SMITHSONIAN

CONTRIBUTIONS TO KNOWLEDGE

VOL. XXXV

EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES
KNOWLEDGE FOR MEN—SMITHSON

(No. 1740)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1916

ADVERTISEMENT.

This volume forms the thirty-fifth of a series, composed of original memoirs on different branches of knowledge, published at the expense and under the direction of the Smithsonian Institution. The publication of this series forms part of a general plan adopted for carrying into effect the benevolent intentions of JAMES SMITHSON, Esq., of England. This gentleman left his property in trust to the United States of America to found at Washington an institution which should bear his own name and have for its objects the "*increase* and *diffusion* of knowledge among men." This trust was accepted by the Government of the United States, and acts of Congress were passed August 10, 1846, and March 12, 1894, constituting the President, the Vice-President, the Chief Justice of the United States, and the heads of Executive Departments an establishment under the name of the "SMITHSONIAN INSTITUTION, FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN." The members of this establishment may hold stated and special meetings for the supervision of the affairs of the Institution and for the advice and instruction of a Board of Regents to whom the financial and other affairs are intrusted.

The Board of Regents consists of two members *ex-officio* of the establishment, namely, the Vice-President of the United States and the Chief Justice of the United States, together with twelve other members, three of whom are appointed from the Senate by its President, three from the House of Representatives by the Speaker, and six persons appointed by a joint resolution of both Houses. To this board is given the power of electing a Secretary and other officers for conducting the active operations of the Institution.

To carry into effect the purposes of the testator, the plan of organization should evidently embrace two objects; one, the increase of knowledge by the addition of new truths to the existing stock; the other, the diffusion of knowledge, thus increased, among men. No restriction is made in favor of any kind of knowledge, and hence each branch is entitled to and should receive a share of attention.

The act of Congress establishing the Institution directs, as a part of the plan of organization, the formation of a library, a museum, and a gallery of art, together with provisions for physical research and popular lectures, while it leaves to the Regents the power of adopting such other parts of an organization as they may deem best suited to promote the objects of the bequest.

After much deliberation, the Regents resolved to apportion the annual income specifically among the different objects and operations of the Institution in such manner as may, in the judgment of the Regents, be necessary and proper for each, according to its intrinsic importance, and a compliance in good faith with the law.

The following are the details of the two parts of the general plan of organization provisionally adopted at the meeting of the Regents December 8, 1847:

DETAILS OF THE FIRST PART OF THE PLAN.

I. To increase Knowledge.—*It is proposed to stimulate research by offering rewards for original memoirs on all subjects of investigation.*

1. The memoirs thus obtained to be published in a series of volumes, in a quarto form, and entitled "Smithsonian Contributions to Knowledge."

2. No memoir on subjects of physical science to be accepted for publication which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.

3. Each memoir presented to the Institution to be submitted for examination to a commission of persons of reputation for learning in the branch to which the memoir pertains, and to be accepted for publication only in case the report of this commission is favorable.

4. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision be made.

5. The volumes of the memoirs to be exchanged for the transactions of literary and scientific societies, and copies to be given to all the colleges and principal libraries in this country. One part of the remaining copies may be offered for sale, and the other carefully preserved to form complete sets of the work to supply the demand from new institutions.

6. An abstract, or popular account, of the contents of these memoirs to be given to the public through the annual report of the Regents to Congress.

II. To increase Knowledge.—*It is also proposed to appropriate a portion of the income annually to special objects of research, under the direction of suitable persons.*

1. The objects and the amount appropriated to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects, so that in course of time each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made:

(1) System of extended meteorological observations for solving the problem of American storms.

(2) Explorations in descriptive natural history, and geological, mathematical, and topographical surveys, to collect material for the formation of a physical atlas of the United States.

(3) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of scientific facts, accumulated in the offices of Government.

(4) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5) Historical researches and accurate surveys of places celebrated in American history.

(6) Ethnological researches, particularly with reference to the different races of men in North America; also explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

I. To diffuse Knowledge.—*It is proposed to publish a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. Some of these reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons interested in a particular branch can procure the parts relating to it without purchasing the whole.

5. These reports may be presented to Congress for partial distribution, the remaining copies to be given to literary and scientific institutions and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoology, geology, etc.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, etc.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world; penal reform, etc.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature.
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. To diffuse Knowledge.—*It is proposed to publish occasionally separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.

2. The treatises to be submitted to a commission of competent judges previous to their publication.

DETAILS OF THE SECOND PART OF THE PLAN OF ORGANIZATION.

This part contemplates the formation of a library, a museum, and a gallery of art.

1. To carry out the plan before described a library will be required consisting, first, of a complete collection of the transactions and proceedings of all the learned societies of the world; second, of the more important current periodical publications and other works necessary in preparing the periodical reports.

2. The Institution should make special collections particularly of objects to illustrate and verify its own publications; also a collection of instruments of research in all branches of experimental science.

3. With reference to the collection of books other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found elsewhere in the United States.

4. Also catalogues of memoirs and of books in foreign libraries and other materials should be collected, for rendering the Institution a center of bibliographical knowledge, whence the student may be directed to any work which he may require.

5. It is believed that the collections in natural history will increase by donation as rapidly as the income of the Institution can make provision for their reception, and therefore it will seldom be necessary to purchase any article of this kind.

6. Attempts should be made to procure for the gallery of art casts of the most celebrated articles of ancient and modern sculpture.

7. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art Union and other similar societies.

8. A small appropriation should annually be made for models of antiquities, such as those of the remains of ancient temples, etc.

9. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science and to exhibit new objects of art. Distinguished individuals should also be invited to give lectures on subjects of general interest.

In accordance with the rules adopted in the programme of organization, each memoir in this volume has been favorably reported on by a commission appointed for its examination. It is, however, impossible, in most cases, to verify the statements of an author, and therefore neither the commission nor the Institution can be responsible for more than the general character of a memoir.

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SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE
PART OF VOLUME XXXV

THE YOUNG OF THE CRAYFISHES ASTACUS AND CAMBARUS

BY
E. A. ANDREWS

(No. 1718)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1907

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Commission to whom this memoir has been referred:

WALTER FAXON
WILLIAM KEITH BROOKS
WILLIAM PERRY HAY

WASHINGTON, D. C.
PRESS OF JUDD & DETWEILER, INC
1907

ADVERTISEMENT.

The present memoir by Professor E. A. Andrews, of the Johns Hopkins University, on "The Young of the Crayfishes Astacus and Cambarus," forms part of Volume XXXV of the Smithsonian Contributions to Knowledge.

The memoir describes and illustrates the young of two kinds of crayfishes, one from Oregon and one from Maryland, which represent the two most diverse forms found in North America. Of these, one genus, found only in North America, is widely distributed all over the United States, except the Pacific Slope; while the other is restricted almost exclusively to the Pacific Slope in North America, and at the same time it is almost the only genus in Europe and Asia. This memoir fills a gap in the knowledge of these common animals that still remained notwithstanding the extensive researches of Huxley and many others.

It determines the form and habits of the first, second, and third larval stages; gives the first detailed description and illustrations of the appendages of the first and second stages; describes the hitherto unknown nature of successive mechanical attachments of the offspring to the parent; and opens up the problem of the nature and causes of the incipient family life in the crayfish.

The new facts and comparisons add to the data for solution of the important problems of the geographical distribution and the origin of the species of crayfish, and they furnish a basis for practical application to the problems of artificial culture and introduction of new kinds of crayfish.

In accordance with the rule adopted by the Smithsonian Institution, the work has been submitted for examination to a commission consisting of Dr. Walter Faxon, of the Museum of Comparative Zoölogy, at Cambridge, Massachusetts; Prof. W. K. Brooks, of the Johns Hopkins University, and Prof. W. P. Hay, of Howard University, who recommended its publication in the present series.

Chas. D. Walcott,
Secretary.

Smithsonian Institution,
Washington, *June*, 1907.

CONTENTS.

The Young of the Crayfishes Astacus and Cambarus.

By E. A. ANDREWS.

INTRODUCTION.

The object of the present paper is to figure and describe the external forms and the appendages of the early larval stages of the crayfishes Astacus and Cambarus and to illustrate the details of the connections that exist between these larvæ and the mother.

It is well known that the genus Cambarus is found only in North America and here only to the east of the Rocky Mountains, while the genus Astacus is the only one found in Europe and Asia and in America is found almost exclusively west of the Rocky Mountains. It is thus natural that the history of scientific knowledge of crayfishes has been first the study of Astacus in Europe and later the study of Cambarus in the eastern United States. The Astacus of the Pacific States remains less well known.

Despite all the work that has been done upon these common animals, several parts of their life histories have received scant attention. The geographical distribution and systematic description have been studied in detail by Hagen, Faxon, Huxley, Ortmann, and others; the embryology minutely observed by Rathke and by Reichenbach; and the general knowledge of crayfish natural history added to again and again since the days of Roesel von Rosenhof. Yet little attention has been given to the study of the young crayfish after it leaves the egg; a comparative neglect that naturally arose from the centering of scientific interest upon the larval changes of marine crustacea in which remarkable metamorphoses occur.

When these metamorphoses were established by Vaughn Thompson and others it was already known from the work of Rathke that the crayfish hatches from the egg in essentially the adult shape and thus passes through no series of metamorphoses. Interest in the crayfish young was then restricted to the fact that it was exceptional in having no metamorphosis. In the preoccupation of students of crustacean life histories in study of metamorphoses the young of the crayfish were left without any illustrations excepting only those given by Rathke to show the condition of the embryo when nearly ready to hatch and the two wood cuts given by Huxley. These latter illustrations were evidently made from specimens preserved in alcohol, and, however excellent for their purpose, fail to give the just proportions of the larvæ, since all alcoholic specimens of young crayfish are much swollen and distorted.

While two more figures of the young crayfish have recently been given, (Andrews, '04) details of external structure are still lacking.

Having obtained the young of both Astacus and Cambarus by hatching the eggs in the laboratory, it seemed well to fill in some of the gap in our knowledge of the early larval life of crayfish, and especially so as the details of a curious mode of connection with the parent were here first made evident.

HISTORICAL.

