamellar, laminar and Haversian System. These were represented as recognizable in the lamellar or in outline in the laminar and Haversian System types.

It may be further stated that cross sections of the femora of 39 amphibians have been examined microscopically to determine the type of differentiation present. Of these,30 were lamellar, one lamellar, one laminar and early Haversian System types; that is, an advance in bone type of differentiation was evident, although no type had reached its culmination. The majority, 30 remained true to the lower primitive lamellar or fish type, one had advanced to the lamellar and laminar type, 7 had reached the lamellar and early Haversian System type and one had reached the lamellar, laminar and early Haversian System type. This means that the amphibians were not all true to one and the same type, but showed an advancing differentiation. While the amphibian advance in type is not great, as might be expected, it is, nevertheless, an advance which function does not account for. Biological movements are slowly and gradually rising to an objective by a force which tends towards a higher level of organization. The reverse of this destroys the conception of the true nature of life as we understand it. Bone and teeth are the only tissues which remain for ages after death to tell the story of progression through the long struggle of the life of the vertebrate and its arrival at a final state of culmination. If bone and teeth had remained stationary from the beginning to the end of vertebrate life or from fish to man, there would be no valid reason for thinking that a biological advance was in progress, at least, as far as material evidences are concerned, since the soft tissues so soon return to the chemical elements of their decomposition; but just the opposite is true. They have not remained stationary, but show an ever changing variation in their structural units from the simplest unorganized bone and tooth substances in the fish to the most complex Haversian System in man. One of our greatest difficulties is to be found in the proper estimation of the true value of the minute variations by which biological advances are made. They are not made by leaps and bounds, but by almost imperceptible gradations. It is by comparing the different classes of vertebrates with each and the first with the last class that we are able to recognize the valuations of progressive differentiations. In accordance with our belief that bone advance in type means tooth advance on account of tissue kinship operated upon by a common biological law towards a culmination of type, the following examiantions of bone and teeth of the amphibians have been made and are herewith presented for comparative purposes.

1. Diagram of the upper jaw of a large bull frog—Rana catesbeiana—showing the maxillary and vomerine teeth. A, maxillary teeth which in this particular frog numbered more than 200. B, one of two clusters of eight vomerine teeth, on either side of the median line, the central tooth in each cluster being the largest. C, a new tooth springing up at the base of the old tooth and gradually displacing it. D, sphenethmoid bone.

At first sight, the large number of teeth on the upper jaw—maxillary and vomerine—does not admit of as ready an explanation on the basis of function as it does on the basis of a biological development. The teeth are usually described as prehensile, but with teeth on the upper jaw and nothing on the lower jaw excepting a soft oral membrane to serve as an occlusal surface the thought of prehension as the most essential function of the teeth is not wholly satisfactory as it seemed to be in the teleost fishes; but the idea of prehension becomes much more clearly evident when we consider the double curve of the two jaws, one of which is a concavo-convex curve equal to the arc of a circle with a 55 mm. radius and the other a lateral curve equal to the arc of a circle with a 55 mm. radius. The jaws close very tightly and the short, sharp, curved teeth of the upper jaw by closing tightly on the lower jaw make prehension secure by the combined action of the two curved jaws and maxillary teeth and this is, furthermore, reinforced by the voluntary assistance of the anterior limbs. In Fig. 2, is shown the concavo-convex curve of the tooth surface. A, upper jaw, B, tooth curve, and C, lower jaw. In Fig. 1, the lateral curve of the jaws may be seen. Prehension, therefore, is accounted for as much by the double curved jaws as by the teeth.

3. Diagram of the lower jaw. The lower jaw is hinged to the upper at a point posterior to the eyes giving a very wide gap to the mouth when the jaws are opened. It has the same curves as the upper jaw. A, point where a cross section was made and shown in Fig. 6. B, region of attachment of an eversible tongue. The jaw bone is absolutely destitute of teeth and covered with a soft oral membrane.

4. Cross section of a vertebra extending into the ribs. The frog has nine vertebrae and a long extension of bone articulated to the last vertebra and called the urostyle. A, body of vertebra surrounded by a lamellar or First type bone; the lacunae are long and narrow and their canaliculi are long and straight—characteristics of the later differentiation of the lamellar type of bone. Within this lamellar layer the structure is limited almost entirely to the early Haversian System type, so that we find an evident advance in bone type beyond that observed in the vertebrae of the teleost fishes. B, neural canal enclosed by a wall of lamellar and early Haversian System bone types as seen at C; between this wall and the anterior surface wall there is a more or less circular area of early Haversian Systems as seen at D, a short extension into a rib and composed of the same bone types is seen at E. N, canal of notochord.

5. Longitudinal section of the urostype—the articulated extension of the vertebrae. This bone is 55 mm. long, 4 mm. wide and has a third dimension of 5 mm. It has the shape of flat key with a slot in the key blade. A, articulation, B, central, vascular canal surrounded by well defined lamellae, C, a slot in which are seen groups of spherical, amorphous bodies. The section is composed of a lamellar bone interrupted by early differentiations of the Haversian System.

6. Cross section of the lower jaw at A, Fig. 3. A. wall of the bone, B, central vascular canal. The wall of the bone is composed of well defined lamellae in which are many well defined Haversian Systems. The central canal is surrounded by a lamellar bone. This is the site of the original Meckel's cartilage. The lower jaw is better developed than the upper and yet is without teeth.

7. Cross section of the femur of a large bull frog—Rana catesbeiana. The section is composed of a large number of radiating, bush-like vascular canals, A, between which are round or oval lacunae arranged more or less concentrically on minute vascular branches and seen at B, at C, is seen a blood vessel in the medullary canal which supplies the radiating vessels of the wall, D, medullary canal filled with marrow.

8. Cross section of the femur of a medium sized bull frog of the same species. A, radiating, bush-like vascular canals, B, intermediate branches with their lacunae, C, blood vessel of the medullary canal, D, medullary canal, E, portion of the bone composed of concentric lamellae from which the radiating, bush-like canals have been eliminated by the cumulative pressure of development.

9. Cross section of the femur of a small bull frog of the same species. The radiating canals have all disappeared and the section is composed of bone lamellae as seen at E. In making an estimate of the relative stages of development indicated by this series of femora, the following structural changes observed in the different sections are significant as expressions of an advancing bone type and ascending levels.

9. Fig. 7, represents a vascular bone with the minimum amount of bone substance and hence the earliest frog, Fig. 8, represents the next in the series; the radiating, vascular, bush-like vessels have disappeared from one-third of the section and bone lamellae have been substituted. The section shows a decided gain in bone and, therefore, a higher level of advancement, since bone organization is the ultimate and toward which this form of inorganic tissue is directed. Fig 9, represents the last or final degree of bone differentiation of this level. The radiating, bush-like vessels have all disappeared and bone lamellae forms the structure of the entire section. The lines of advance have been along the degrees of elimination and substitution, that is, the elimiantion of the blood vessels and the substitution of bone. Evidently, bone substance, in some degree of differentiation, is the objective of vertebrate life. The bone in bone Fig 7, could not arise from that in Fig. 9, by way of Fig. 8, that is, vascular canals or blood vessels could not arise from bone in a physiological state, but bone could and would arise from the circulatory system as an objective product. These important variations in the structure of the femora of three vertebrates of the same species, but of different sizes would indicate that the large frog was earliest, the medium frog next and the small frog was the latest in point of development.

10. Cross section of the last rib. A, lamellar bone forming the external wall and interrupted by early differentiations of the Haversian System, B, cancellous bone-lamellar in type-forming the central portion, C, crystalline and amorphous contents in the meshes of cancellous bone. The cancellous arrangement of bone serves a useful physiological purpose in the distribution of the blood vessels and in making possible the freedom of cells in their dividing and metabolic activities.

11. Cross section of the brain case. A, external, lamellar layer of bone, B, central, wide layer of closely set vascular canals (not Haversian canals) extend-

ing lengthwise of the bone, C, internal layer of lamellar bone surrounding the brain cavity. The peculiar feature of this section is the very vascular bone of the central layer which is composed of vascular canals, each one of which is surrounded by wall differentiated lamellae.

Comparing the bone sections of the frog with those which were shown of the fish, it is evident that the amphibian frog has advanced in the type of bone differentiation, since their only rather obscure lamellae and mere outlines of Haversian Systems in the fish, while there are various differentiations of the Haversian System in the frog.

There has been a change in bone type towards a higher objective in the frog. This being the case we would not expect to find the same unchanged type of tooth in the frog as we found in the fish. The cone shaped tooth has been established in the fish; this is rather gross than minute anatomy and the multiplication of cones as are seen in later teeth does not signify a change in histological structure since such a change is biological.

12. Teeth of the maxilla as drawn from a gross specimen. A, notch in the enamel, B, dentine or tooth proper, C, osseous shaft, D, bony envelope, E, new tooth arising from a base of bone, F, bone of the maxilla; the teeth proper are very small and loosely attached to bone bases which arise from the jaw bone. They are very closely set together and enclosed in bone which is pigmented. Each tooth is capped with a finely striated enamel which is notched at the tip as may be seen at A. Below this is a short curved, stout body of dentine, forming the tooth proper, separated by a distinct line of demarcation from an osseous shaft seen at C, and this is enclosed within an envelope of bone which is an upward extension of the jaw bone and seen at D. At the bases of the teeth and arising from the jaw bone are small new teeth, E, formed within the hollow cavities of the old teeth, F, bone of the maxilla. Unlike the shedding of the teeth in the fish, the shedding of the teeth in this vertebrate shows a different plan; the new tooth has come from the jaw bone and displaces the old tooth by growth from below which is suggestive of teeth displacement in the more advanced stages of development as seen in later vertebrates.

13. Cross section of the maxilla with a tooth in position. E, enamel, N, notch in the enamel, D, dentine or tooth proper, C, chamber in the dentine, T, dentinal tubules, J, junction of the dentine or tooth proper with the bone shaft or base, B, bone shaft or base composed of bone substance with fine striations at the left, L, and bone cells in parallel rows at the right, R, a few small bone cells are seen in the striated portion. The cell portion R, is continuous with the jaw bone, H, and has the same cells. The jaw bone has a large central vascular canal, K, and enclosed a large vascular canal, I, at its base. The bone of the jaw is composed of bone substance in which are many large bone cells with many long uniting dendrites surrounding Haversian canals. The bone shows an early differentiation of the Haversian System. The central chamber of the dentine has small branching bone cells arranged in parallel vertical rows; from their location these cells may represent the early odontoblasts of that period of development. As observed in other sections, they are extensions of the bone cells of the bone shaft below. As we look at the teeth of the jaw with a 48 mm. objective they can be seen arising from the jaw bone as may be seen in Fig. 12.

14. Maxillary tooth and bone ground flat-wise. A, enamel, B, dentine, C, large branching cells in the central chamber of the dentine, the branches of which form the core of the dentinal tubules. As suggested above, the cells may be early odontoblasts; they have the same general characters as the cells of the bone to which the dentine is attached. D, bone to which the dentine is loosely attached at E. In the center of the bone at F, are seen large branching cells

similar, in appearance, to those in dentinal chamber. The section is especially interesting on account of the cells and dendrites of the dentinal chamber and their relations to odontoblasts.

15. Another maxillary tooth ground flat-wise. A, enamel, B, dentine, C, large branching cells in the central chamber of the dentine, E, junction of the dentine with bone, F, large branching cells of the bone shaft, H, blood vessels in the jaw bone, I, bone of the jaw.

16. Vomerine tooth and bone ground flat-wise. A, enamel, B, dentine, C, wide central chamber in the dentine, D, laemellar bone at the base of the tooth, E, early bone differentiation from which the vomerine teeth arise.