A brief statement of the history of our knowledge of the young of crayfish will show that as yet the character of the appendages in the early stages, the exact number of stages present in the life of the young while associated with the mother, and the nature of the means by which the young are held attached to the mother have waited discovery and illustration.

To Roesel von Rosenhof belongs the credit of an enthusiastic appreciation of the care of the mother crayfish for the young; the observation that the young are transparent and like the parent; the description of their crowding upon the abdomen of the parent and of their finally forsaking her after a few days, during which, however, they would return to her at times as if recalled by a signal.

Rathke ('29) was chiefly concerned with the embryology of the crayfish, but also described something of the growth in proportions and in internal anatomy of the young after hatching and gave figures of the embryo and of some of its appendages shortly before hatching.

Reichenbach ('86) also added to his classic study of the embryology only a figure of the abdomen of a recently hatched larva.

Soubeiran ('65) measured young crayfish grown at the farm of Clairfontaine and recorded their moultings and rates of growth. More facts of this same kind were gathered by Chantran ('70, '71) from prolonged study of larvæ reared in the laboratory of M. Coste. Chantran also discovered a peculiar filament that held the young to the egg shell after hatching and he finally convinced himself that the young ate their egg shells and their cast-off skins. Some other observations upon the size and times of moulting of young crayfish in Sweden were also made by Steffenberg ('72).

Huxley ('79) illustrated the recently hatched larvæ by two wood cuts, one showing the early larva fastened to the maternal pleopods by its peculiarly recurved claws, which he first described and figured, and the other a dorsal view of such a larva. He rectified the previous statement that the young at hatching are exactly like the adult and pointed out their differences in lack of setæ, in lack of abdominal appendages on the first and sixth somites, and in various proportions.

In America Hagen ('70) in his fundamental study of our crayfish observed the young of Cambarus attached to the mother in alcoholic specimens and recorded the dimensions of young in which the sexes were externally recognizable. From like specimens Faxon ('85) in his revision of American crayfish was able to make a number of comparisons with specimens of young *Astacus pallipes* from France, and also to demonstrate the important facts that the young Cambarus agreed, in general, with Astacus as described by Huxley, but that in the early larva as in the adult, Cambarus showed no vestige of the gill found on the last thoracic somite in Astacus. These facts were verified by Steele ('02), who for the first time described living larvæ of Cambarus hatched from eggs in the laboratory and also recorded facts as to the habits and sizes of young larvæ. From like living material Andrews ('04) added details of hatching and behavior of these larvæ with figures of side views of living larvæ in the first and in the second stages and noted the occurrence of two successive attachments of the larvæ by means of special structures.

To complete that last preliminary paper by adding details and many new facts observed in Cambarus and to describe similar stages in our American Astacus is the purpose of the present paper.

III. ASTACUS LENIUSCULUS.

As far as known, no observations have been made upon the life histories and habits of any American crayfish of the genus Astacus and as the following facts were gained from animals kept in Baltimore far from their native habitat they will need the corroboration of future studies made in the Pacific States, but for the present they supply all our knowledge of the young of American Astacus.

The material for study of the young Astacus was obtained as follows: Sixty-four specimens were received February 23, 1904, by express from Portland, Oregon, and, though packed only in wet excelsior, ten females and eighteen males survived the journey and lived in running water in the laboratory for some time. Shipped without selection of sex, the sixty-four were found to be made up of thirty-one females and thirty-three males, which indicates an equal distribution of the sexes. The males, however, seem to have endured the journey better than did the females.

During March, April, May, and June these crayfish died slowly one by one, leaving one survivor in October. As they were fed from time to time with small oligochætæ, with fragments of crayfish and with pieces of frogs, the cause of the very slow and lingering deaths was not evident, but probably the food was not sufficient for such large and active crayfish.

It was decided that this Astacus was probably *Astacus leniusculus* Dana as distinguished from *A. Trowbridgii* by Faxon ('85) and the following observations upon their habits in captivity seem to be all that is known of this species, beyond its specific characters.

The largest specimen was a female measuring 155 mm. from tip of rostrum to end of telson, 205 mm. from tip of chela to tip of telson, 40 mm. wide across the thorax and 35 mm. deep; the abdomen was 45 mm. wide and its tail fan expanded to a width of 70 mm., exclusive of the setæ. With only about one-half of its eggs left upon its pleopods this female weighed 106 grams.

The smooth clean shells and large well colored claws gave these crayfish an attractive and decidedly lobster-like appearance, which was enhanced by their very active pugnacious nature. In shallow water they quickly responded to approaching objects and readily threw themselves into a defensive attitude, leaning back with the whole anterior region raised high from the bottom of the tank, thrusting their brilliantly colored claws above them high into the air and either holding them wide apart and open or clashing them together towards an approaching object, towards which they lunged, or even seemed to spring.

Their quickness to react to distant objects, their quick reflexes and irritability led me to suppose they might well be carnivorous and their clear colors suggested a life in clear water, but the collector reported that the Willamette River, whence they came, was a rather muddy stream, though formerly used as water supply for Portland. In captivity they were nocturnal, lying quiet and away from the lighter parts of the tank in the daytime and crawling about in the night. They sometimes injured one another and also ate parts of their dead fellow-crayfish and, as is so common with many kinds of crayfish, there were cases of regeneration, which may have followed from injuries caused by their pugnacious and carnivorous habits. One male 95 mm. long, when received, had two regenerating limbs. The left chela was represented by its original basal two segments and by a delicate new limb only 9 mm. long protruding from the truncated end of the second large segment. This little, bluish protuberance was made of six movable segments and it was movable upon the old limb whence it sprang, so that to make the seven normal movable segments of a complete limb a reduction in the number of movable joints must take place, probably by the base of the new growth ceasing to move upon the old second segment. The other regenerating limb was the third left walking leg and here again the old second segment bore a soft protuberance, which, however, was as yet not segmented. Thus in this Astacus, as is common in other crayfish, regenerations had started from the preformed breaking plane, and in handling this same specimen, though dead, the right third walking leg fell off at the breaking plane.

In captivity shedding, or ecdysis, took place in early summer, in some; thus on June 11, when the water had risen from 9° C. in March to 22° C., one large male cast its shell as one perfect piece containing also the "teeth" and other part of the lining of the "stomach." The creature was then quite soft and easily indented by touch upon its carapace; it lay inert but could be made to crawl in a somewhat palsied way and even to flap its abdomen. On each side of the heart region the carapace bore a white, indented, scar, as if made by the claws of some other crayfish, so that the advantage of concealment at this season as practiced by other crustacea doubtless applies here as well. The entire shell was covered by a slimy soft mucus and its colors were brighter than before, the under side of the legs showing also more blue. As seen from below, the flesh of the abdomen had a peculiar coagulated appearance.

The new carapace had a length of 57 mm. and the old of 43 mm., and had enlarged in diameter from 25 to 28 mm. The cast shell had one broken antenna, 53 mm. long, which was replaced in the new shell by a perfect antenna 68 mm. long. A week later this crayfish was active and keenly seized and ate a large lumbriculus.

Two more males cast their shells June 15 and one of them was attacked by others when only the carapace had been shed and the abdomen was as yet in its old shell; one-half of the thorax and part of the abdomen were devoured. The other large crayfish was able to flap its abdomen vigorously when lifted out of the water though its body and chelæ were soft and flaccid. In both cast shell and new one the rostrum was broken off and had evidently not been regenerated. Still another large male, received in October, 1904, cast its shell May 19, 1905, and could move about though still soft.

The breeding season of these crayfish was far advanced when they were received in February. In many cases the males had no sperm left in the deferent ducts and the females had laid their eggs, which in four dead and six live specimens formed large dark masses attached to the abdominal limbs, or pleopods, and to the sternal hairs of the abdomen. Contrary to expectations, these eggs were still alive and it was found possible to rear them and to get the subsequent stages in the life history as described below. In the hope of getting light upon the early part of the breeding season, another lot of thirty-seven crayfish of the same species were got from the same place October 29, 1904; but here again the beginning of the breeding season had passed. The only two survivors on arrival were both males, and three others recently dead were also males, so that here again the vitality of the males seems to exceed that of the females. In all there were twenty-two males and fifteen females. Five of the females had eggs upon the pleopods and these were in early cleavage, showing some twenty nuclei migrating to the surface. It would thus seem that egg-laying takes place in the autumn, probably in October, and subsequent observations showed that the eggs are carried by the female all the winter and hatch in the spring. The eggs on each female were about 500 in number and formed a dark brown or more usually nearly black mass all over the under side of the abdomen. Each egg was very large, about 2.5 mm. in diameter, and as in other kinds of crayfish, enclosed in a complete capsule of hardened secretions that extended as a slender stalk to fix each to the setæ on the pleopods, or, in some cases, to the setæ on the sternal ridges of the abdomen. All the eggs seemed in good condition except a cluster of four or five among the brown eggs of one female and these few were overgrown with a fungus.

The darker eggs plainly showed embryos in the stage represented by Reichenbach ('86) as J, fig. 12, standing out as a whitish area on one side of each egg. Thus the embryo had already advanced to a condition in which the embryonic area occupied a considerable part of one-half of the spherical egg. There was still a wide margin between the appendages and the well elevated wall that surrounded all the posterior part of the embryo. The eyes, two pair of antennæ, mandibles, maxillæ, maxillipeds, and five periopods were well marked. The posterior four periopods and the abdomen projected forward over the thorax so that the abdomen reached to the first maxillæ. The eggs of one female showed in addition to the above embryo many nuclei scattered over the nonembryonic areas of the egg and plainly seen against the brown background of yolk.

In one female the eggs were covered by a dark deposit that had to be scraped off before the glossy egg capsule and the contained embryo could be seen.

A few eggs were greenish and covered by a deposit that could be scraped off; when these were opened, or when boiled, the contained embryo was found to be in the stage H of Reichenbach.

In one black egg the heart of the embryo was seen to beat very faintly, and after the eggs had been kept in water twenty-four hours many eggs showed the heart beating and were kept in the hope that they would develop. In water about 9° C. the eggs that were still attached to the abdomen of living females did develop, though very slowly, as will be seen from the following results.

After nine days, March 2, the embryos were perceptibly enlarged with longer antennæ and abdomen, the second antennæ reaching back nearly half way to the end of the limb-bearing region. The heart, now lying in a plane at right angles to the ventral surface and above the base of the abdomen, was beating so strongly as to give a decided jerk to the thoracic limbs. In one embryo it beat at the rate of 66 to the minute and in another at 82. Inside the outer egg capsule there was evidently a delicate inner membrane investing the embryo.

For six days more the only change noted was a slight increase in size and the extension of the second antennæ beyond the middle of the limb-bearing region.

Four days later a marked widening of the anterior part of the embryonic area had taken place and the slow growth of the abdomen had brought its tip up to the posterior edge of the mouth. In another week the still larger embryos had antennæ reaching nearly to the end of the depressed, limb-bearing, region and the abdomen reached forward over the mouth as far as the bases of the second antennæ.

Embryos of this age, some twenty-five days after they were received, were very attractive objects seen through the transparent egg capsules. The transparent limbs stood out strongly contrasted against the dark red yolk mass that still took up the major part of the spherical egg. On each side of the egg the boundary of the yolk mass was slightly incised where the "liver" was forming. When such embryos were plunged a moment into boiling water and then put into cold water a mere scratch of a needle sufficed to cause the tough outer capsule to open with explosive force and the embryo was readily removed, leaving even its thin membrane sticking to the inside of the capsule.

During another week there was but little increase in the length of the appendages, but through the transparent walls of the limbs and body a few blood corpuscles were seen passing along in the large median thoracic artery and in the antennæ and periopods.

Ten days later, April 5, when the water had risen from 9° to 11°, the size had markedly increased and the embryo instead of being restricted to a flat region upon one side of the sphere could no longer be seen from a single point of view, since it now extended in a curved surface over one-half of the egg. The long antennæ now met one another and their tips overlapped at the deep notch where the abdomen joined the thorax. The legs and chelæ had grown long enough to overlie the abdomen and to conceal its tip. Such embryos were nearly in the stage K of Reichenbach and were prettily colored. The carapace had bright red pigment along its ventral border, the dark red-brown yolk took up less than half the bulk of the egg and was divided by a deep fissure into anterior and posterior lobes which were encroached upon by the "liver" which was conspicuously colored. In one its contents were red and in fifteen greenish and translucent or else white-yellow and opaque. The large eyes had also some pigment formed in them.

Eleven days later the elongated walking legs and chelæ reached forward over the posterior edges of the eyes. Pigment cells were as yet not seen in the above limbs, but were conspicuous in the first and second antennæ and in the abdomen as well as the thorax. The delicate inner membrane was seen loosely investing the tips of the chelæ like a cast-off exoskeleton.

Some six days later the embryo had passed beyond the stage K and was nearly ready to hatch. The limbs were even longer, so that the chelæ reached over part of the eyes and the antennæ overlapped one another the whole width of the abdomen in such a way that the left passing posterior to the right had its tip on the right side and the right passing anterior to the left had its tip on the left side. While all the eggs were still alive and had been kept well aërated by the swaying movement of the pleopods that the mother makes, seemingly for this purpose, yet some of them showed the effects of such a very long existence in the water by being covered over upon the outside of the egg capsule with deposits which in some cases were mixed with growths of minute fungi and in some with vorticellæ. The eggs seemed under tension and burst open when thrown into hot Worcester's liquid; the touch of a needle to the live egg also caused its capsule to pop open.

As seen under a pocket lens, these eggs nearly ready to hatch present a most attractive appearance. The carapace is spangled with branching, vermilion, pigment cells that are especially numerous along its ventral edges and near the base of the abdomen, which is broad and also well pigmented with the same kind of cell. The antennæ and antennules have both red and blue pigment cells on their basal part, but these cells are not numerous and are entirely absent from the filaments. The chelæ and walking legs have some few scattered pigment cells. The still large dark red-brown yolk mass has the forked, light-colored, "liver" projecting into it. The eyes are darkly pigmented in all their central parts, while the surface is still clear and transparent for some distance inward.

The actual hatching of the eggs took place on one female April 25-27, and on another May 1-6, and was prolonged over several days, that is, not all the eggs on one female hatched at the same time, but whether this is normal or induced by the artificial conditions remains to be found out from study of these crayfish in their native waters. These eggs had thus required 62 to 64 days in one case and 67 to 71 days in the other to develop from the well advanced embryo of stages H and J of Reichenbach to the hatching larva. The temperature of the water had slowly risen from 9° C. to 14° C.

When a female died before the eggs hatched, it was found possible to hatch the eggs by cutting off the pleopods of the mother and fastening them to pieces of floating cork so that the eggs would be suspended in well aërated water.

In hatching, the egg capsule burst open over the back of the embryo, and usually opposite to the egg stalk, and then the embryo slowly glided out backward, much in the same way as has been described for Cambarus (Andrews, '04).

In all crayfish, and in many other crustacea, the eggs remain firmly fastened to the mother during the whole period of development and when the embryo escapes from the egg-shell the old shell remains still fastened by a strong stalk that is stuck to the maternal setæ. In this Astacus as the embryo slowly emerged from the egg capsule it was evidently in a very inactive, helpless state, soft and unable to use its limbs, so that one might expect it to drop away from the egg-shell, fall to the ground, and continue its life, if at all, away from the mother. However, it is well known that young crayfish remain for some time upon the abdomen of the mother, which they do not leave till they are well able to swim and to walk. This period of interrelation between mother and offspring deserves special study and we will describe more in detail than has hitherto been done for any crayfish the remarkable structures used in ensuring the connection of mother and young from the moment of hatching up to the time of real independence and free life.

Instead of dropping away entirely from the egg-case, each soft, helpless, larva hung attached to the inside of the egg-case by a delicate thread which was firmly fastened at one end to the inside of the egg-case and at the other end to the telson of the larva. The soft, pink-colored larvæ thus at first hung out from the egg capsules like the pulps from burst grape-skins and were then prevented from entirely falling away from their capsules by these threads, so that they suggested the seeds of the "cucumber tree" dangling out of their pods. As the young remained limp and helpless for some time these "telson threads," as we may call them, appeared to be of great use, since without them the larvæ would have fallen to the bottom of the water and having lost connection with the parent have had small chance of survival, lacking the protection or aëration furnished by the mother.

Such telson threads are doubtless found in the European Astacus, for in a footnote added by M. Robin to Chantran's paper ('70), we read: "J'ai pu constater, à l'aide du microscope, comme l'a montré M. Chantran a l'Academie, que les petits restent pendus sous l'abdomen de la mère, par l'intermedaire d'un filament hyalin, *chitineux,* qui s'etend d'un point de la face interne de la coque de l'œuf jusq'aux quartre filaments les plus interns de chacun des lobes de la lame membraneuse médiane de l'appendice caudal. Ce filament existe déjà lorsque les embryons n'ont encore attaint que les trois quarts environ de leur developpement avant l'eclosion." And the same general fact is mentioned in the report of the committee awarding the Montyon prize to Chantran (C. R., 75, 1872, p. 1341). Of the above passage Huxley ('80, p. 352) says: "Is this a larval coat? Rathke does not mention it and I have seen nothing of it in those recently hatched young which I have had the opportunity of examining."

The exact mode of attachment of this filament, or telson thread, and its probable nature will be described below in connection with the telson of the larva of this American Astacus and later on in considering the like structure in Cambarus.

The size of the larva in its first stage is indicated by the following rough measurements of preserved specimens: Length of head-thorax, 4 mm.; width, 3 mm.; depth, 3 mm. Length of abdomen, 5 mm. Length of antenna, 6 mm. Length of chela, 5 mm.

Returning to the account of the hatching young, it is to be noted that the activities of the young were but slowly acquired; here and there amongst the mass of eggs and young upon the female some larvæ showed feeble movements of the scaphognathites and, later, rhythmic respiratory movements; the long antennæ projecting into the water moved somewhat, the legs and chelæ sometimes moved and the claws opened and shut. Upon escaping from the spherical egg-case the larva became but little straightened out and remained essentially a spheroidal head-thorax with a weak abdomen bent in under it and with soft, pendent limbs. However, in from one to six hours the limbs reaching about, the claws opening and shutting and the abdomen sometimes flapping up and down, it was seen that the chelæ managed to get hold of the stalk of the egg-case. Henceforth the larvæ held fast by the chelæ though for a time still fastened by the telson thread also.

The pleopods of the parent were now covered over with a mass of flesh-colored young, showing slight movements and conspicuously marked by the two-lobed, red yolk mass, by the dark eyes and by the yellowish "liver" areas. The dark yolk masses showing through the pale bodies gave somewhat the general appearance represented in figure 2, which was made from a photograph of a living female shortly after the eggs (excepting one) had hatched.

When forcibly torn loose from the mother the recently hatched larvæ, too spheroidal to rest on their ventral side and unable to stand on their legs, lay for two days on their sides, kicking their legs but unable to walk; when, however, much disturbed, they managed to swim forward along the bottom of the dish by flapping their abdomens, though they still remained on their sides. When offered a piece of rough string, such young seized it and remained suspended in the water, holding fast by their chelæ. In this way some larvæ were kept suspended in running water and successfully carried into later larval stages away from association with the mother.

This tending to seize hold with the chelæ is accompanied by a tendency to push far in amongst the general mass of young attached to the pleopods, so that in a few days all the young are densely crowded together in a compact mass and their long chelæ are seen to reach far in and to be fastened either to the stalks of egg-cases or to the coagulum that binds the setæ together on the pleopods. Generally both chelæ grasped the same egg stalk but not always and one larva was seen holding by one chelæ to an egg stalk on one pleopod and by the other chelæ to an egg stalk upon the next pleapod. As the rhythmic movements of the pleopods continued after the young were hatched, this larva was in danger of having its chelæ stretched apart.