The especially interesting features of the teeth and bone of this amphibian vertebrate may be briefly summarized as follows:

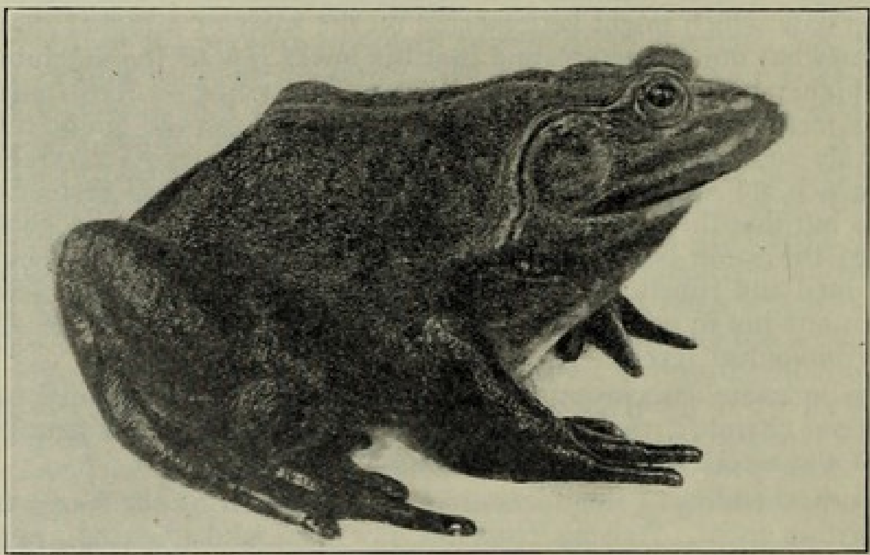
1. The large number of teeth on the upper jaw and the complete absence of teeth on the lower jaw; by this we may know that tooth absence in vertebrate had a remote origin. We are familiar with the fact that the first teeth in man appear on the lower jaw which might be expected on the basis of a higher development; but it is somewhat unexpected to find that the lower jaw of the amphibian, which also has a higher bone differentiation than the upper has no teeth whatever and especially if teeth and bone are really interdependent; but the biological status of this vertebrate so willed it be a law of its being and thereby introduced a tooth deficiency which appears now and then in all of the succeeding vertebrate classes. Who knows but that the absence of wisdom teeth in man can be accounted for by obedience to the same biological law? Tooth function, we may believe, is the same in all men and functional variation could not well account for wisdom teeth in some men and not in others. The absence of wisdom teeth may be an evidence of a higher biological level.

2. The intimate association of the tooth with bone as indicated by the cells of the dentinal chamber, their resemblance to bone cells of the maxilla and the dendrites of those cells occupying the dentinal tubules.

3. Tooth shedding: the formation of new teeth at the bases of the old teeth and within them. Arising from the jaw bone and growing gradually into the old teeth they displace them as they wear away. This suggests a later method of tooth shedding than that seen in the fish.

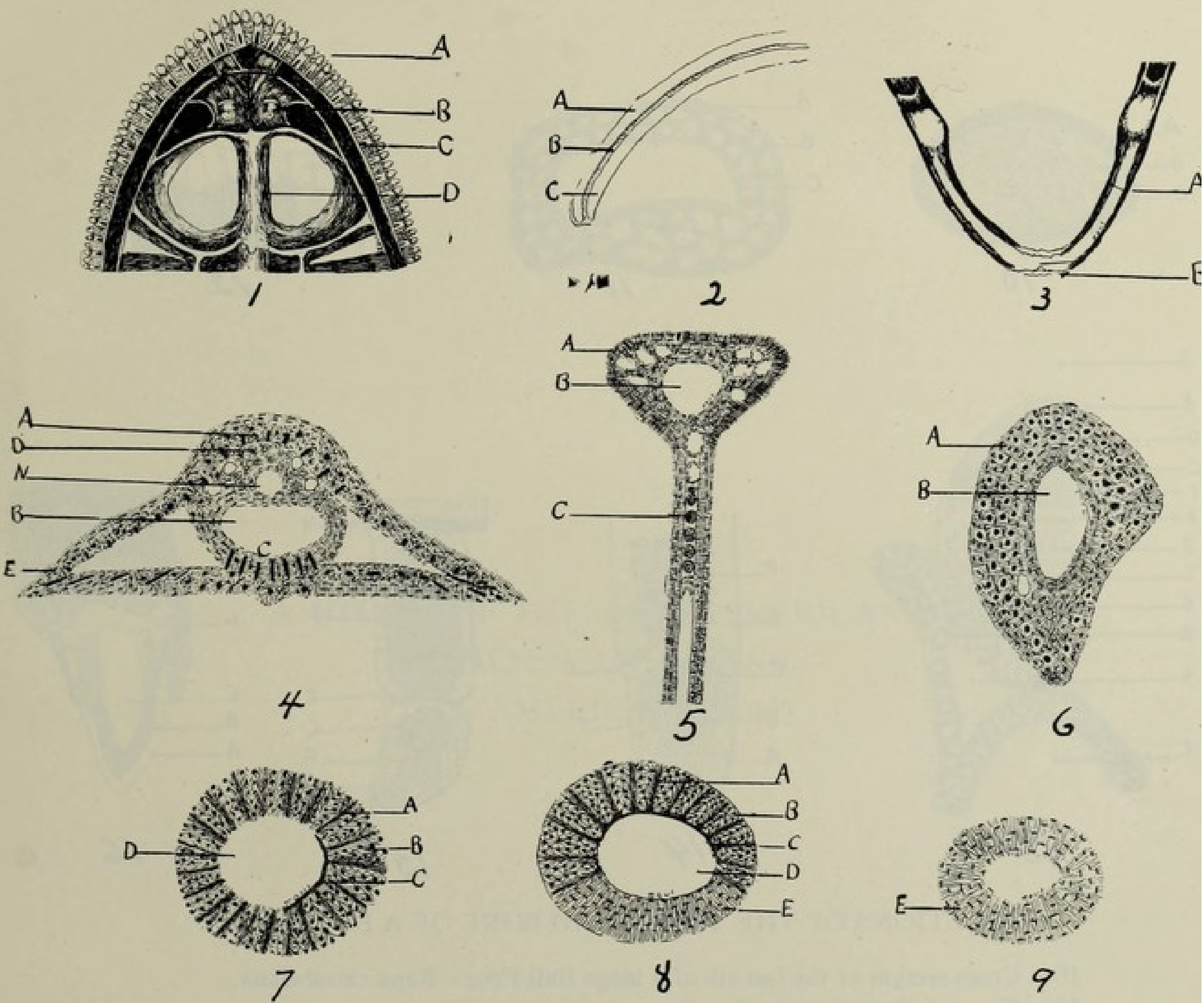
4. The early bone differentiation of the maxilla and the later bone differentiation of the mandible which has retained such a relationship throughout the later vertebrates.

5. Advancing bone differentiations by which members of a species rise to higher levels as seen in the femora of three frogs, as shown in sections 7, 8, 9. These three sections show how bone advances in type by a power which resides within the the circulatory system; for it is the circulatory system which first undergoes a change in distribution and is then followed by the different arrangements of bone substance which are called types. The bone in section 7, was first and the bone in section 9, was last in differentiation; the bone in section 7, represented the largest and that in section 9 the smallest animals, indicating that there has been a decrease in the size or mass of the animal as advancement in type took place. The animal represented in section 7, was a very large, giant Bull Frog, while that in section 9, was a small frog of the same species. If we compare the early fossil amphibians and reptiles with the later animals of those classes, we can not fail to notice the great reduction in size or mass as the type advances or, perhaps, that fact can be better expressed by saying that reduction in the size or mass of a vertebrate is an evidence of advancement in type and a rise to a higher level in vertebrate history.



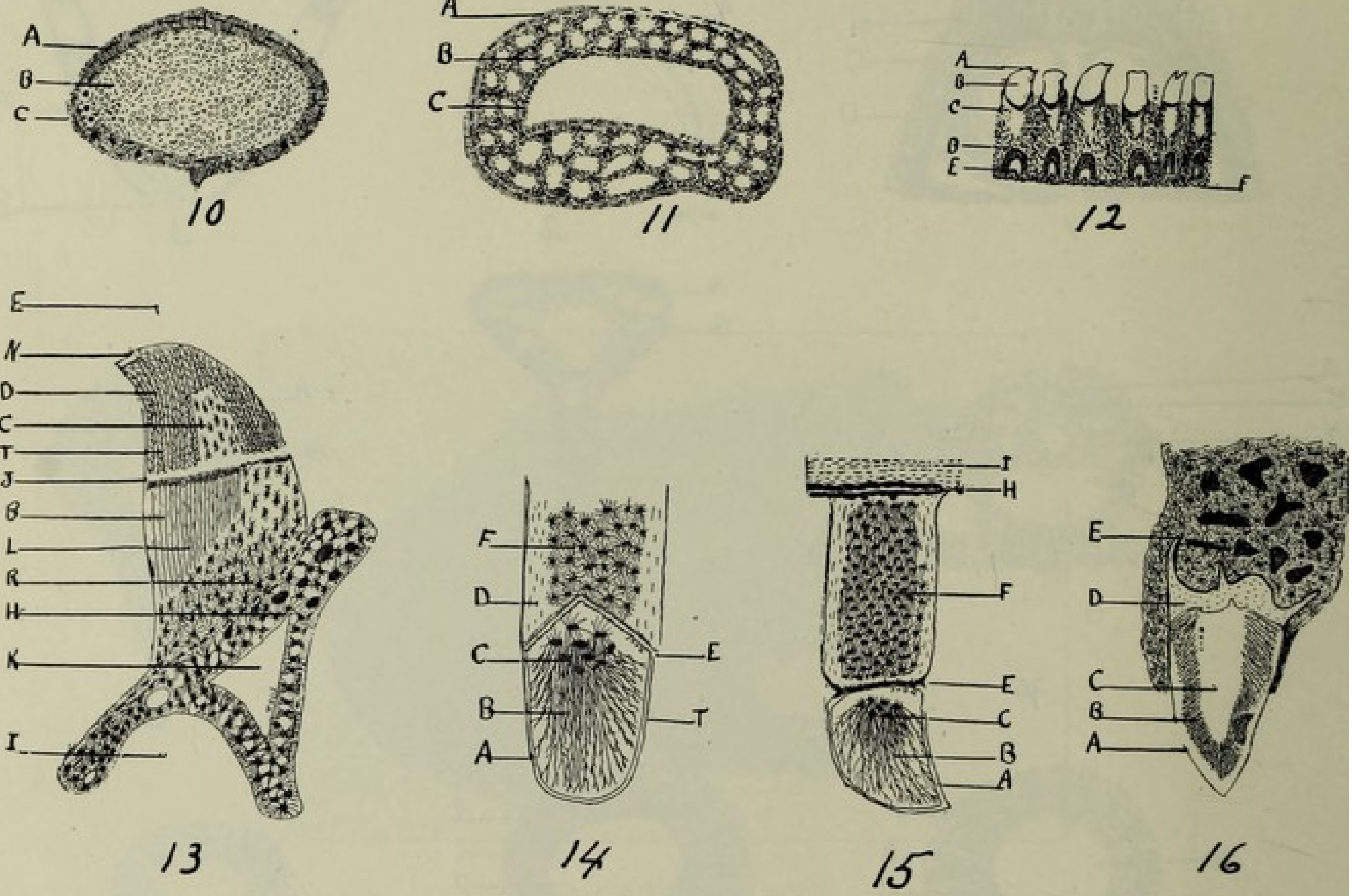
RANA CATESBEIANA.

From Frog Book. *Doubleday, Page & Co.*



SECTIONS OF THE TEETH AND BONE OF THE BULL FROG.

1. Diagram of the upper jaw of a large Bull Frog—Rana catesbeiana.
2. Concavo-convex curve of the tooth surface.
3. Diagram of the lower jaw.
4. Cross section of a vertebra extending into the ribs.
5. Longitudinal section of the urostyle.
6. Cross section of the lower jaw at A, Fig. 3.
7. Cross section of the femur of a large Bull Frog.
8. Cross section of the femur of a medium sized Bull Frog.
9. Cross section of the femur of a small Bull Frog.



SECTIONS OF THE TEETH AND BONE OF A BULL FROG

10. Cross section of the last rib of a large Bull Frog—Rana catesbeiana.
11. Cross section of the brain case.
12. Maxillary teeth.
13. Cross section of the maxilla with a tooth in position.
14. Maxillary tooth and bone ground flatwise.
15. Maxillary tooth and bone ground flatwise.
16. Vomerine tooth and bone ground flatwise.

A STUDY OF THE BUFO AMERICANA--
TOOTHLESS AMPHIBIAN—
THE AMERICAN TOAD

VIII.

A STUDY OF THE BUFO AMERICANA—AMERICAN TOAD—TOOTHLESS AMPHIBIAN.

Bufo americana—American toad. While the toads are placed in the amphibian class by a decree of the zoologists, they have not been able to abide by that decision, since they spend most of their lives on land and seem to have a natural aversion to water instead of a special adaptation to it as the frog has.

In contrast with the frog—Rana catesbeiana—described above and which had a large number of teeth on the upper jaw and none on the lawer jaw, the American toad—Bufo Americana, has no teeth on either jaw. The toothless history of vertebrates is interesting and serves as a prophesy of the probabilities of tooth failure in the later periods of tooth service in the most highly developed mammals.

The absence of teeth in the vertebrate series: The following article is taken in part, from Lull's "Organic Evolution" under the heading of Degeneracy and from Parker and Haswell's Text Book of Zoology.