The fixation of the chelæ was a gradual process; at first the claws of the chelæ were not opened even when those of the walking legs were opened and shut, but soon the chelæ claws opened and shut and soon seized hold of any solid object accessible. Sometimes the object seized was again let loose but before long the chelæ had reached in among the mass of young and eggs far enough to find and fix upon one of the egg stalks, which are of a material and size seemingly well fitted for the attachment of the claws. Henceforth the chelæ seemed to remain always fast and their structure as described below indicates that once imbedded in the material of the egg stalk the tips of the claws could scarcely be liberated by the crayfish. This fixation was first made out in the English crayfish by Huxley ('80), who inferred that when once fast it would be difficult, or impossible, for the claws to open again.

This use of the chelæ to obtain attachment to the mother was exercised with what appeared to be very earnest effort and once successful it was found that the telson thread was soon ruptured. And then if the larvæ were disturbed they flapped their abdomens up and down and it was seen that the telson thread had broken so that a piece of it was still attached to the telson and was waved about by the telson like a bit of rag fastened to it. Henceforth the young held fast by the chelæ only.

The general appearance of this mass of young on the mother was peculiar since the rounded head-thorax was the chief part visible in each and this was of light color with a striking bilobed or horseshoe-shaped, dark red, yolk mass across it. The legs and abdomen were concealed and the dark eyes were generally out of view. With bent heads and outstretched limbs their attitude ludicrously suggested one of supplication.

Thus they remained for some days. When disturbed the young made tramping movements with their legs but did not move from the place to which they were fixed by their long chelæ. The abdomen, carried down under the thorax somewhat as in the embryo, was not readily moved but with sufficient stimulus from a needle point was flapped rapidly back and forth. When a larva was forcibly pulled off from the mass its chelæ, still attached, were stretched out to their fullest extent and when the larva was released the chelæ contracted and made the larva spring back into place where its limbs and abdomen were again drawn in under the thorax and the creature became again one of the herd of "bison" presenting only their humped backs to the observer. If by stronger pulling the larvæ were torn loose from the mother the chelæ parted from the egg stalks without breaking and reaching about seized hold of adjacent objects such as the antennæ of other larvæ. Left to themselves on the mass, these separated larvæ soon got back again amongst the crowd; but if put upon the bottom of the dish they did not yet stand up but only gyrated about by flapping their abdomens.

The long antennæ remained for the most part low down amongst the general mass and did not yet project up above the level of the rounded backs; they were, however, carried out in front and not, as in *Cambarus affinis,* tucked in between the legs.

Fastened thus to the mother, the larvæ remained some days and then casting off their shells passed into a second larval stage which also lived upon the mother. In one female kept in running water at 17° C., the duration of the first larval stage was only four days, but some young of another female which were kept suspended from strings hanging in water in a warm room remained five to seven days before changing to the second stage and their fellows kept in water at 14° C. remained eleven to thirteen days in the first stage. During this long existence in the first larval stage the only change noted was a slight darkening of the color which, owing to the scattering of bright red, branching, pigment cells on a white background appeared to the naked eye flesh-color.

Before considering the transition from the first to the second stages we will describe the details of the external form and appendages of the first larva.

A side view of the living larva (fig. 3), suggests embryonic incompleteness in that the antennæ, abdomen, and limbs are carried downward in a way not adapted to locomotion, while the globose cephalothorax and large eyes with short stalks are features of an embryo rather than of an active larva. The dark mass seen in the figure was the still conspicuous red yolk mass which from the dorsal view (fig. 4), was balanced right and left in the anterior half of the cephalothorax. In life the larva was translucent yet brilliantly colored by the scattered pigment cells indicated in black in the figures and which were absent only from the terminal filaments of the antennæ and from most of the segments of the legs. In the side view the first and second antennæ are conspicuous, the three maxillipeds are seen in part, the chelæ are very long and heavy and the four walking legs are long and weak. The abdomen bears only four pairs of pleopods and these are small, weak, and bifid. The first and sixth pleopods are not seen and the abdomen ends in a simple telson in place of the locomotor fan of the later larvæ and adults. The larva is evidently very defective in locomotor apparatus, has its sensory organs not perfected, and is specialized in its strong clinging organs, the chelæ, and in its large digestive apparatus for utilization of the stored-up yolk. It is still essentially embryo-like in structure and in mode of dependent life, but is exposed free to the water.

The same general features are shown in the dorsal view (fig. 4), which shows the split-open egg capsule and its stalk, connected by a slender thread to the telson of the larva, a "telson-thread" that is fast at one end to the peculiar fan-like telson of the larva and at the other end to the inside of the ruptured egg capsule. It will be noted that the head-thorax though globoidal is considerably elongated and does not have the swollen sides shown in Huxley's figures of the English Astacus, which, however, were doubtless drawn from alcoholic specimens, and in *A. leniusculus* the action of alcohol is to cause great distortion of the branchiostegites. As compared with the adult, however, the proportions of the head-thorax are embryonic and there must needs be much greater elongation as well as lateral and vertical changes to bring about adult proportions.

While both from side and top views (figs. 3 and 4), the characteristic rostral spine of such crustacea seems absent, full front and diagonal side views (fig. 5) show the rostrum to be well developed and armed with lateral spines, but so bent down between the eyes as to be of no such use as a defense as it later will be in active stages of the larva. The habit of the first stage which clings to the parent is thus correlated with imperfections of defensive armament as well as with presence of food yolk and imperfections of locomotor organs. Among the latter characters may be reckoned the smooth surfaces of the limbs and absence of setæ that later will increase the areas of resistance for striking against the water as well as furnish means of sense perception. The lack of setæ represented in figures 3 and 4 is still more striking in enlarged views of the limbs and is in strong contrast to the hirsute character of all parts of the active larvæ and of the adults, and this absence of setæ gives the larvæ a decidedly embryonic appearance.

The pronounced incompleteness of locomotor organs is also associated with the shortness of the thoracic region bearing legs; thus the chelæ arise farther from the anterior than from the posterior ends of the head-thorax and leave little space for the walking legs, while the anterior region containing the yolk is greatly developed in size.

Next taking up in sequence the nineteen pairs of appendages of the adult we find them represented in the first larva by seventeen pairs that have in the gross, as made out by Rathke for embryos about to hatch, the essential morphology of the adult appendages but lack the setæ and differ in proportion as will be seen from the following account and illustrations.

The whole exterior of the larva in its first stage is covered by a chitinous exoskeleton of such resistance that when the young were thrown into Worcester's liquid they did not die for several minutes; the appendages were cut off separately from such hardened embryos and gave the views represented in the following illustrations.

The first antenna stands out horizontally in front of the head (figs. 3, 4) and is straight; as seen in figure 6, it has three basal segments, five in exopodite and in endopodite. The segmentation of the endopodite is very obscure. The terminal segment in both endopodite and exopodite bears three obscurely pointed spines, one of which, in the exopodite, is long and apparently of the same character as the sensory setæ found there in later stages. On the long basal and next segment of the protopodite there are a few blunt spines as indicated in figure 6. This also shows the auditory organ as an open pit on the upper surface of the basal segment, in the part that is swollen out laterally.

The second antenna (fig. 7), though it has a long filament, is still embryonic in proportions. The base consists of two short segments, the first of which bears the very large prominence that faces inward and has the opening of the green gland, or kidney, within its depressed top. The second segment bears a few blunt distal spines of large size. The exopodite is a very large flat scale ending in a blunt point and bearing some sixteen blunt spines along its serrated inner and anterior edges. The endopodite consists of three large basal segments and of a long round filament of many segments, forty-five to fifty, the first of which is long and slender, while the following ones are each about one-third as long as the first. The terminal segments are again more long and slender. As indicated in figure 7, there are a few spines at the distal edges of some of the terminal segments and of some of the others near the tip. In the adult there may be 125 segments.

The mandibles (fig. 8) have a well developed cutting edge which, however, is smooth and not toothed as it is in all later, functional, stages and there was no evidence found that these organs were used. The palpus has three segments and is smooth except for the distal face of the third segment which is sparsely set with rather acute spines, many of which are shown in figure 8, and more of which are present upon the inner aspect and not seen from this point of view. The palp is thus a blunt club with terminal spines.

The first maxilla (fig. 9) is very small and made of two flat plates and a somewhat rounded and blunt endopodite of curved finger-shape. Here for the first time we meet with a few small, plumose setæ along the outer edge of the distal segment. The two flat plates that represent the protopodite are spinulous at the ends, much as in the palp of the mandible. The distal piece is also armed with a row of a few spines along its proximal edge as seen in figure 9. The ends of both plates are set with spines on the face toward the mouth; the proximal plate is rounded, the distal one truncated to form a jaw-like organ.

The second maxilla (fig. 10) bears the long scaphognathite which has a dense row of plumose setæ all along its extensive free edges. There are also a few plumose setæ at the base of the endopodite, as in the first maxilla (fig. 9). As above noted one of the first muscular activities acquired after hatching is the slowly developed rhythmic beat of the scaphognathite, and with this use of this appendage there is present an armament of plumose setæ lacking elsewhere in the locomotor organs of the larva. While these plumose setæ are not used in locomotion their function as flexible areas of resistance to the water which the scaphognathite bales out of the branchial chamber is akin to that of locomotor setæ. The rest of the second maxilla is nearly bare of setæ, but there are a few, long hair-like setæ standing out from the external face of the protopodite. The protopodite has the same two plates seen in the first maxilla (fig. 9), but each is deeply cleft, so that four free tips project toward the mouth. The four tips each bear blunt spines on the outer and distal faces as shown in figure 10, while upon the inner faces toward the mouth they are all set with longer, sharp, curved spines that are claw-like. The endopodite though longer and more slender than in the firstmaxilla is still very simple and not segmented.

The first maxilliped (fig. 11) shows the protopodite again reduced to two flat plates much as in the first maxilla (fig. 9), and there are simple spinules on their cutting edges. The endopodite is small and simple, intermediate between that of the second and first maxillæ. In place of the scaphognathite there are two movable parts; a long flat plate, the epipodite, which is without setæ though sparsely spinulous on its posterior edge; and a very long and prominent exopodite. The exopodite has a very long swollen basal part with very long plumose setæ on its outer edge as shown in figure 11 and is elsewhere naked. The terminal part is long, slender and with a very few spines at its tip. As the base of the exopodite lies over the distal end of the epipodite it is not readily seen that the epipodite has a short truncated extension suggesting the anterior end of the scaphognathite as well as the evident posterior blade that reached back into the gill chamber and is comparable to the like portion of the scaphognathite.

The second maxilla (fig. 12) is more complex; the two segments of the protopodite are subordinate in mass and extent to the greatly developed endopodite and gill structures, but they bear a few plumose setæ upon their inner edges. The endopodite resembles that of the first maxilla in position, general form and curvature, but is not only larger but subdivided into five segments and bears spines. In addition to the spines shown in figure 12, there are also long curved ones on the inner face of the terminal segment. Compared with that of the first maxilliped, the exopodite of the second has a very narrow basal part which is without plumose setæ but bears a few long spines on its external edge. The epipodite is present as a long, curved lamina, bilobed at the tip, and along its inner face are borne the numerous blunt filaments of the gill, podobranch. This podobranch is free at its tip, but elsewhere adnate to the lamina and bearing two rows of blunt side papillæ or gill filaments which are directed toward the apex, and increase in size in each row from base to apex. The epipodite lamina has a few plumose setæ on the rounded ridge at its base and along its edges are scattered curved, short hooks, while its emarginate tip bears a few blunt, fringe-like papillæ. In addition to the above gill there is one arthrobranch that is shown in figure 12 to have a long slender stem ending bluntly and bearing two rows of blunt, curved, finger-like lateral filaments which may each end with a small, blunt spine. The third maxilliped (fig. 13) exhibits the typical morphology of this organ in the adult; a somewhat two jointed basal protopodite bears a large five-jointed endopodite of great size, a long slender exopodite, a large epipodite and podobranch; and two arthrobranchiæ arise from the region connecting the appendage to the body.

The endopodite bears spines upon all its segments and the protopodite has a couple of small spines upon its distal segment and a plumose setæ upon its proximal segment. The exopodite, in contrast to that of the second maxilliped, has a shorter and more slender basal segment devoid of spines, while the second segment has several spines at and near its tip. The lamina of the epipodite has the same characters as in the second maxilliped, but the plumose setæ along its basal ridge are twice as many. The podobranch is like that of the second maxilliped. Of the two arthrobranchiæ the anterior one is much like its homologue on the second maxilliped, while the posterior one, nearer the observer in figure 13, is smaller and more simple with fewer lateral filaments.

Coming next to the ambulatory appendages, we find the usual large chelæ, the two pairs of slender chelate and two pairs of non-chelate legs (figs. 14, 15, 16, 17, 18). In these appendages of the first larva there are, as in the adults, no exopodites, and even the remarkable exopodite setæ of later larvæ and of adults are absent in this first stage, thus adding to the simplicity of the limbs, which is also expressed in the entire absence of plumose setæ and the presence of but few sharp spines.

The chela (fig. 14) has the recurved terminal hooks first made out by Huxley in the English Astacus, and which lead to the firm locking of the chelæ to the egg stalk, as above narrated; and the opposing edges of the claw are serrated from the presence of sharp spines pointing toward its tip. The chela bears very large sharp protuberances along the inner edge of the meropodite segment, of no apparent use, while the great length and thickness of the whole limb is apparently necessary in that firm holding of the larva to the mother which resists the force of the maternal pleopods that swing the larvæ back and forth.

The epipodite and gills of the chelæ are like those of the third maxilliped.

The following two legs (figs. 15, 16) are like one another in every way except in proportion, the first being shorter than the second. Each has a sharp claw with spines pointing toward the tip, but the tips are not recurved as is the case in the big chelæ. The gills on these two appendages are like those of the chela, but there is in addition a slender simple gill upon the body wall near the arthrobranchiæ. This pleurobranchia is a single filament with no lateral outgrowths and may be regarded as rudimentary at this stage, as it is also in the adult.

The remaining legs (figs. 17, 18) have terminal segments almost like those of the preceding legs, but there being no opposing outgrowth of the propodite, there is no claw. The legs increase in length and in slenderness from before back in the series behind the chelæ. The penultimate leg (fig. 17) has a longer pleurobranch associated with it but otherwise its gills are as in the preceding limb. The last leg, however (fig. 18), has its gills suddenly reduced; in place of the epipodite and podobranch there are but a few plumose hairs such as stand upon the basal ridge of the epipodite of the preceding somites. The arthrobranchs are entirely absent and there is but one gill which is a pleurobranch, which, however, in place of being a simple filament or rudiment, resembles a reduced or simple arthrobranch in that it has about seven short lateral processes in two imperfect rows.

The branchial formula of the first larval stage of *Astacus leniusculus* is then as is given in the table below. This was found to be just the same in the adult of this species and it is said to be the same in the English *Astacus pallipes*, except that the latter lacks the rudimentary pleurobranch on the somite of the first leg.

	Podobranchiæ.	Arthrobranchiæ.		Pleurobranchiæ.	Total.
		Anterior.	Posterior		
Somite of 2d maxilliped	1	1	0	0	2
Somite of 3d maxilliped	1	1	1	0	3
Somite of chela	1	1	1	0	3
Somite of 1st leg	1	1	1	1 R	3 + 1 R
Somite of 2d leg	1	1	1	1 R	3 + 1 R
Somite of 3d leg	1	1	1	1 R	3 + 1 R
Somite of 4th leg	0	0	0	1	1
	6	6	5	1 + 3 R	18 + 3 R

The above illustrations of the separate appendages of the head-thorax are the first ones as yet given of any larval Astacus, since the previous illustrations of European forms are only the small maxillæ and maxilliped of an embryo not yet hatched as depicted by Rathke ('29, fig. 29), the tip of the chela shown by Huxley ('80, fig. 8), and the under side of the abdomen with its pleopods figured by Reichenbach ('86).

Upon comparing the adult appendages of *Astacus leniusculus* with those of first larva as above described, the fundamental agreement in morphology was obvious, but there were the following differences which all suggest a lingering on of embryonic characters into the life outside the egg-shell. Throughout all the appendages there was a marked lack of setæ correlated with evident lack of locomotion and probable weakness of sensory activity. Excepting the chelæ the cephalothoracic appendages had no obvious use. The first antenna, having but five segments in its exopodite and in its endopodite, is but embryonic compared with the adult that has at least thirty-five in its exopodite and almost as many in its endopodite, a difference which is of great moment when we consider the repetition of special sense organs that are found on many successive segments of the exopodite of the adult. The auditory organ also is apparently of no functional value in the early larva.* The number of segments in the filament of the second antenna must also increase greatly to form the one hundred and twenty-five of the adult; an increase apparently brought about by interpolating new segments at various places by division of the old ones into two.

While all the adult appendages of the head-thorax are represented in the larva at hatching, this is not the case for the abdomen, for the sixth pair of abdominal appendages are not externally present and the first pair which in the adult male are so essential are absent in the first larva as they also are in the adult female. The other abdominal appendages are four pairs of simple pleopods which hang down beyond the pleural plates of the abdomen so that they are seen from a side view (fig. 3). Each pleopod (fig. 19) is as in the adult composed of a short and a long segment that make up the protopodite and of two simple terminal plates, the endopodite and the exopodite. These are slightly curved and armed at the ends and to some extent on the edges with small weak spines and they entirely lack the plumose setæ that makes them useful in the adult for fanning the water. The illustration is of the anterior face of the left pleopod of the second abdominal segment and shows that the exopodite is longer and wider than the endopodite, while in the adult the exopodite is much the shorter and smaller in the female pleopods that bear the eggs and in the male pleopods that transfer sperm. The appendages of the sixth somite though not externally free are yet present and of large size though imperfect in development and lie within the substance of the telson, as can be seen in transparent living larvæ. It is their presence which swells out this region ventrally and gives rise to the protuberance seen from the side view (fig. 3). Looking at the telson from above (fig. 20), the very imperfect future sixth pleopods are seen as two somewhat less translucent areas, right and left in the anterior part of the telson and each having an outline suggesting that of a mitten. Only later will these concealed buds of the sixth appendages burst out after a moulting and expand as the very large lateral parts of the caudal fan, so essential in quick locomotion. This retention of these appendages within the telson in Astacus was known to Huxley ('80), and figured by Reichenbach ('86).

The telson requires special consideration in connection with the "telson-thread," as mentioned above. The telson itself is a very large plate with nearly circular outline and is thin posterior to the above region occupied by the buds of the pleopods on either side of the intestine and anus. In structure it is essentially a translucent, vascular, connective tissue mass over which are scattered brilliant vermilion pigment cells, indicated in black in figure 20, and which is covered by a thin epidermis and thin chitinous cuticle. Along most of the free margin of the telson is a row of blunt, stiff papillæ, or spines. In all there are about sixty-six of these spines arranged symmetrically, half on each side of the median plane. In the figure of Astacus given by Reichenbach ('86) there are but twenty-five spines or dentations on each side of the median line and this may well be a character of systematic value. In addition to the thirty-three lateral spines of *Astacus leniusculus* there were six or seven smaller, blunt spines on each side which stand in between some of the larger ones, one small one between two larger ones, and generally not so near the edge but more up on the dorsal surface of the telson.

The interior of the telson has a radiated appearance like that figured by Remak and by Reichenbach and which was referred by Huxley to the disposition of vascular canals; but in our present larvæ this radiation is due to long delicate lines passing centrally inward, one from each lateral spine and from some of the smaller spines, thus making the divergent system radiating from near the anal region as shown in figure 20. Subsequent events show that these lines are the forming plumose setæ for the perfect locomotor telson of later larval stages. Each when enlarged (figs. 21, 22) is a bundle of fibrillæ that are very small in comparison with the nuclei of the epidermis as each bundle of very many fibrils is but once or twice the diameter of a nucleus. These radiating lines are in fact to be likened to compressed bottle brushes which later will expand as the perfect locomotor plumes on the telson of the second larval stage (fig. 23). The plumes are being made within epidermal tubes or glands and between the successive radiating glands the vascular spaces, also radiating, form the justification for Huxley's interpretation.