Physical degeneracy is a trait paralleling certain senile characteristics. Among them is a loss of teeth which is recorded several times: first, among fishes such as the sturgeon and certain deep sea forms like the "gulper eel" macropharnyx, which evidently feeds upon the bottom oozes. Among the amphibians as seen in the present frog-Rana castesbeiana, there is an entire absence of teeth on the lower jaw; in the American toad, Bufo-Americana, there is an entire absence of teeth on both jaws. The turtles, which are among the oldest of living reptiles, had lost their teeth by Triassic time, when they first appear in the rocks; among Dinosaurs; three phyla were, at the time of their extinctions, rapidly losing their dental armament; the birds, which were toothed during the Age of Reptiles, have also been toothless since its close. In each of these instances the jaws are sheathed with a horny beak variously modified, so that while the turtles are fewer than of old, the birds, except for man's interference, can hardly have begun to wane as a whole, although many races are extinct. Among mamals the Monotremes have no dentiniform teeth, but have teeth of horn. Teeth are sometimes absent in the upper jaw of sperm whales and entirly absent in the whalebone whales.

In the Edentates as the sloth, armadillo and ant-eater, there is a great loss of teeth; in the vegetable feeding rodents there are no canines, two incisors in the upper and lower jaws. In the Ruminants, among Ungulates, teeth are absent in the upper jaws, the lower incisors biting against a horny pad. In man, among Primates, the lateral incisors and third molars are disappearing; in cleft palate the teeth are developmental failures; while in tooth cavities may be seen the beginnings of the tooth losses of modern man.

This is an interesting account of tooth history. Tooth losses seem to have been the rule and not the exception in the vertebrate series. If we go back to the fossils in our investigations, there are indications in the monuments of early vertebrate life that teeth were more often present and were in better form than they are in the later periods of developments; in other words, teeth have been falling off in their power of differentiation ever since they started. They were highly specialized calcium compounds, even at first, because the cells which produced their constituent parts operated, under their pristine vigor which had not been impaired by long tumultuous demands. From the nature of the case, the more highly specialized organs were the first to decline in the wear and tear of time and a changing geological environment. It is not because the calcium salts are failing in their chemistry that modern teeth are becoming poorer, but because the bond of union between the calcium salts and protoplasm has been slowly and gradually failing and the consequent release of these parts, the one from the other, has contributed to the tooth losses in vertebrate history.

1. Drawing of the upper jaw and roof of the mouth of Bufo-Americana: A, upper jaw which is entirely devoid of teeth; it has an outer and inner rim separated by a concave furrow. B, bony framework of the head; C, eye stalks.

2. Drawing of the lower jaw: A, site of the reversible tongue; B, rim of the jaw; C, soft tooth-shaped bodies having the appearance of being flattened against the upper surface of the jaw.

3. Longitudinal section of the lower jaw showing the structure: A, horny rim; B, vascular canal in cross section; C, upper portion of a horny sheath surrounding the bone; D, central core of bone composed of a central body of large, branching bone cells; E, in bone substance, enclosed by a sheath of bone; F, with long lacunae and long straight canaliculi, thus showing later differentiation of bone than the central core. The bone is the successor of Meckel's cartilage.

4. Cross section of the brain case: A, pigmented skin; B, underlying supporting tissue; C, bone of skull composed of thin external and internal plates of bone of unlike differentiations—the external plate being the most highly differentiated; D, brain cavity.

5. Cross section of a vertebra and a portion of the ribs: A, dorsal; B, ventral portions; C, layers of bone substance alternating with parallel blood vessels extending into the ribs; the bone substance has small, oval lacunae and short, bushy canaliculi; D, neural canal surrounded by a narrow ring of lamellae; E, remains of the notochord. The notochord is first areolar tissue, the areolae of which are filled with a liquid derived from the blood which gives it some rigidity, next hyaline cartilage and last, bone; F, ventral body composed of bone substance in which are seen short radiating blood vessels derived from a circumferential blood vessel seen at H. The vertebra shows a lower bone type than that seen in the frog. The ribs have the same alternating layers of bone substance and parallel blood vessels and a vascular canal extending through the center and seen at K.

6. Longitudinal section of the urostyle: The bone articulates with the last vertebra and is 17 mm. long and 2 mm. wide, gradually tapering from the articulating surface to the distal extremity. A, articulating surface having a layer of long, columnar cells with round nuclei in their attached extremities. The shaft of the bone is composed of alternating layers of bone substance and parallel blood vessels which form angles with the external and internal surfaces and seen at B. A vascular canal extends through the center of the bone as seen at C. The plan of structure is the plan of the fish.

7, 8, 9 show an interesting series of cross sections of the femora. 7 is a cross section of the right femur at its mid-line; 8 is a cross section of the left femur of the same animal at the mid-line of the bone. Notice the difference in shape and structure. The section of the right femur is round, of the left, triangular. Of 39 cross sections of as many right femora of amphibians formerly examined by the writer, 28 per cent were round, 26 per cent triangular, 41 per cent elliptical, and 5 per cent irregular; that is, the most common shape was elliptical. In this particular animal the right femur was one shape and the left another. Remarkable differences also are found in structure, as may be seen from the figures and descriptive text. Right femur: a narrow ring of external circumferential lamellae surrounds the section as seen at A, a wide central ring of lamellae with numerous radiating and longitudinal vascular canals is seen at B. The radiating canals are seen at E, and cross sections of the longitudinal canals (which are really Haversian canals) are seen at C. A narrow ring of internal circumferential lamellae surrounds the medullary canal, D.

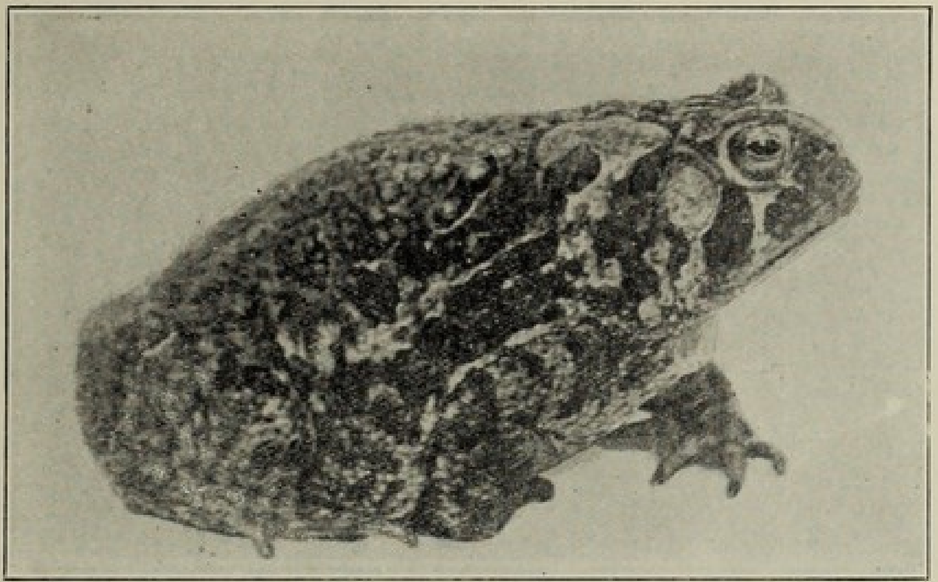
Comparing the structure in Fig. 7, with the structure in Fig. 8, there is seen a remarkable difference which is biological in character. In Fig. 7, there are both radiating and longitudinal vascular canals. In Fig. 8, the radiating canals have all disappeared, while the longitudinal canals remain and thus establish the position of Haversian systems in all later long bones. The bone type in both femora is a crude first. It is difficult to account for the variations in shape and structure on the basis of function or environment. The two bones are on different levels or differentiation, Fig. 8 representing a higher level than Fig. 7, for the reason that it has more bone, which is the ultimate end of bone differentiation. In both of these sections may be seen the first differentiations of the Haversian system.

9. Cross section of the right femur of another and different toad of the same species—Bufo-Americana. This section shows another and very important variation in the appearance of a single lamina which occupies an irregular position in the wide central zone of the wall as may be seen at A. Here, again, function does not account for the variation.

While this series does not appear to have any connection or relation to the teeth and may seem to be extraneous matter in the consideration of tooth development, and especially in an animal which has no teeth, yet it shows a peculiar biological disturbance in organic structures which may be important, inasmuch as it gives a visible evidence that variations may and do occur and sooner or later establish new bone types regardless of function or environment. It is such variations which give character to species. Unaccountable variations may occur at some period of the history of life and become serviceable types in later developments; for example, the lamina, which made its appearance in Fig. 9, and without any apparent reason, later becomes the most important and characteristic bone unit of structure of birds and the ungulates among mammals.

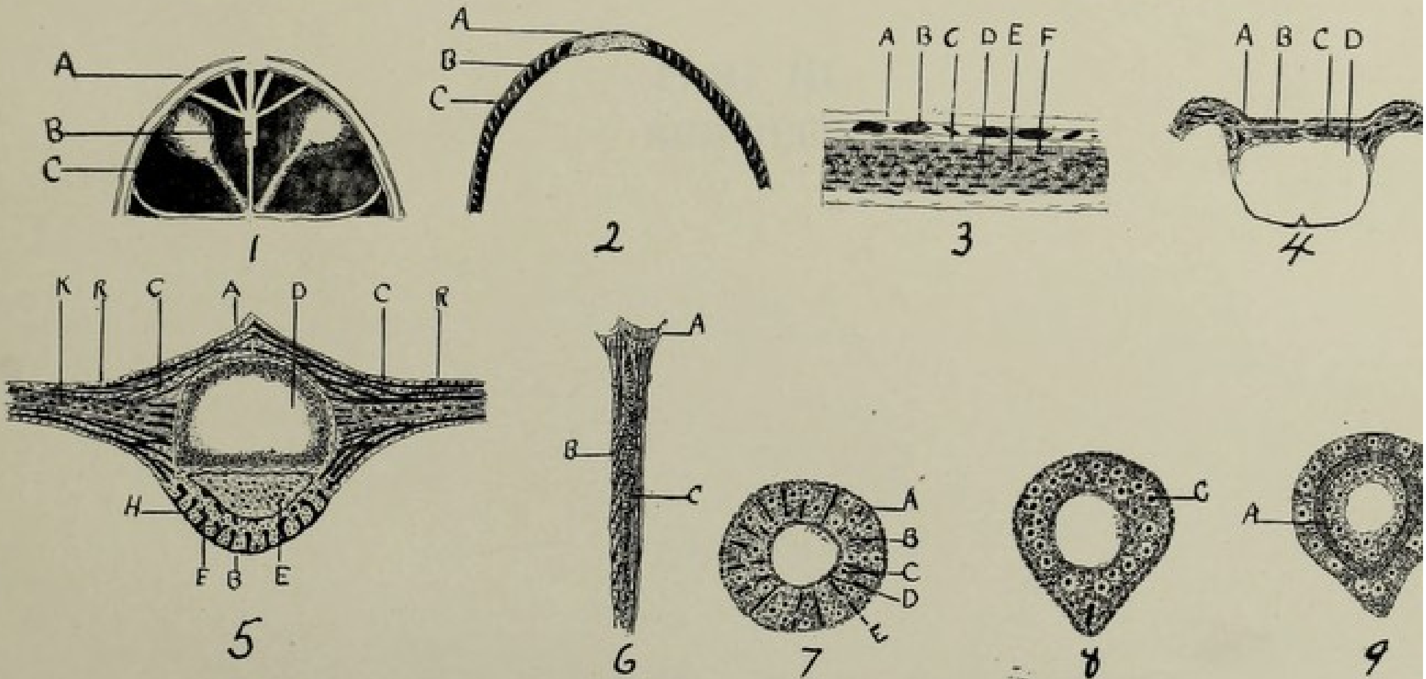
If now we consider the inorganic structures of the American Toad—Bufo-Americana—in their comparative relations, with those of the frog-Rana catesbeiana—we are confronted with a confusion of biological evidences which are more or less contradictory in their apparent values; the toad is a vertebrate without teeth; the frog, a vertebrate with many teeth and both are members of the same class. The toad has a mixed type prophetic of vertebrate advancement inasmuch as it shows in outline the three bone units, lamella, lamina and Haversian System. The prevailing bone type resembles that of the fish rather than that of the frog. The most important thing in biology is the start or introduction of a type, after this, function and environmental changes will utilize the type for the best interest of the individual. On the whole, therefore, the bone sections of the toad indicate a disturbance in biological factors which is awaiting the selective action and adjustment of the class to which it belongs.

The bone of a toothless amphbian is a lower type bone than that of a toothed amphibian which may be a significant prophesy.



BUFO-AMERICANUS.

From Frog Book. *Doubleday-Page & Co.*



BONE SECTIONS OF A TOOTHLESS VERTEBRATE.
BUFO-AMERICANA—AMERICAN TOAD.

1. Drawing of the upper jaw and roof of the mouth.
2. Drawing of the lower jaw.
3. Longitudinal section of the lower jaw.
4. Cross section of the brain case.
5. Cross section of a vertebra and portion of the ribs.
6. Longitudinal section of the urostyle.
7. Cross section of the right femur at its mid-line.
8. Cross section of the left femur at its mid-line.
9. Cross section of the right femur of another toad of the same species.

PART III.
REPTILES.

CONTENTS.

Index

REPTILES.

The reptiles are especially interesting for the reason that it was in this class of vertebrates that a very important change in bone type appeared and raised the level of vertebrate advancement above that of the foregoing fishes and amphibians. If there is an existing kinship between bone and teeth, as the chemical foundations of both imply, we may reasonably expect to find a corresponding change in teeth which would also have an advancing value over and above that shown in the preceding vertebrates.

The bone in the fishes and amphibians is essentially a first type bone and the teeth are single cones, that is, a first type bone and the single cone tooth are found together. Dentinal substance appeared before bone substance in vertebrate history as was seen in the fish.

The following account of the change in bone type in reptiles may serve a useful purpose here: Vertebrate life began in the water and was cold-blooded; it was extended without much visible change throughout the fishes and amphibians into the reptiles where an important change in bone type occurred. A distinct line of differentiation between the amphibians and the reptilian lizards is not well defined; if it can be distinguished at all. As a matter of fact, it is not a simple matter to decide just where amphibian life terminates and reptilian life begins on the basis of bone type. The same lamellar bone type prevails in the fishes, amphibians, lizards and snakes; while the first evidence of a distinct advance in bone type is seen in the alligator where the second type lamina appeared and occupied a prominent place from that time in bone construction; there was also a noticeable change in the degree of differentiation of the early Haversian System and in its proportionate increase. The bone of the snake is interesting in its relation to heredity. This was suggested by the femur of the python; this bone was not an outgrowth from a femur, but the entire bone produced in a vertebrate which does not require such an organ to serve any mechanical purpose whatsoever and the significance of such an organ would be free from any functional causes. There were femora in the lizard ancestry of the snake, but just when they disappeared or why they disappeared, when they reappeared or why they reappeared are questions which are unanswerable at present. The femur of the snake was true to the lizard type of structure, although it had lost the lizard function and was a purposeless bone; in no sense did it resemble the femur of the alligator which followed. From such evidence as this, it may be supposed that it is not function that decides when a bone shall exist or what type of bone it shall be when it does exist, but the level of biological advancement which an animal occupies in the vertebrate series. The femur of the alligator gives the three bone units—lamella, lamina and Haversian System and thus represents an important station in bone history.

The teeth of the fishes and amphibians are single cones and as we approach the reptiles and find within their limits a change in bone type directed toward a higher level, we may very well wonder if some similar change will be found in the teeth and with this in mind we begin the study of the first group of reptiles, viz., the lizards an snakes.

In the Cambridge Natural History Series—Amphibians and Reptiles, by Gadow, is given the following brief account of reptilian characterization:

"The recent reptiles comprise, broadly speaking, the crocodiles ,tortoises, lizards and snakes. They may be described as monocondylia, (one condyle) with a scaly skin. The reptiles, probably through some branch of the Thermorpha (an extinct order of reptiles of the Triassic Age) have given rise to the mammals and some other reptilian branch, at present unknown, has blossomed out into birds.

Some characteristics of the reptilia:

The skull articulates with the atlas by one condyle.

The mandible consists of many pieces and articulates with the cranium through the quadrate bones.

The ribs form a true sternum.

The skin is covered with scales.

The red corpuscles are nucleated, biconvex and oval.

Respiration is effected by lungs and gills are entirely absent even in embryonic life.

The eggs are meroblastic (undergoing partial or complete cleavage).

Fertilization is internally effected, with one exception, by means of the male copulatory organ.

Heloderma suspectum—The Gila Monster.

"This animal is found along the banks of the Gila (Hela) River in Arizona. It is a large lizard with a rough, tuberculated skin and thick tail, dull orange and black in color, sluggish, ugly disposition, attains a length of about two feet and is generally supposed to be the only poisonous lizard. The poison glands, unlike snakes, are on the mandible. They inhabit dry localities, spend most of the day-time in concealment between roots of trees and crawl about in the evening in search of worms, centipedes, frogs, flies, and eggs of lizards. Its prey is held by the sharp teeth and powerful jaws and is paralyzed or killed by the poisonous bite. During the hot season they lie in a state of torpor.

The teeth are strong, sharp-pointed and fang-like. They are embedded in a red, highly vascular, compressible soft tissue which almost conceals them. There are about 24 in the maxilla and 16 in the mandible and these vary in size; those in the premaxillary bones are short and small and gradually increase in size toward the maxillary areas. The teeth are pleurodont, arranged in a single row on the inner edge of the bone and firmly attached by ankylosis. There is a groove along the lingual surfaces of the lower teeth leading from a gland at the bases of the teeth."

The animal herewith photographed and described was 20 inches in length, the body was covered with a heavy bead-like skin—orange and black in color—and variegated in pattern, the tail was short and thick and the protruding tongue and bifurcated at its extremity. (Photo 1.)

When the mouth was opened, the most noticeable feature was the apparent absence of teeth and the presence of a thick, soft red oral membrane and the enormous masseter muscles on either side of the mouth; on running the finger over the oral surfaces of the jaws, however, small, fine points of teeth could be felt.

Photo 2 shows the mouth opened, the soft tissues removed which brought the upper and lower teeth plainly into view. The teeth presented a formidable array of sharp, curved cones on both jaws adapted to prehensile purposes. Photo 3 shows the jaws open, soft tissues removed which brings into view the teeth and articulation of the two jaws. The mandibular articulation is adapted by construction to firmly hold struggling prey. The mandible is lifted bodily by the two heavy masseter muscles and thrown into a locked position by the articular and coronoid processes of the lower jaw. Photo 4 shows the occlusion of the jaws and their locked feature.

Gross and Microscopic Anatomy of the Bone and Teeth.

1. Drawing of the under surface of the skull showing the upper jaw and teeth.

A, Dental arch; B, teeth; C, maxillary bone, D, vomerine bones; E, masseter muscles; F, articulation with the lower jaw; H, condyle; V, entrance of blood vessel at base of tooth; I, site of a lost tooth.

The maxilla has a single row of curved, sharp-pointed teeth which are very much smaller in premaxilla. They point backwards and are firmly ankylosed to the inner, slanting surface of the maxillary bone; at the bases of the teeth are seen the points of entrance of the blood vessels derived from the thick, spongy vascular oral membrane similar to that seen in the fish. The arrangement of the teeth is prehensile.

2. Drawing of the lower jaw showing the locking processes and teeth.

A, articular process; B, coronoid process; C, sharp-pointed curved tooth directed backwards; D, jaw-bone; S, site of a lost tooth.

The two jaws when closed are locked by the articular and coronoid processes in their adaptations to the jugal and extopterogoid bones of the upper jaw. The lower jaw is lifted bodily into the locked position by the masseter muscles attached at M.

Histology of the Bone and Teeth.

3. Cross section of the anterior portion of the skull; the bone shows a distinct advance in differentiation beyond that seen in the fish and amphibians. The Heloderma, however, is not a primitive reptile and a somewhat abrupt change in bone type might be excepted. A, thin, pigmented layer covering the beaded bone of the skull; B, line of separation between two plates of bone which form the skull; C, well developed first type bone with long, narrow lacunae and long straight canaliculi which characterize the later bone differentiations; D, well developed Haversian Systems; E, vascular canal.

4. Cross section of the left femur at its mid-line: This shows the second type bone in the making. A, vascular canal extending lengthwise of the bone. Such canals are the beginnings of future Haversian Systems. B, lamellae assuming a concentric position which is the beginning of the laminar or second type formation; C, internal circumferential lamellae; D, medullary canal. The structure of this femur is a forecast or, perhaps a broad cast of developmental factors in operation at this level of biological advancement.

5. Cross section of a dorsal vertebra. A, anterior spinous process; B, bony sheath extension of the spinous process; C, first type bone enclosing the neural canal, the lacunae are somewhat oval and the canaliculi are very indistinct. The bone is not advanced in the type of differentiation; D, neural canal; E, cancellous bone of the body of the vertebra; F, sheath of a low type bone surrounding the body of the vertebra; H, canal of the notochord. The whole vertebral bone is low in type of differentiation. It seems to be true that in the beginning of vertebrate life, as in the fish, the vertebral type of differentiation is first to advance and later falls behind in the race of individual progress. The first type bone is the prevailing type in all vertebrae.

6. Cross section of the lower jaw with a tooth in position. A, sharp-curved tooth; B, groove extending from the bone attachment to the tip of the tooth. This groove which is found along the lingual surfaces of all of the larger lower teeth are supposed by many to be poison grooves or canals. While the poisonous nature of the animal is denied by some, yet the groove remains and is suggestive; in snakes the poison canal is within the tooth and emerges form it a short distance above the point; in the Gila Monster it is a groove on the outside of the tooth and in this location is not as deadly as poison would be injected into the tissues; C, blood vessel between the base of the tooth and jaw bone sending branches into the central chamber between the dental divisions of

the base of the tooth as may be seen at D; E, first type bone of the jaw with long narrow lacunae and long, straight canaliculi; F, dental divisions at the base of the tooth; H, Haversian System.

7. Cross section of the upper jaw with a tooth in position. A, first and second type bone; B, blood vessel from the outside; C, blood vessel between the base of the tooth and the jaw bone sending branches between the dental divisions of the base of the tooth into the central chamber; these divisions appear as ridges on the inside of the tooth with cores of dentine; F, dentinal tubules arising in the divisions and in the shaft of the tooth from the blood vessels by simple extension; such a source of the dentinal tubules is significant in connection with tooth values as it makes dentine dependent upon the character of the blood supply; H, tooth; I, jaw bone.

8. Tooth and bone attachment of the upper jaw. The tooth is sharp, stout, pointed, curved with a branching base ankylosed to the bone; B, branching base unlike that seen in the teeth of fishes or amphibians; C, shaft; D, entrance of blood vessel. The teeth in the premaxillary region are smaller and much inferior to those of the maxillary region.

9. Tooth and bone of the lower jaw showing the supposed poison groove. The teeth of the lower jaw are more slender and slightly longer than those of the upper jaw. A, tooth; B, groove; C, position of the gland at the base of the tooth; D, jaw bone. These teeth are the venomous teeth of the animal and have the same general structure as the upper teeth.

10. Cross section of a lower tooth at the branching base showing its intimate relation to the circulatory system and bone. The tooth is ankylosed to the bone as far up on the side as the dental branches extend. A, clear external space around the tooth; B, fine branching ends of the dentinal tubules; C, central chamber; D, bone attachment along the side of the tooth with interdigitating blood vessels and dentinal branches; E, first type bone of the jaw; F, dentinal tubules of the shaft; H, dentinal branches of the shaft; V, blood vessel sending branches up between the dentinal tubules. The interesting feature is the apparent origin of the tubules from the blood vessel.

11. Cross section of an upper tooth at its branching base. A, first type jaw bone with blood vessel sending branches up into the dentinal divisions of the shaft of the tooth; B, interdigitations of the blood vessels and dentinal divisions; C, clear space surrounding the tooth; D, branching dentinal tubules; E, central chamber. The relation of the dentine, blood vessels and bone is very intimate at this point.

12. Cross section of the shaft of a lower tooth. A, clear space beyond the tubules; B, branching dentinal tubules; C, central chamber. The tubules are well differentiated with many intertubular branches and fine branching extremities.