During the first hours of larval life the telson is connected to the inside of the egg case by the long telson thread represented in figure 4. This is a translucent, chitin-like membrane, or flat ribbon, showing a striated appearance due to fine wrinkles in it (fig. 20), but otherwise apparently homogeneous. Though seemingly but superficially attached to the telson the contact is a very firm one so that when the larva succeeds in getting hold of the egg stalk and finally flaps its abdomen strongly enough the telson thread is broken before it is torn loose from the telson. When enlarged (fig. 21) the mode of attachment of the very thin but tough membranee is seen to be, that ten of the marginal spines of the telson bear special hook-like projections that are fast to the membrane. These few spines are different from the others though some of the adjacent ones have somewhat of the same structure at their tips. While in figure 21 the spines and their processes are represented in black, they are in nature transparent, colorless and very inconspicuous, especially the processes which are hyalin, myelin-like protrusions, suggesting the products of glandular activity. While many of these protrusions end bluntly others seem to be continued as fine threads that are fast to the membrane or telson thread. Moreover, many of the protrusions bridge over the space from one spine to the next and are continuous with adjacent protrusions as if they had flowed out when viscid and then coagulated. Such bridges make adjacent spines into hooks that hold fast to the membrane, but the ultimate and essential fastening of the membrane to the telson is by fine threads of some coagulated material that seems to be a continuation of the grosser protrusions figured in black in figure 21.

It would appear from the statement of M. Robin cited above (page 15) that in the Astacus studied by Chantran there are but eight spines used for attachment to the telson thread.

The origin of these peculiar glandular spines, for such they seem to be, is to be sought in the embryo. At the time of hatching the egg capsule breaks and for a brief period the embryo may still be enveloped in a very delicate membrane which passes over the abdomen and all about the telson. At that period the spines of the terminal part of the telson abut against the investing membrane as shown in figure 22, which is from a specimen just hatching and killed in Pereny's liquor. Here are shown the epidermal nuclei, the striations, or forming plumes of the future telson, continuing up through the body of the spines, only three of which are drawn; and at the tips of the spines fountain-like masses of blunt protrusions, swollen at the tip and in many cases pressed against the membrane. It would seem that a viscid mass had been poured out from the tips of the spines and that this oozing out in threads had become firmly soldered to the membrane.

As far as made out the origin of the supporting telson thread is thus as follows. The thread is really a membrane and when the embryo is hatching this membrane is spread like a loose skin all over the embryo inside of the egg case. When the embryo hatches it also sheds this membrane, coming finally to pull its abdomen out of the part of the membrane that surrounds the abdomen like a long bag. The bottom of the bag is, however, fastened to the tip of the telson as indicated in figure 22, so that the creature cannot get entirely free from the bag but pulling out its abdomen pulls up the bottom of the bag and turns the bag inside out. The struggles of the larva drag the membrane into a long thread, and one end of this remains attached to the telson spines as seen in figure 21. Once this is accomplished the fact that the clear thread is really a cast-off membrane would not be suspected, since it seems a homogeneous, finely wrinkled thread that might well be a secretion.

The similar structure in the European Astacus was mentioned merely as a filament as cited above, page 15, but Huxley intuitively queried if it might be a larval skin.

The other end of the telson thread remained fast inside the egg capsule (fig. 4), and this attachment is as important as the above described attachment to the telson in making the thread of use to secure the larva from being lost. How the connection of the inner membrane to the egg capsule was brought about was not determined but it was existent long before the embryo hatched. Embryos three days before hatching killed in Worcester's liquid and soaked a week in five per cent potash showed an outer egg capsule, an inner shell and a membrane that was loose and visible over the chelæ and over the deeply bifid telson which already bore terminal spines. And embryos nine days before hatching showed the same double shell and membrane, but no telson spines.

The telson thread is thus a thin membrane formed about the embryo and early fastened by radiating fibrils (fig. 4) to the inside of the inner of the two layers of the egg capsule. Later in the life of the embryo this membrane becomes also fastened to the telson by secretory activity of the terminal spines. When the embryo hatches the membrane is ruptured and in part turned inside out and drawn into a thread-like form, fastened at both ends. Other facts regarding the telson thread will be given below in the description of Cambarus, in which it also exists.

The passage from the first to the second larval stages was seen in some larvæ lying in the bottom of a dish, and in others that had fixed themselves to strings. In these the old larval skin burst open and the second larva, as it were, "oozed" out backward for several minutes and its chelæ and abdomen remained longer inside the old skin but were then suddenly withdrawn. For a few minutes the larva in its new stage lay stretched out straight, as if dead but then flopped its abdomen, moved its legs, got upright and walked and even swam backward and finally crawled up into the piles of other young in the same second stage.

While the larva in the first stage was inactive and remained always fastened to the mother, the second larva was active and finally abandoned the mother though for a time still associated with her. Upon casting off their first larval skins the larvæ in the second stage leave those skins fastened by their chelæ to the egg stalks on the mother's pleopods, and are free to crawl about over the pleopods of the mother amongst their numerous fellow-larvæ. Soon these larvæ descend the pleopods and make short excursions under the abdomen of the resting mother and over various parts of the mother's body, finally wandering off over the bottom of the aquarium for short distances to return frequently to the mother again.

The mother thus had fastened to her pleopods a large mass of old egg stalks and capsules to which were fastened the cast-off skins of the larvæ, and over this mass crawled the active larvæ till after a few days the egg cases and cast skins as well as egg stalks were found to have disappeared leaving the pleopods clean but still occupied by the larvæ. In the Astacus in France Chantran ('71) finally convinced himself that the larvæ ate their cast skins and the egg capsules; and the same probably occurs in *Astacus leniusculus*.

The habits of the second larvæ showed much greater diversity than was possible in the attached larvæ in the first stage but through the early part of the second stage a tendency to climb seemed a dominant feature of their lives. When a number were put into a dish by themselves they tended to climb up onto one another to form a mass but if put back with the mother they soon climbed up onto her pleopods where they held on so firmly that when a pleopod was cut off and thrown into 70 per cent alcohol, some of the larvæ still retained their hold though most of them did not. When the larvæ alone were in a dish with a spray of myriophyllum they climbed up it and crawled together in a mass between the plant and the glass; but they did not climb up onto a piece of cotton cloth hanging down in the water from a floating cork. Even when the mother was dead, the young twenty hours after passing into the second stage continued to hold firmly to the maternal pleopods. But after three more days the young had ceased to huddle together so much, and crawling about over the bottom of the aquarium, and sometimes swimming, they were at times carried away with the current of water. Though some of the larvæ concealed themselves under ooze and dead leaves at this time, others continued to hold on to the abdomen of the dead mother for four or five days, when the abdomen was cut off and fastened at the surface of running water, but about May 18 these larvæ also dropped to the bottom and lived there. This climbing instinct can then be satisfied in various ways, and when thirteen larvæ were removed and put into a dish with another female bearing young, but few minutes sufficed for five of the thirteen to find and to climb up onto the pleopods of the strange female. The possibility of resolving these habits of the young second stage crayfish into so-called tactic phenomena, into chiefly geotactic and stereotropic responses, will be considered in connection with some observations upon the young of Cambarus.

The general form of the second stage as represented in figures 23 and 24 is obviously more like the adult than like the first stage as is true also of the habit. Comparing these figures with 3 and 4 there is a noteworthy change in size; after casting off the first skin the crayfish measured 11 mm. from tip of rostrum to end of telson, exclusive of the long fringe of plumose setæ which made the length 12 mm. if the setæ were included, and so greatly enlarged the area of telson available for locomotion. The thorax was 2 mm. wide and about 2.5 mm. deep. The cephalothorax was 6 mm. and the abdomen 5 mm. long; the telson was 2 mm. wide without the setæ, and 4 mm. with the setæ. The antennæ were 10 mm. and the chelæ 8 mm. long. All these measurements were taken from preserved material and show that the animal was now a large larva.

Its brilliant color added to its size made it an attractive larva resembling a young lobster after the swimming stages. As indicated in black in the above figures the pigment cells were scattered over the head thorax and abdomen and more sparingly over the chelæ, walking legs and basal parts of the antennæ. To the naked eye the larva walking on the bottom of a dish seems light flesh-color, translucent and inconspicuous, but the chelæ look red, the eyes are dark and the yolk is still a very evident dark, red-black mass of bilobed form across the middle of the head thorax. The liver lobes anterior and posterior to the yolk were noticeably yellowish and greenish. The abdomen was flesh colored for the most part, but the telson was nearly colorless and with a fringe of white, clear setæ so long as to suggest a peacock's tail. On the first abdominal somite the densely crowded pigment formed a conspicuous cross-band (fig. 23). Another such aggregation of pigment was found posterior to the eye and external to the base of the rostrum. In addition to the color due to the much branched red pigment cells, indicated in black in figures 23 and 24, there soon came to be a variable amount of blue color not so readily seen and due to large blue pigment cells. In strong light the red pigment often stood forward on a background of blue. The blue was evident on the basal part of the antenna and antennule, on the mandible and its palp, but not on the maxillipeds. On the dorsal side of both thorax and abdomen there were some blue, faint, scattered areas internal to the red.

As shown in figures 23 and 24, the cephalothorax in passing from the first to the second stage had become long, narrow, and angular with a long gothic rostrum standing straight out in front between the eyes on a level with the back. The rostrum also had large lateral spines at its base and half way out its length.

In walking about these larvæ carried the antennæ and the red chelæ forward and the abdomen straight out behind as in figure 23, and not bent in under the thorax as in the first stage. However, when not walking the abdomen was bent as in figure 24. As in a young lobster the slow walking was quickly replaced, at alarm, by rapid backward swimming caused by flapping the abdomen with its extensive telson fan. As the larvæ went about more and more away from the parent, they became more individual and more complex in their movements; they were seen to scrape the backs of their heads with their legs, to raise their chelæ as if in defense when a shadow passed over them, and in other ways to act like an adult crayfish much more than did the sluggish and simple first larvæ.

In watching one of these second larvæ slowly walking, the movements of the five long limbs seemed to be as follows. The fifth, fourth, and third limbs standing out at the sides of the body (fig. 23), were so bent as to hold the body high up above the bottom of the dish and swing back and forth as the chief locomotor organs. The chelæ were held in readiness in front of the animal and the second limbs (fig. 23) were bent inward under the body with the tip forward so that in moving forward the body rode over these appendages as upon levers with very little movement of the base of these appendages. The third appendages always pointing forward swung from an angle of about 45° with the side of the body to one of about 70°. The fourth limbs had a very long swing from a forward position about 45° with the side of the body back past 90° with the side of the body. The fifth limbs had a very short, hobbled, movement like the third but always directed backward, from about 100° to 120° with the side of the body.

In taking up the appendages of the second larva, in sequence (figs. 25 to 39) it will be noticed that the relative nakedness of the first larva has given place to a hirsute condition, indicated in figures 23 and 24; setæ occur upon the antennæ, chelæ, legs, pleopods as well as the sides of the abdomen and, as the separate sketches show, upon all the other appendages. The active second larva has thus come into possession of sensory and locomotor setæ lacking in the imperfect first stage, and similar to those of the adult stages.

The first antenna (fig. 25) still has the same general form as in the first stage (fig. 6), it has five segments in exopodite and in endopodite but it is noticeably more finished in being well armed with setæ. The narrow part of the proximal segment bears a sharp spine upon its inner side. The auditory pit on the basal segment is now well guarded by a row of plumose setæ passing from the outer edge inward and spread across the orifice of the pit. There is also a row of sparsely branched plumes along this upper face of this segment and parallel to its inner edge and in addition there are a few other setæ arranged as in figure 25. The second and the third segments bear long plumose setæ on their inner sides and long, stiff spine-like setæ on the external sides of their distal ends. The endopodite and the exopodite each bear a few long stiff spine-like setæ at the distal ends of their five segments and in addition the characteristic blunt sense clubs of this appendage are now evident. These organs are placed in groups upon the inner and lower faces of the third, fourth, and fifth segments of the exopodite. The third segment has a cluster of three upon its distal edge, the fourth has a group of two at its distal edge while the fifth has a group of three at its middle part, where its diameter suddenly diminishes. As all these sensory clubs face downward they are foreshortened in the above figure and in reality are much longer than shown.

The second antenna (fig. 26) has increased greatly in length over its former state (fig. 7). Its basal parts are more angular and the excretory cone on the basal segment is relatively very much smaller while the spines of the second segment are borne upon a large, scale-like protuberance. The exopodite scale bears a row of long, plumose setæ all along its outer edge while in the first stage there were only simple spines to anticipate some of these plumes. The three large segments of the exopodite are more angular than before and now bear a few setæ while the filament has some fifty-four segments of the form and proportions shown in figure 26. As these bear needle-like setæ on their distal edges the filament seems under a low magnification somewhat like a brush.

The mandible is not only greatly enlarged but more complex in having an effective cutting edge no longer smooth but serrated by seven unequal angular projections (fig. 27). The palp is more complex in having more numerous long, acicular setæ both on the exterior and interior faces of its terminal segment and a very few sparsely-branched plumes on the distal part of its second segment. When folded down the palp fits into a deep depression on the inner face of the mandible (fig. 28), and the proximal border of this depression is irregularly dentated with rounded protuberances. The exoskeleton over these dentations and over the sharp teeth of the cutting edge is now very thick and horny, being solid as far back as the second line in figure 28. While the acicular setæ over the terminal segment of the palp appear smooth under Zeiss 2 A, they are really set with short, fine, side branches along their distal halves as seen with 2 D, and they have rather blunt points so that they would seem to aid in a brush-like use of the palp.

The first maxilla (fig. 29) has progressed beyond its former stage (fig. 9), chiefly in the outgrowth of long setæ in place of blunt spines and also in the addition of setæ where there were no outgrowths at all. The setæ are of two kinds, a few plumose and many acicular; the latter are found chiefly on the ends of the two plates of the protopodite where they replace simple spines, while the plumes are chiefly lateral. On the basal, or first segment, however, there is somewhat of a transition, since its proximal border is set with setæ that extend out to the tip as very long and sparsely branched plumes that thus extend close up to the acicular setæ. These latter under 4 D are seen to be set with very few and fine side branches so that they are really somewhat plumose. The similarly placed acicular setæ upon the second segment, however, show no side branches but are really smooth. The small tuft of setæ already present in the first stage at the base of the endopodite remains but little changed in the second stage.

The second maxilla has undergone like changes (fig. 30). The terminal spines of the first stage (fig. 10) are replaced by plumose setæ and a few more long plumes are added. Here again the plumose setæ of the proximal edge of the first segment extend out as far as the acicular setæ of the apex. The endopodite has a few long plumose setæ on its distal part in addition to the cluster at its base. The scaphognathite is but little changed, the setæ along its outer edge being so bent down that they do not show their full length in the view represented in figure 30. However, at the posterior tip of this respiratory organ there is a peculiar growth of one or two setæ. These are very long and though appearing quite smooth and hair-like, with 2 D, they are seen to be really set with short, fine side bristles, and they are sharp pointed. On the inner faces of the four lobes of the protopodite there are now many long, sharp, curved, setæ.

In the first maxilliped (fig. 31) the process of substituting plumes and acicular setæ for spines has been carried on in the same general way. The cutting edges of the protopodite now bristle with setæ most of which are simple, some straight, some with curved tips; but the tendency to run the plumose setæ up to the tip of the basal segment is carried so far that these plumes take entire possession of this basal segment and only the second segment has acicular setæ. Even on the second segment a few plumes come up nearly to the tip, on the distal side. The endopodite bears but a few plumose setæ while the long exopodite has in addition to the former series of plumes along the outer edge of the basal part (fig. 11) several remarkably long and conspicuous plumes near its tip. The terminal part of the exopodite is cylindrical and tends to become segmented and it is from its last and its penultimate segments that the long plumes project and form a terminal brush. The flat epipodite scale has still a few minute, blunt papillæ along its posterior edge (figs. 31, 11), and on its outer and inner edges a few of the remarkable exoskeletal hooks characteristic of these organs.

The second maxilliped (fig. 32) has changed chiefly in adding plumes and setæ. The gills remain as before (fig. 12) but are longer. The protopodite has added longer and more numerous plumose setæ and a very few acicular ones. The exopodite has substituted for its few terminal spines a brush of several remarkably long, strong plumes (fig. 32), and for the sparse spines along the outer edge of its basal segment a few setæ which proximally are sparsely plumed and distally smooth without barbs. The endopodite looks much changed owing to the development of many long and stout acicular setæ over its terminal parts and inner edges. The setæ of the endopodite are smooth as seen with 2 A, but with 2 D some five or six on the inner face of the second segment and again on the distal edge of the fourth segment are finely barbed. In the latter position two at the corner toward the exopodite have their fine lateral branches flattened like saw teeth, so that they resemble the cleansing setæ upon the penultimate segment of the fifth leg of the adult, elsewhere described (Andrews, '04). The fifth, or terminal segment of the endopodite, is armed with long, smooth, stout, spine-like setæ, with blunt points.

The third maxilliped has added but few plumes but many very long acicular setæ (figs. 33, 13). The plumes are a noticeable bunch at the tip of the exopodite and a few on its basal part, as well as very few on the protopodite and an increased number at the base of the epipodite. The gill region is now for the first time provided with the phenomenally long hair-like coxopoditic setæ found in the adult and in all but the first larval stages on this and all the following thoracic somites. As seen in figure 33, these setæ arise external to the exopodite and add a conspicuous element to the appendages as they are longer than the entire exopodite and coil about like stiff wires. The endopodite bristles with exceedingly long, sharp needle-like setæ and has no real plumes whatever, though with 2 D it was evident that some of the longest needles on the terminal segment were very finely barbed. On the anterior, and inner, face of that segment there were also numerous stout setæ with flat saw-teeth like those above described, on the corner of the penultimate segment of the endopodite of the second maxilliped.

The chela (fig. 34) has greatly increased in size, as shown in comparing with fig. 14, and now has simple acicular setæ scattered over it but no plumose setæ. The terminal claw is no longer used as a holdfast and has no longer recurved tips. Henceforth of use as a cutting shears it now bears a large tooth on each blade as well as the rows of spines formerly present. At the base of the appendage the gills have increased in size and there is a long tuft of coxopodite setæ, which, however, are short in proportion to the enormous endopodite.

The four walking legs (figs. 35, 36, 37, 38) though much larger than in the first stage (figs. 15, 16, 17, 18) have not increased as much as have the chelæ and they retain their relative proportions and sizes. Like the chelæ they now bristle with acicular setæ and show no plumose setæ. However, at the distal edge of the penultimate segment of the fourth and of the fifth legs (figs. 37, 38) there are a few of the saw-like "cleansing setæ" previously referred to as occurring in the adult. The gills have changed only in size; the coxopodite setæ are very long threads, but only few in number and on the last leg reduced to one.

The branchial formula in the second stage was thus just like that above given for the first stage.

On the abdomen of the second stage there were still but four pairs of pleopods since the first were not yet formed and the sixth still remained inside of the telson. But each pleopod was now so well provided with plumose setæ that the appendage simulated a locomotor organ. The larvæ also now had the adult habit of swinging the pleopods back and forth and so producing currents in the water which may well be of aid in respiration as they would change the water supplied to the inhalent openings of the gill chambers. Each pleopod (fig. 39) had grown greatly in length as compared with its first appearance (fig. 19); the long plumose setæ arose from the distal parts of the exopodite and endopodite and resembled the plumes upon the exopodites of the maxillipeds (figs. 31, 32, 33). The exopodite was still the longer and the endopodite the shorter of the two flat lobes that bear setæ so that the adult relationship in size of these parts was not yet arrived at.

While the telson of the first larva was nearly circular, in the second it was swollen laterally (fig. 23), and became thus transversely elongated since the sixth pleopods had now grown within it as very large lateral masses. The posterior edge of the telson was somewhat incised on the median plane and thus recalled the early bilobed condition found in the embryo some days before hatching.

The long plumose setæ of the telson (fig. 23) that aid the larva in swimming are the expanded products of the radiating glands seen within the telson of the first stage (fig. 20).

Thus provided with effective swimming setæ and more numerous sensory setæ the second stage larva gradually depends less and less upon its mother and finally leaves her altogether. After some eight to ten days these active larvæ cast off their shells and passed into a third stage.