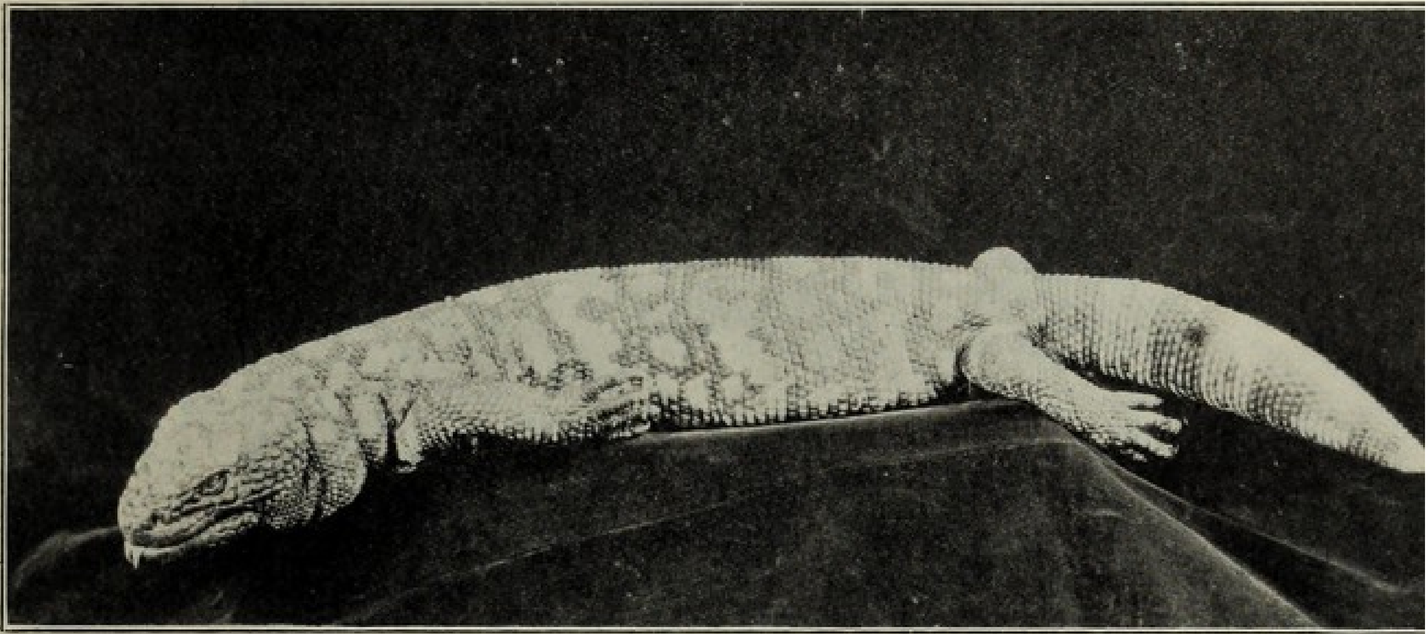
13. Cross section of the beaded skin of the left thigh. The whole body is covered by a bead-like skin which over the skull is bone (Fig. 3) and elsewhere has the structure shown in Fig. 13. A, external pigmented layer; B, dark brown or black homogeneous layer; C, recticular, keratinized tissue, the meshes of which are filled with dark granules (possibly calcium carbonate) and these form the beads; D, thick keratin layer upon which the beaded layer rests.

14. Thin transparent more ar less pigmented layer covering the beaded layer and forming the outside covering of the body; when stripped off it retains the beaded shape of the underlying layer. It is composed of rectangular scales united by cement substance. A, a scale; B, small epithelial cells composing the scale, uniting cement substance.

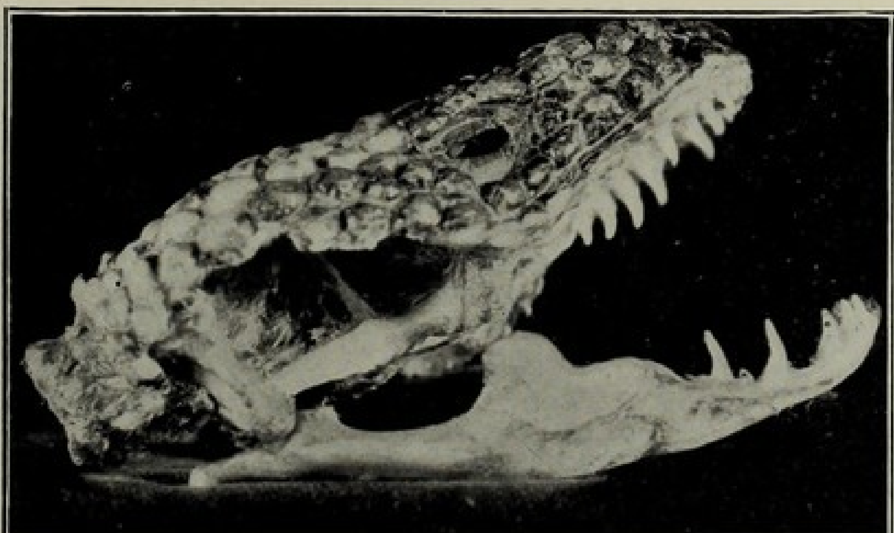
Thus there is found an advance in bone differentiation in the heloderma, but not in the characteristic bone type. The advance has occurred chiefly within the existing bone unit rather than in establishing an advanced bone unit. The bone is still a first type bone as it was in the amphibians and fishes, but shows an advance in differentiation; the second type is merely in the making. While the third type unit of Haversian System has appeared, it does predominate as a type, so that we have in this reptile a more advanced first type than that seen in the foregoing vertebrates.

Under such circumstances the teeth would not be expected to show any particular advance or change, but would remain as they were found in their first type antecedents, that is, as single cones, ankylosed to the jaw bone and receiving their blood supply from the oral membrane and jaw bone. We would not look for any fundamental change in the type of tooth until we had found an advanced type of bone and evidence of a rise in biological level and this has not occurred in the Heloderma.

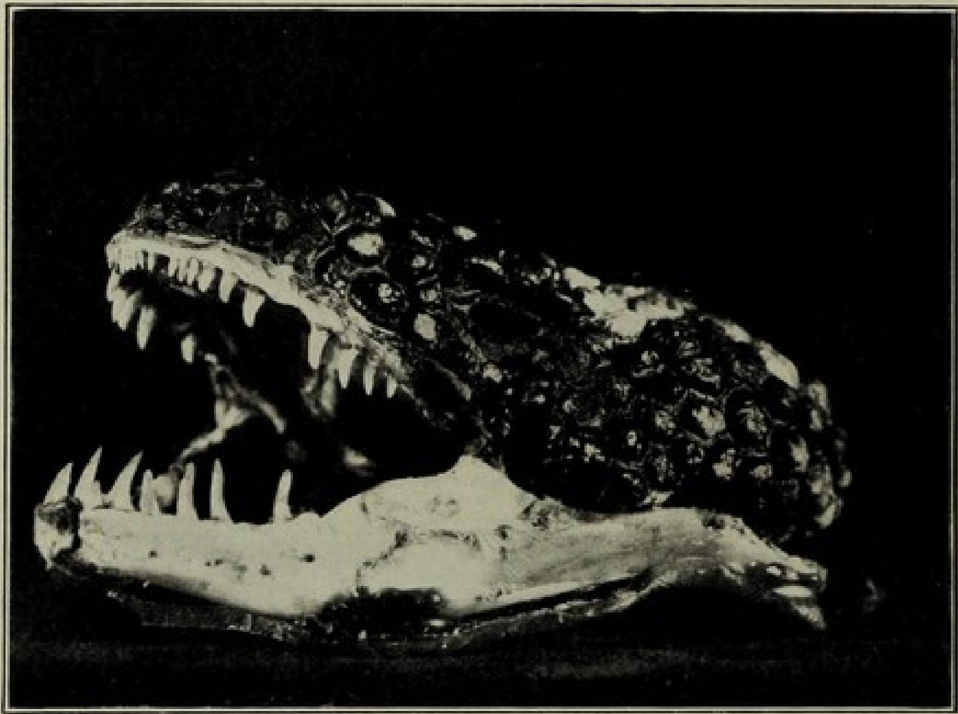
PHOTOGRAPHS OF HELODERMA SUSPECTUM—
THE GILA MONSTER.



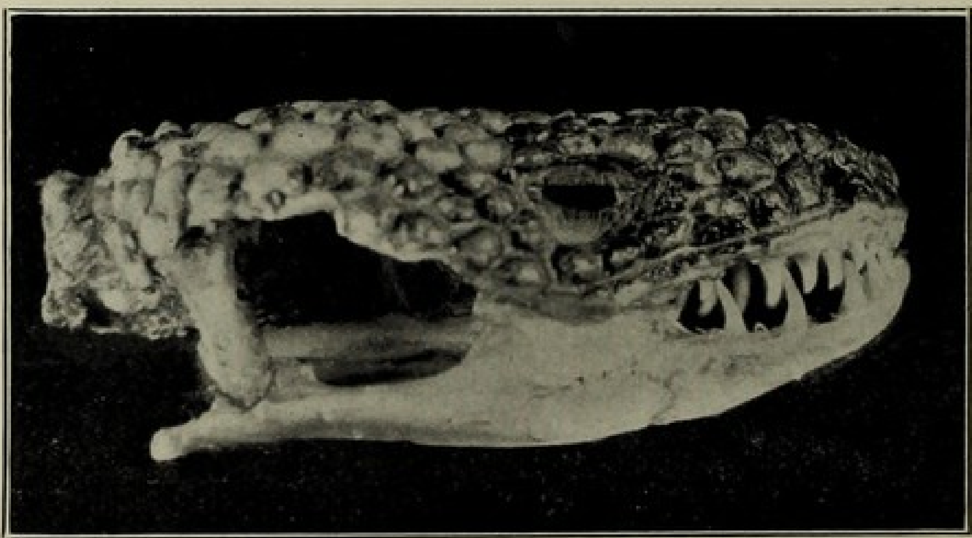
1. Heloderma suspectum—The Gila Monster.



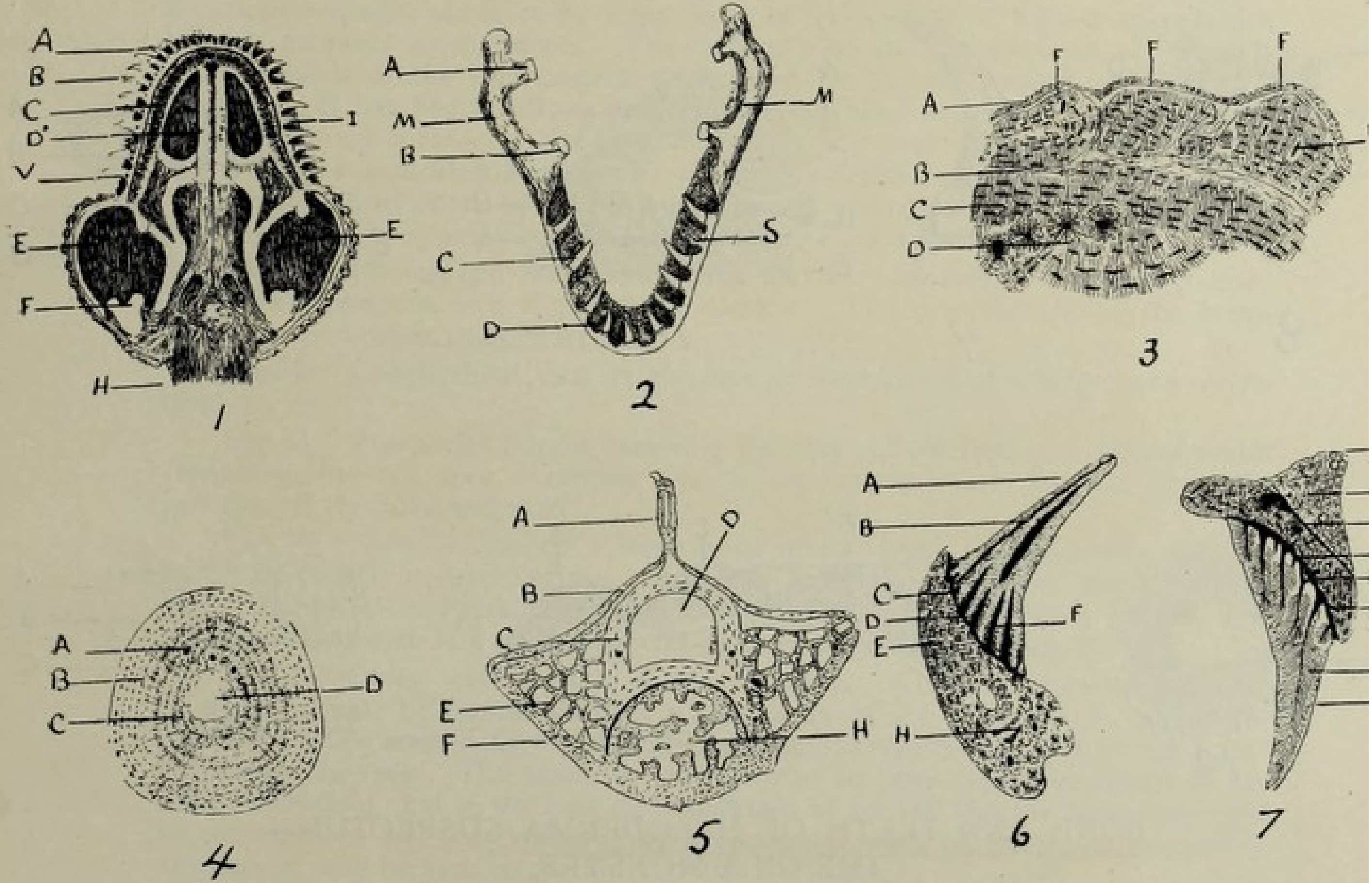
2. Mouth open, soft tissues removed showing teeth.



3. Jaws open, soft tissues removed, showing teeth and articulation.

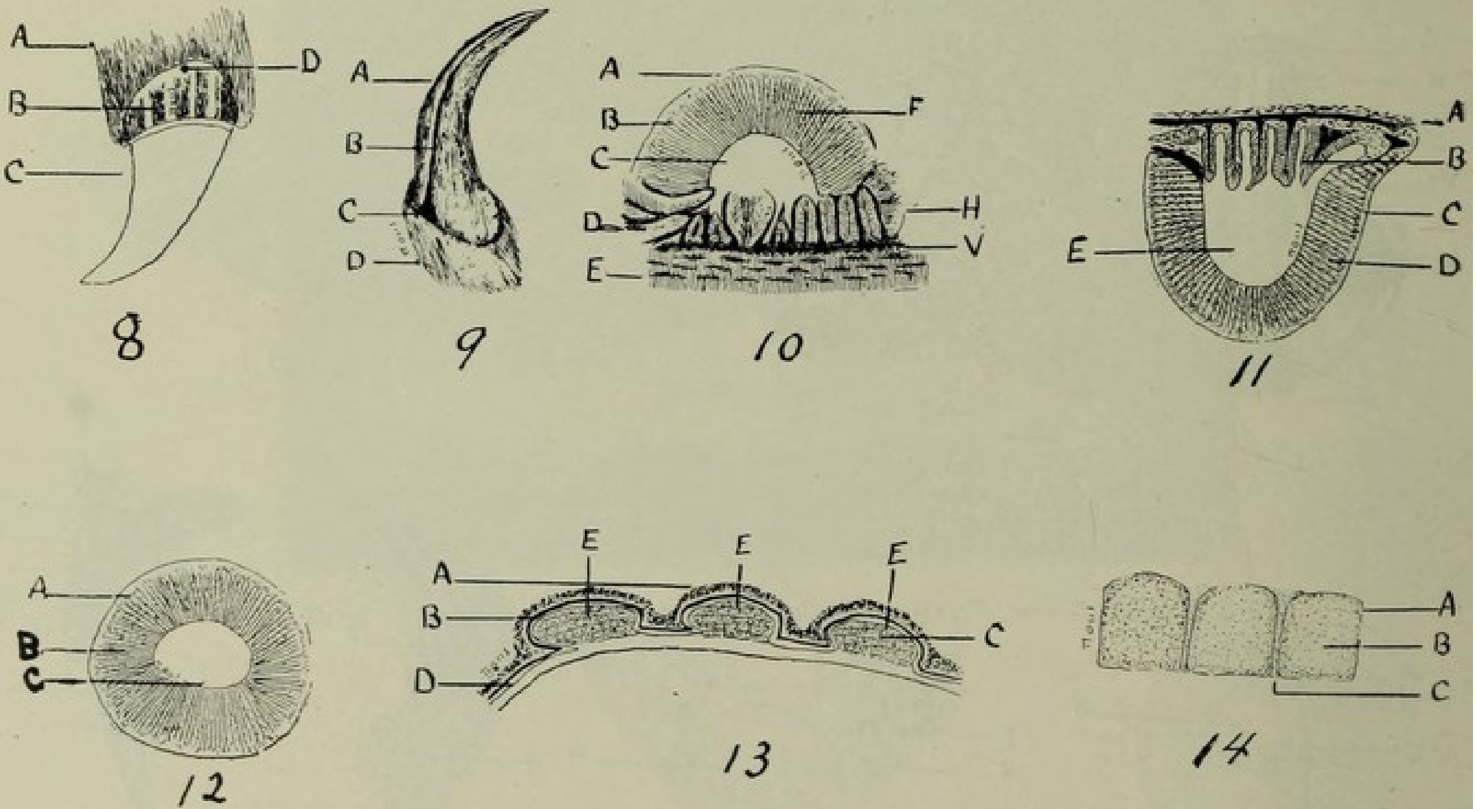


4. Jaws occluded.



BONE AND TEETH OF HELODERMA SUSPECTUM—
THE GILA MONSTER.

1. Under surface of the skull showing upper jaw and teeth.
2. Lower jaw showing teeth and articulation.
3. Cross section of skull showing advanced type of bone.
4. Cross section of left femur at the mid-line.
5. Cross section of a dorsal vertebra.
6. Cross section of lower jaw with tooth in position.
7. Cross section of upper jaw with tooth in position.



BONE AND TEETH OF HELODERMA SUSPECTUM—
THE GILA MONSTER.

8. Tooth and bone attachment of the upper jaw.
9. Tooth of the lower jaw showing groove and bone attachment.
10. Cross section of a lower tooth through its lateral bone attachment.
11. Cross section of an upper tooth through its lateral bone attachment.
12. Cross section of the shaft of a lower tooth.
13. Cross section of the beaded skin.
14. Thin transparent layer covering the beaded skin.

PHRYNOSOMA CORNUTUM—HORNED TOAD.

This animal, shaped something like a toad, but having a tail and covered with an armor of scales and spikes, is classified among the reptiles, although not conforming strictly to all reptilian characters. The body is flattened and broad and without a dorsal crest. The animal is especially noticeable on account of its prominent horns or spikes which give the name to the species. Instead of being oviparious like the fishes, amphibians and lizards, it is viviparious—a curious example of the early appearance of the method of reproduction which belongs properly to mammals. The horned toad is an inhabitant of the dry, sandy regions of the southeastern portion of the United States and of Central America. It has five horns on each side of the head and short horns scattered over the dorsal surface of the body and extending over the tail (Fig. 1). The horns have a central foundation or core of cancellous bone which is enclosed by a thin shell of horn, being the same general arrangement as its found in the bills of birds; the type of bone is the same as that of a skeleton.

Fig. 1. Photograph of the drawing in the Cambridge Natural History Series—Amphibians and Reptiles—by Gadow. The drawing shows the horns or spikes somewhat exaggerated.

Fig. 2. Longitudinal view of the core or foundation of a large horn of the head.

Fig. 3. The shell of horn enclosing the core; at the base, the dermal scales from the skin are seen extending up on the horn a short distance from the junction of the horn and skin.

Fig. 4. Cross section of a large horn of the head. A, enclosing shell of horn; B, cancellous bone of the core. The horn slips off from the bone very easily when detached from the scales. The core has a surrounding wall of first type bone C, which is thin and central portion of cancellous bone D.

Fig. 5. Cross section of a dorsal vertebra. A, dorsal spinous process; B, neural canal; C, cancellous bone of the body of the vertebra; D, transverse processes. The bone is first type and cancellous to which the cores of the horns correspond in type. The same correspondencee in bone type was found in the bill of a chicken, that is, the core or foundation of the bill had the same bone type as the skeleton and was enclosed by a removable shell of horn. A suggestive antecedent may be seen in the horn of the Phrynosoma cornutum.

Figs. 6, 7. Keeled scales from the ventral surface of the skin. A, keel, which extends from the anterior to the posterior border of the scale and is sharpened at the posterior end; B, minute granular bodies composing the body of the scale; C, sharp pointed posterior end of the keel.

Figs. 8, 9. Keeled scales from the dorsal surface of the skin. A, keel; B, granular bodies; C, sharp points of the posterior ends of the keels.

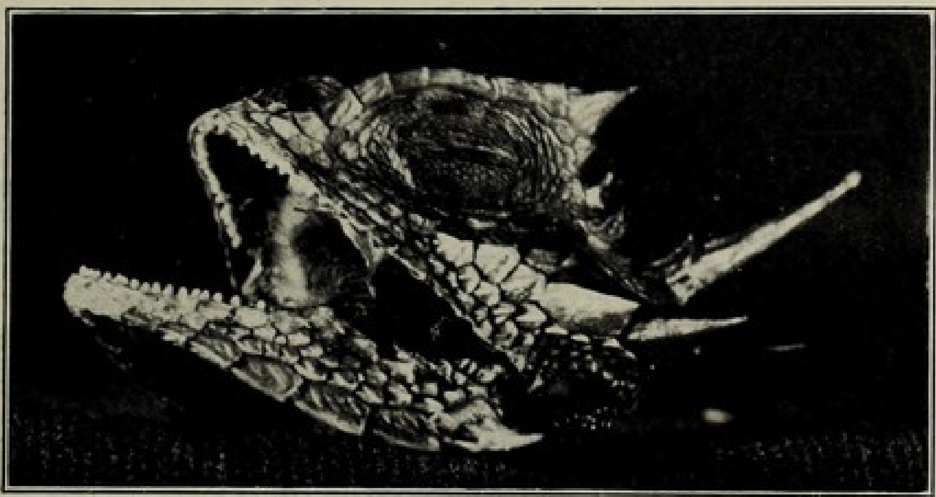
Fig. 10. Pyramidal scale from the hind leg. This scale projects above the other scales, is pyramidal in shape, the apex terminating in a point and, while it resembles a horn in shape, it is composed of keratin structures without a bone foundation. It is merely a specialized scale.

Fig. 11. Under surface of the skull showing the upper jaw and teeth. A, skin; B, a row of microscopic teeth—16 on a side—attached to the bone at C; D, groove between the jaw bone and outer portion of the skull; E, roof of the mouth. The teeth are too small for grinding purposes; they have a base which is surmounted by a cap and have a firm bone attachment. A low power objective was required to see the teeth and the function of such teeth is not clear, but their presence suggests a biological result. The animal is a tailed, reptilian vertebrate and teeth on both jaws are called for by such a vertebrate.

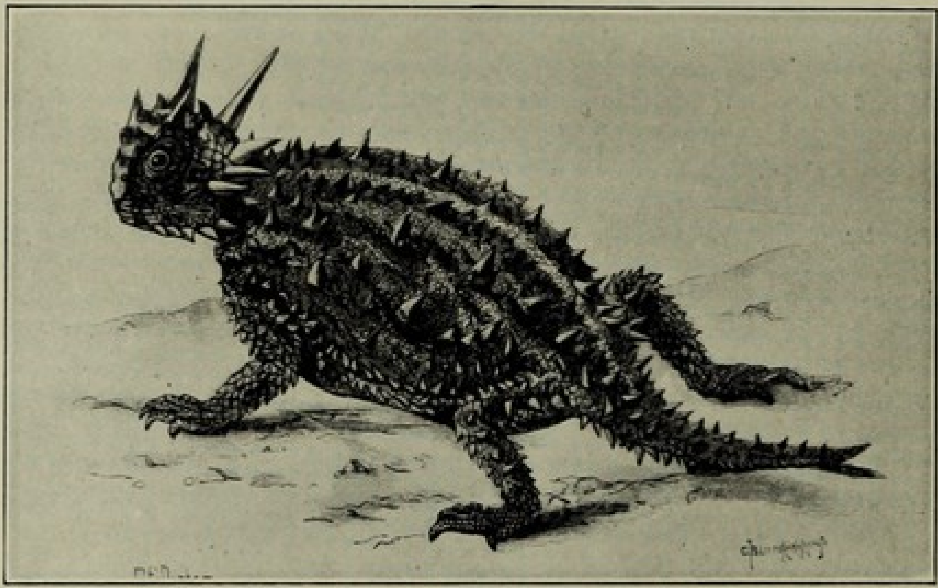
Fig. 12. A drawing of the lower jaw. A, external dermal surface; B, a row of small teeth—16 on a side—quite similar in shape and size to those of the upper jaw; C, jaw bone. There are, therefore, teeth on both jaws, although their diminutive sizes hardly suggest any useful function; the complete absence of these teeth, as insignificant as they appear to be, would bring to mind the thought of reversion to a lower level of vertebrate development as we saw in the amphibian toad—Bufo-Americana. Such a thought, however, is not compatible with the biological law as we understand it. What we call reversion from a higher to a lower type may be better explained by the projection of the lower type into a later stage of development where it does not properly belong for example, peg teeth do not properly belong in man and can not be satisfactorily explained on the basis of reversion from the molar type, but can be understood by assuming that the single cone teeth had been projected forward from the fish, amphibian or reptile where they properly belong. The projection of a primitive type of structure into a later development is a freak act in biology and results in a pathological condition. Projection is the expression of the dominant force of a primitive form of life which prevails beyond its time of usefulness.

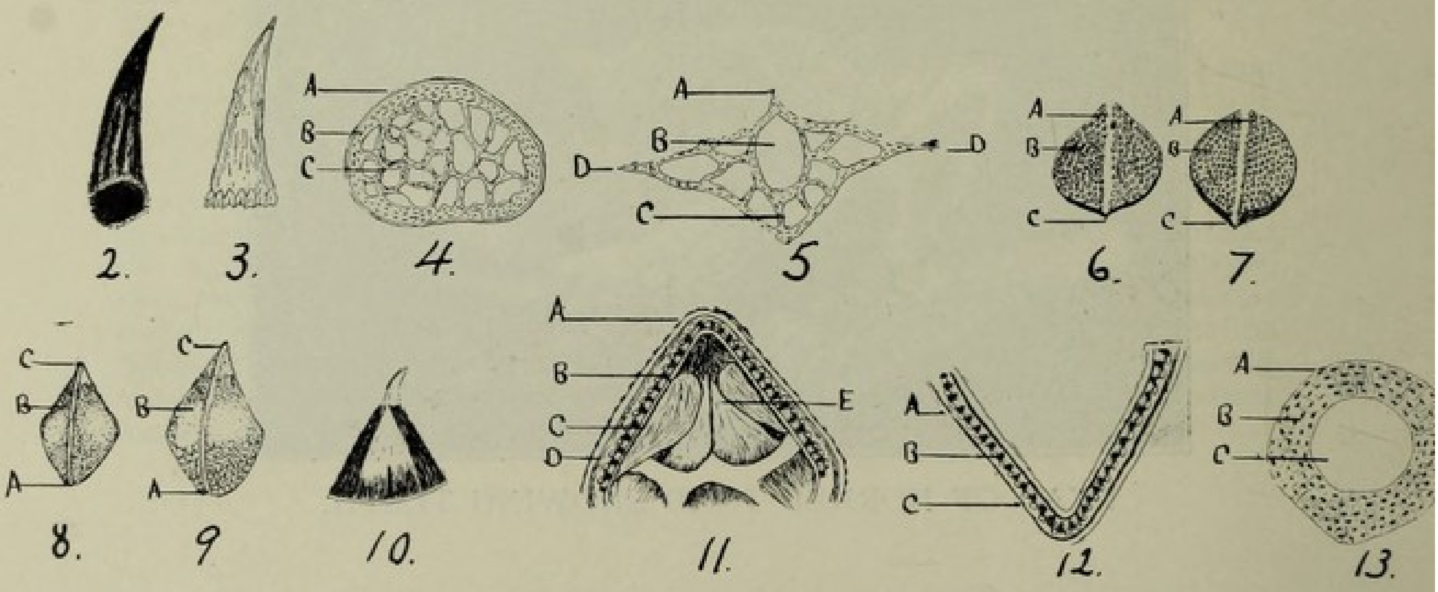
Fig. 13. Cross section of the right femur at its mid-line. A, anterior wall; B, first type bone; C, medullary canal. The wall of the bone is composed of bone substance in which are very many oval lacunae with rather short canaliculi. The medullary canal is filled with marrow.

It was stated above that the bone type of the horns of this animal and that of the bills of the birds were the same as that of the general skeleton of those animals. It was found that the bone of the horns, in this case, was cancellous while that of the femur was compact bone; this is simply stating the case in two different ways. They are both first type bone. Cancellous bone is a retiform arrangement of first type bone, while compact bone is first type bone without the retiform plan. Cancellous bone is the most important tissue of the body, since the red marrow which its meshes contain is the source of the most important cell of the body, viz.: the red blood cell. The cancellous bone is found in the heads of the long bones and in the short, flat and irregular bones. The mass of red marrow must hold a definite ratio to the mass of the body since a constant number of red cells per cubic centimeter of blood must be maintained.



HEAD OF HORNED TOAD SHOWING TEETH.





PHRYNOSOMA CORNUTUM.

1. From Cambridge Natural History Series; photo of Horned Toad.
2. Longitudinal view of the core of a large horn of the head.
3. Shell of horn enclosing the core seen in Fig. 2.
4. Cross section of a large horn of the head.
5. Cross section of a dorsal vertebra.
6. Keeled scale from ventral surface.
7. Keeled scale from ventral surface.
8. Keeled scales from the dorsal surface.
9. Keeled scales from the dorsal surface.
10. Pyramidal scale from the hind leg.
11. Under surface of skull showing upper jaw and teeth.
12. Lower jaw and teeth.
13. Cross section of the right femur.

THE HORNED TOADS—PHRYNOSOMA CORNUTUM AND PHRYNOSOMA DOUGLASSII.

The comparative histology of the bone and teeth of the two varieties of Phrynosoma—the Phrynosoma cornutum and Phrynosoma douglassii: Phrynosoma cornutum, represented in the photograph, is 150 mm. in length, the head having five or six large, cone-shaped horns firmly attached to the bony skull, the body being covered with keeled, barbed scales, which along the sides of the body and tail form projecting, triangular rows; the horns have a foundation of cancellous bone which are enclosed within thin shells of horn or keratin and these are easily removed by separation from the bases. The horns of this reptilian toad have about the same structural arrangement as the bills of birds. The bony skull and skin are inseparable, the scales of the skin are extended up a short distance on the horns. The tail, 40 mm. long, is somewhat shorter than that seen in the tailed amphibians. Variations in the tails of vertebrates seem to be directed toward extinction as the higher levels are reached. In Science News of Science, June 26, 1925, occurs the following item: "Even in the matter of getting rid of a tail, certain of the apes have out-evolved man himself. And during the time before birth, man's tail is well developed externally, reaching a length nearly one-fifth that of his body. Sometimes the external tail in man persists after birth. A record case of this kind is cited by Professor Schultz, who shows a picture of a twelve-year-old boy from Indo-China with a tail nine inches long." The loss of tail is, furthermore, interesting in its relation to the loss of teeth as we have already observed in the amphibians.

1. Drawing of the head of Phrynosoma cornutum showing the horns, scales, jaws and teeth. A, large horn; B, triangular projecting scale from the lower jaw; C, C, upper and lower teeth which occur in single rows on each jaw; D, scales covering the head and extending up on the horns. Another view may be seen in the photograph. The head presents a formidable appearance.

2. Drawing of the head of Phynosoma douglassi. A, short, leathery, flexible horn; B, triangular, leathery scale projecting from the lower jaw; C, C, upper and lower teeth in single rows on each jaw; D, scales firmly united to the bony skull. By placing the drawings of the two varieties side by side in (1) and (2) the principal differences may be noted. In Fig. 1 the head is large, the horns are large, by subjective feeling the horns are rigid and the scales are keeled and barbed. The teeth are small pointed cones extending the whole length of both jaws. In Fig. 2 the head is small, the horns short, small, leathery and flexible, the scales are flexible and not keeled nor barbed. In point of structure, that of the horns of Phrynosoma cornutum has a foundation of bone, while that of Phrynosoma douglassii has a keratin foundation. The replacement of bone by keratin is interesting in the foundation structures of the horns of the two vertebrates. As we leave the reptiles and enter upon the following bird series the external covering has lost its inorganic and assumed an organic constitution. Calcium compounds have been replaced by keratin compounds, scales by feathers. An advance is suggested. The tail is 25 mm. long or about one-third of the length of the animal. The biography of the tail is wrapped up in vertebrate mystery. The vertebrate tail appeared in the fish, disappeared in the anural amphibians, reappeared in the reptiles, disappeared in the birds, reappeared in the mammals, disappeared in man. With this peculiar history of the tail, it would not be at all surprising if the tail reappeared in man, by virtue of a former impress, as it did in the Indo-Chinese boy above referred to.

3. Drawing of the under surface of the skull of Phrynosoma douglassii showing the upper jaw, teeth and large muscular cavities. A, teeth; B, upper

jaw; C. skull; D. muscular cavities. The teeth are more regularly pointed cones than in Phrynosoma cornutum; they are longer, more deeply set in the jaw bone and have more well defined tooth structures. They occur in single rows on each side, those in front being more or less deficient in differentiation. The bone of the upper jaw is a variable first type bone. The cavities of the masseter muscles, seen at D, are relatively large and seem to be out of proportion to the requirements of the case.

4. Drawing of the lower jaw of Phrynosoma douglassii showing the single row of teeth. A, joint of articulation with the upper jaw; B, teeth which are longer, narrower and rather less pointed than those of the upper jaw.

5. Longitudinal section of the lower jaw of Phrynosoma cornutum showing bone and teeth in section. A, A, early first type bone; B, blood vessel supplying the teeth; C, short, triangular teeth with structural caps, enamel by position, relatively large central chambers into which the blood vessels project; the dentinal tubules are well defined and are seen coming off from the blood vessels of the central chambers.

6. Longitudinal section of upper jaw of Phynosoma douglassii showing long teeth a variable differentiation of bone. A, bone; B, blood vessel supplying the teeth; C, long, more or less cylindrical cone shaped teeth resting on bone; A, with a background of earlier bone differentiation seen between the teeth. Comparing the two upper sets of teeth in (5) and (6) the teeth in (6) are more highly differentiated than those in (5) or in Phrynosoma cornutum; furthermore, the bone shows a better differentiation in (6) than in (5).

7. Longitudinal section of the lower jaw of Phrynosoma cornutum bone, blood vessels and teeth. A, bone surrounding teeth; B, blood vessel supplying teeth; C, first type bone of the jaw; D, blood vessel of the jaw; E, teeth. The bone is fairly well differentiated as indicated by its long lacunae. The blood vessel supplying the teeth is relatively large. The teeth are rather short, blunt and more or less ellipsoidal in section, the enamel caps are clearly marked, the central chambers are large, the dentinal tubules are well defined and arise from the blood vessel of the central chamber; they seem to be bush-like expansions of the blood vessel.

8. Longitudinal section of the lower jaw of Phrynosoma douglassii showing the bone, blood vessels and teeth. A, bone of the jaw; B, blood vessels of the jaw; C, blood vessel supplying the teeth; D, long narrow, more or less cylindrical teeth. The bone is first type bone, not completely differentiated as the lacunae are more or less oval. The teeth are long, rather irregular in shape, with well defined caps and dentinal tubules arising from the vessels of the central chambers. The teeth of the two varieties of Phrynosoma do not resemble each other excepting in their origin from the blood vessels.

9. Cross section of a dorsal vertebra of Phrynosoma cornutum. A, anterior spinous process; B, rib extensions; C, neural canal; D, canal on the notochord. The bone is an early first type bone. It is composed of bone substances with lacunae and very few, if any, canaliculi; the walls of bone enclosing the canals are very thin.

10. Cross section of a dorsal vertebra of Phrynosoma douglassii. A, anterior spinous process; B, rib extensions; C, neural canal; D, canal of the notochord. The bone is early first type bone; the walls of the canals are very thin, the lacunae are oval and the canaliculi are not visible. Merely a slight amount of bone substance is all that can be seen.

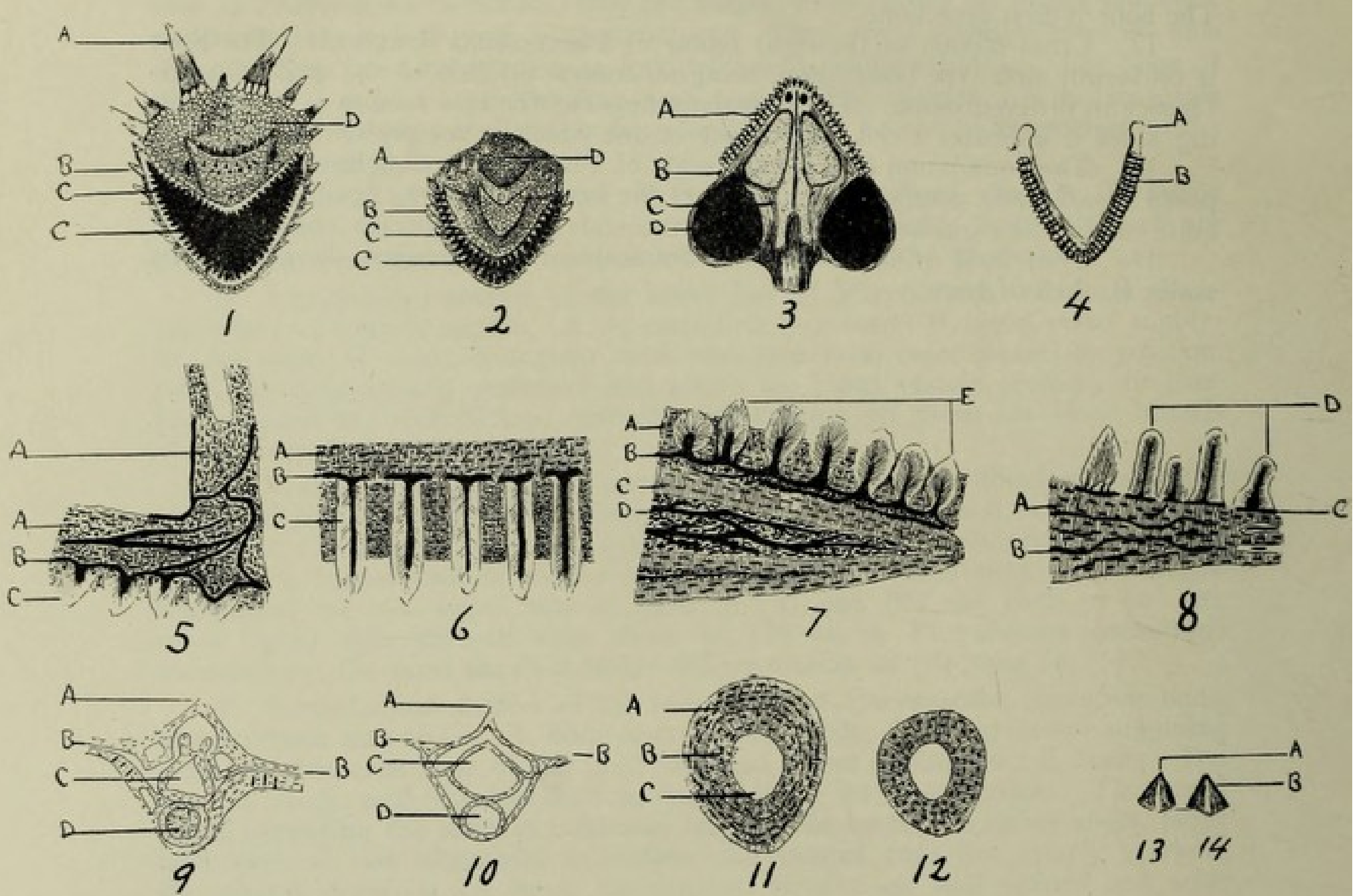
11. Cross section of the right femur of Phrynosoma cornutum. The bone is divisible into external and internal portions by a slight difference in the differentiation of the external portion which shows a better differentiation than the

internal portion. A, external portion; B, internal portion; C, medullary canal. The bone is first type bone.

12. Cross section of the right femur of Phrynosoma douglassii. The bone is uniformly first type bone, there being no central division of the wall by a difference in differentiation. The difference between the two femòra is in interesting, since it indicates a cell disturbance in one which is not present in the other.

13. The foundation of a dermal scale of Phrynosoma douglassi. It is composed of a keratin compound which gives the scale a leathery, flexible character, quite unlike the rigid bone character of the scale of Phrynosoma cornutum.

14. Thin shell of horn covering the scale of Phrynosoma douglassii. A, scale; B, shell of horn.



COMPARATIVE HISTOLOGY OF BONE AND TEETH OF PHRYNOSOMA CORNUTUM AND PHRYNOSOMA DOUGLASSII

1. Drawing of the head of Phrynosoma cornutum showing horns and teeth.
2. Drawing of the head of Phrynosoma douglassii showing horns and teeth.
3. Drawing of the under surface of the skull of Phrynosoma douglassii.
4. Drawing of the lower jaw of Phrynosoma douglassii showing teeth.
5. Longitudinal section of upper jaw of Phrynosoma cornutum.
6. Longitudinal section of upper jaw of Phrynosoma douglassii.
7. Longitudinal section of lower jaw of Phrynosoma cornutum.
8. Longitudinal section of lower jaw of Phrynosoma douglassii.
9. Cross section of a dorsal vertebra of Phrynosoma cornutum.
10. Cross section of a dorsal vertebra of Phrynosoma douglassii.
11. Cross section of the right femur of Phrynosoma cornutum.
12. Cross section of the right femur of Phrynosoma douglassii.
13. Foundation of a dermal scale of Phrynosoma douglassii.
14. Thin shell of horn covering the scale of Phrynosoma douglassii.

SMITHSONIAN INSTITUTION

UNITED STATES NATIONAL MUSEUM

WASHINGTON, D. C.

September 27, 1927

Dr. R. H. Volland,
First National Bank Building,
Iowa City, Iowa.

Dear Dr. Volland:

Dr Foote published three memoirs in our Institution, viz: Comparative Histology of the Femur, Misc. Coll. S. I., 1913; Contributions to the Histology of the Femur, Contrib. Knowl., S. I., 1916; and the Circulatory System in Bone, Misc. Coll., S. I., 1921.

Dr. Foote was a personal friend of mine, and one of the most conscientious of workers.

It would be most useful if his work on the teeth could be carried out. To do this however, would require the complete devotion to the task, of a thoroughly able and earnest young man, for several years. There would be no difficulty about the facilities; I could help such a man very materially myself, and direct him to other collections. I believe a proper scholarship for this purpose would be one of the best possible investments for American dentistry.

If it were not possible to get the right man here, he might be found in Europe. But an American would be preferable.

Very truly yours,

A. Hrdlička

(Curator, Division of Physical Anthropology)

THE CREIGHTON UNIVERSITY
OMAHA
SCHOOL OF MEDICINE

December 30, 1927.

The American Dental Association.

Gentlemen:

It is a matter of gratification that you have undertaken the publication of the scientific papers of Dr. James S. Foote.

During a life-time of teaching and generations of Creighton students have owed a debt of stimulation and encouragement to his untiring interest in their scientific progress. Dr. Foote quietly and persistently devoted his leisure to his studies of bone and teeth.

By temperament and taste Dr. Foote stood somewhat aloof from the eager and ambitious research of his period. Concentrated upon his problems, deriving from them intellectual satisfaction, finding in them a refuge from the stress of life and consolation for its sorrows, it would have seemed to him, had the thought ever occurred to his mind, a vulgarity to exploit them in the interests of a career or of notoriety of any sort. When recognition came it was welcomed as bringing the opportunity of larger means and increased leisure for the work into which he had put the energy and undeviating devotion of a long life.

His findings are the result of personal observation upon a wide range of material, a distinctive contribution to the data of science: his life was a model of scientific detachment from personal motives, inspiring in its loyalty to an enduring purpose.

As one who knew Dr. Foote in his later years and was honored to be counted among his friends and admirers, your undertaking to preserve his work as a collected whole has my hearty commendation as a worthy memorial to a loyal man of science, generously planned and executed by your distinguished Association.

Sincerely yours,

H. VON W. SCHULTE, Dean.

THE CREIGHTON UNIVERSITY

OMAHA

COLLEGE OF DENTISTRY

December 30, 1927.

The American Dental Association.

Gentlemen:

The work of Dr. James S. Foote, Research Professor of The Creighton University College of Dentistry, was an inspiration to all with whom he came in contact. He had assigned himself the task of tracing the development of teeth from their earliest appearance in the lower animals. Laboring zealously to complete the task, he died within a few hours after the last sentence of this book was written. His oft-expressed wish was that he might contribute something worth while to scientific knowledge. To what extent he succeeded must be left to the judgment of the scientific world.

A. HUGH HIPPLE,
Dean of College of Dentistry,
Creighton University.

IN RE DR. FOOTE'S WORK.

CABLE ADDRESS "MUSEOLOGY NEW YORK"

THE AMERICAN MUSEUM OF NATURAL HISTORY

77TH STREET AND CENTRAL PARK WEST
NEW YORK CITY

DEPARTMENTS OF COMPARATIVE ANATOMY
WILLIAM K. GREGORY, PH. D., CURATOR
S. H. CHUBB, ASSOCIATE CURATOR
H. C. RAVEN, ASSOCIATE CURATOR
J. H. MCGREGOR, PH. D., RESEARCH ASSOCIATE
DUDLEY J. MORTON, M. D., RESEARCH ASSOCIATE

November 14, 1927.

Dear Doctor Bruening:

In studying Doctor Foote's publications on the femur of mammals and on the minute anatomy of the teeth of the bowfin I have been impressed by his unquenchable passion for finding out new facts, by his constant efforts to gain wider views and deeper insight into the history of dental and bony tissue, and above all by his colossal industry and patience, which carried him through the labor of grinding thousands of sections and drawing hundreds of thousands of bone cells.

In establishing so clearly his major types of bone construction (lamellar, laminate, Haversian) with their combinations and inter-grades in the different groups of vertebrates, and in showing the great preponderance of the "Haversian" arrangement in modern man, Doctor Foote opened the way for fruitful research in many directions. Why, for example, do bone cells arrange themselves in the three standard forms and in the immediate conditions? Will the lamellar type finally grow into the Haversian type unless it is inhibited? Does the inhibitor originate in the capillaries? In what ways do osmosis, surface tension and the properties of colloids determine the structure? Why should one type predominate in one group of forms and another in another? And on the palaenontological side, how do the older representatives of each group compare with their modern relatives?

In leaving for posterity such a wide range of carefully drawn figures of cross-sections of the femora of vertebrates of many orders and families, Dr. Foote has made it possible for each subsequent inquirer to make fruitful comparisons for himself. For example, is the distinction between the histology of the human femur and those of other mammals a constant one or are there intergrading conditions? The inquirer may see for himself that intergrading conditions do occur by comparing Plate 13, Figure 220 and Plate 27, Figure 365, of Doctor Foote's memoir. From this it will be evident that the histological differences between certain human femora and a certain orang-utan femur are minor differences of degree rather than of kind.

In his manuscript on the microscopic structure of the teeth and bone of the bowfin Doctor Foote entered a field in which some important work had already been done (by Pander, Williamson, Goodrich), and his conclusions are confused by a failure to realize that the bowfin represents a survivor of one of the latest, most advanced of the stock of fishes of the ganoid fishes rather than one of the earliest. But in spite of this, his figures are of great value and his manuscript teems with suggestive ideas and inquiries.

When some years ago Doctor Foote came to the American Museum of Natural History it was both my pleasure and my duty to make available to him such material as we had for his researches. It is a privilege to unite now in honor of his memory with Doctor Hrdlicka of the National Museum and with his colleagues of the Creighton Medical College, Doctor Bruening and others, who all so actively and unselfishly aided him in handling his vast mass of hard won facts and in publishing his results.

Let us cherish his memory then for the great labors that he accomplished for the advancement of science and let us hope that others may rise up to carry on the work he rejoiced in to the end.

Sincerely yours,

WILLIAM K. GREGORY.

Dr. Edward H. Bruening,
620 City National Bank Building
Omaha, Nebraska

NOTES

Dr. Foote expected to find the first important change in Dental Structure Histologically in the crocodile, which would have been the next animal to be studied, because here he had found a marked difference in bone development which is described in his monograph, "Comparative Histology of the Femur," and also in Book I of this volume. He completed the dissection and description of the horned toad on June 30th, 1925, the day he passed away, at the age of 74.

He had been engaged in microscopic work since his graduation in medicine from Columbia University in 1877. For over 33 years of this time he was a member of the faculties of Creighton Medical and Dental Colleges. He had been carrying on an intensive comparative study of the hard tissues during the last 16 years and in this subject he was recognized as an authority.

The Scientific Foundation and Research Commission of the American Dental Association recognized the value of his research work and for four years he was assisted by a grant from this commission, and it was with its aid and encouragement that this volume was published.

The Commission regrets very much that this work cannot be continued at this time and trusts that someone can be found who will be qualified to carry on this important research.

The task of preparing the book was considerably lightened by the material aid given by Dr. Charles F. Crowley, who corrected the proof and arranged the index.

The American Dental Association is very grateful to the following for their generous co-operation and assistance in the publication of this work.

The Creighton University, Omaha, Nebraska.
Dr. Charles F. Crowley, Omaha, Nebraska.
Dr. Charles E. Woodbury, Council Bluffs, Iowa.
Mrs. F. L. Bradbury, Naugatuck, Connecticut.
Miss Willystine Goodsell, Columbia University, New York City.
Walter W. Head, Omaha, Nebraska.
Mr. and Mrs. Joseph P. Frenzer, Omaha, Nebraska.
Douglas Printing Co., Omaha, Nebraska.

EDWARD H. BRUENING,
Member, Scientific Foundation of Research Commission of the American Dental Association.