The third larva was in the main very like the second but it had advanced a very important step in freeing its sixth abdominal appendages which henceforth are not inside the telson, but lying by the side of it to make the effective tail-fan that is used in rapid locomotion. Some hours before shedding the second larva plainly showed the sixth pleopods as dark red, partly opaque masses within the base of the telson and after shedding these appendages were expanded as is shown in figures 40 and 42. As both the end of the telson and the edges of these great flat sixth pleopods are set with plumose setæ the combined fringe of setæ augments the surface used by the larva in escaping backward by vigorous blows of the telson and sixth pleopods against the water.

The details of this effective and very large sixth pleopod which has been forming slowly on each side within the base of the telson ever since the larva came out of the egg, that is from some two to three weeks, are shown in figure 42, which shows the dorsal face of the left appendage of the sixth abdominal somite. This appendage joins onto the sixth somite and lies by the side of the telson as indicated in figure 40. The protopodite bears a prominent spine over the base of the endopodite; the endopodite is armed with two spines near its edge and the exopodite with five spines, along the edge of the two segments into which it is divided, as in the adult, by a movable hinge. Scattered over the surface are a few relatively short acicular setæ. It will be noted that the plumes along the edges of both endopodite and exopodite are arranged to make a most effective fan since those of the endopodite overlap some of those of the exopodite, when, as in figure 42, the exopodite is not extended as far as possible away from the median plane. At times the exopodite may be shut in under the endopodite like a part of a fan.

The real length of the terminal plumes is somewhat greater than shown in the figure since they are foreshortened there; they do not stand out in straight continuation of the plane of the telson and sixth appendage but are curved downward so that their tips tend to point forward under the animal. The entire fan is thus somewhat concave on the ventral side and in life the larva carries its abdomen with its tip close to the substratum upon which it walks or stands (fig. 41), and seen from above the fan is foreshortened. Both the habit of carrying the fan inclined downward and the curved growth of the plumose setæ combine to make the fan a hollow scoop, which form would seem to be a more efficient one for striking the water forwards and thus propelling the animal backward. The forward bending of the setæ by making it more difficult for them to be forced back beyond the plane of the stiff parts of the fan would seem to make them a more efficient addition to the striking surface.

The period of life in which the effective tail fan is formed by the liberation of the sixth pleopods has hitherto remained unknown for the genus Astacus. Huxley ('80) says: "I imagine * * * that the appendages of the sixth abdominal somite are at that time (during the first ecdysis) expanded, but nothing is definitely known at present of these changes." Faxon ('85) records that specimen of *Astacus pallipes* 11 mm. long and ten days old still had the sixth pleopods enclosed within the telson and supposed that they would be set free after the second or third moult. Other observations seem to be lacking.

The telson seen foreshortened in the natural position figure 40, is seen in its true proportions in figure 43. From the circular form of the first stage (fig. 20) it has passed through the transversely elongated form of the second stage (fig. 23) to its present complex and angular form. By an imperfect transverse hinge it is now divided into an angular anterior part and a rounded posterior part. The fact that this transverse division of the telson does not show till the third larval stage is of interest in connection with the fact that this seems one of the recent acquisitions of the highest crayfish. In the lobsters and other marine forms, as well as in all the crayfish of the Southern Hemisphere, the telson is not at all divided and amongst the Potamobine or higher crayfish of the Northern Hemisphere the division of the telson is much more perfect in the highest forms, such as *Cambarus affinis,* less pronounced in some lower forms as *Cambarus Clarkii* and in *Astacus leniusculus,* which is doubtless less specialized than Cambarus, the division of the telson in the adult is by no means a perfect one.

In figure 43 are shown groups of acicular setæ symmetrically placed right and left; the rounded, terminal lobe is the only part bearing plumose setæ. These plumes stand in a single row and on the right and the left begin anteriorly as short setæ followed by others that very soon are much longer and of about constant length along the posterior border till near the median line when there is a sudden falling off in length and one very short setæ ends the series.

Just dorsal to this row of long plumes there is a row of much fewer and relatively short acicular setæ, shown in black in figure 43. In the reentrant angle between the two lobes of the telson, each side, there is a rounded spine similar to the one formed on the sixth pleopod (fig. 42) where the basal lobe of the exopodite joins the distal lobe.

Beyond this perfection of the locomotor apparatus of the abdomen the third larva differs but slightly from the second though there are differences in size, proportion, color and habits. Comparing figure 40 with figure 23 it is seen that the abdomen is wider, the cephalothorax more cylindrical, the limbs stouter, the entire aspect more heavy and crayfish-like.

The third larva is still sufficiently transparent to allow the heart to be seen through the shell, under the microscope, beating at about three times a second; the stomach and intestines also show dimly as dark areas.

The animal is not conspicuous upon sand or mud; its color is, as before, light with fine, dark-red specks. The eyes are black and the chelæ not red but pink. The liver region is greenish but the dark yolk so long conspicuous has disappeared with the perfection of sensory and locomotor organs. Where the head-thorax ends posteriorly there is a dark rim caused by concentration of pigment cells there and the abdomen still has a dark band across the dorsal side of the first somite. The region above the heart is quadrangular and very pale in color. Back of each eye there is a dark longitudinal band. The groove between the head and thorax dorsally is light and the pigment anterior to it is more dense. Under the microscope the arborescent red pigment cells often have a blue background and in some regions there are arborescent yellow cells amongst the red ones.

The considerable increase in size in passing from the second to the third stage may be seen by comparing the measurement given above, page 28, with the following. In third stage a larva measured 14 mm. from rostrum tip to edge of telson and 15 mm. to end of plumose setæ. The antenna was 12 mm. and the chela 10 mm. long. The width of the thorax was 3.5 mm. and its depth 4 mm. The telson was 2 mm. wide and the fan formed by it and the sixth pair of pleopods 5 mm. without the plumose setæ, and 6 mm. with them. The length of the head-thorax was 7 mm. and of the abdomen 7 mm.

In the third stage the larvæ were active and voracious, walking and swimming with ease and speed so that they were hard to catch. When kept together they soon lost chelæ in fight with one another and greedily devoured their dead fellows. When a piece of frog's muscle was put into a dish with these larvæ they seized as soon as they came into contact with it and holding the main mass with their chelæ and other claws dragged it backward while tearing off fragments with their mouth appendages. Thus twenty-three to twenty-five days after hatching larvæ in the third stage which had had no flesh food, unless it were the chelæ of other larvæ, possessed well developed responses in the presence of flesh food. When meat was put on green ooze on the bottom of small aquaria containing such larvæ they showed no sign of being aware of it till in contact with it when they seized it ravenously with their mouth parts and then holding the mass with their chelæ jerked back like a dog tearing meat from a bone, so strongly as to pull off mouthfuls. When frightened away from the meat, which was then placed one-third of an inch to one side of its former position in the ooze, the larva returned to the place where the meat had been and seemed to masticate the ooze there and very slowly found the piece of meat again as if through touch, taste, or smell and not at all by sight.

The pugnacity of the third larvæ resulted in loss of limbs and specimens with legs pulled off at the "breaking joints" and also rapidly regenerating there were seen. Chantran stated that larvæ of Astacus would regenerate lost limbs in seventy days while the adult males required one and a half to two years and the females three or four years.

Excepting the newly expanded last abdominal appendages all of the appendages agreed with those of the second larva in most all details, but they were larger. The first antenna, however, in place of the eight sense clubs of the second stage, had eleven. These were placed as follows on the exopodite: four in a group on the distal segment; three at the distal end and one upon the middle of the under side of the penultimate segment; two at the distal end of the antopenultimate segment and one at the distal end of the next segment. Just as in the second stage the ear cavity was protected by a row of plumose setæ arching over it from its external border.

The long filament of the antenna was often broken near the tip but contained from 60 to 65 segments and some few of the terminal ones were constricted about the middle as if they might divide at the next moult.

The acicular setæ of the filament were about one-half as long as the segment, from the distal ends of which they arose in whorls of five or six. Toward the tip of the filament these setæ were much longer than in the second larva.

The mandibles, maxillæ, maxillipeds, chelæ, and walking legs with their gills and setæ were the same as in the second stage except for increase of size.

Upon the abdomen the pleopods also were as in the second stage, except in the case of the expanded sixth pair above described. As yet no appendages were seen upon the first abdominal somite but as in this Astacus no appendages were found there in the adult female it may be that only female larvæ were examined. The four pleopods of the somite anterior to the sixth still had the exopodite longer than the endopodite, as was also the case in the new sixth pleopods (fig. 42). In the adult this relative size of exopodite and endopodite is reversed in the abdominal organs that serve as secondary reproductive organs.

Thus in the male the first and the second somites bear the remarkable male sperm conductors in which the endopodites greatly exceed the exopodites or else form the only part developed while in the four following pleopods the larval relation is not much changed in the adult, as the exopodite is as large as the endopodite or, in the sixth pair, larger, and in all these four the function is not sexual but locomotor, or perhaps respiratory. In the female the same state is found in the sixth pair, the first pair are lacking, while the four other pairs have the endopodite much longer than the exopodite and both are used as reproductive organs, as supports for the eggs and larvæ.

Some of the larvæ of the third stage were kept from May 18 to October 2, and some of the moultings and increase in size noted, but no details of the gradual completion of adult structure were studied.

The fourth larval stage was reached by a moult after the larva had lived in the third stage twelve to fourteen days and was a little over one month old. The length then increased from 15 mm. to 17 mm. The color was no longer bright but dull and inconspicuous, pale grey densely spotted with almost black pigment and scarcely any flesh color though the tips of the chelæ were pink. There was a marked transverse band of bluish across the posterior edge of the carapace and the abdomen was much lighter than the thorax.

The fourth stage had advanced beyond the third in one important particular since now for the first time the appendages of the first abdominal somite were seen in some specimens, which were probably males. These pleopods, however, were as yet but very simple rounded knobs which projected from the sternal ridge of the first somite downward and decidedly inward, toward one another, and were about one-tenth of a millimeter long.

At the end of June when the larvæ had been in the fourth stage about a month they passed into a fifth stage which was nineteen millimeters long and in color red-brown or in some cases decidedly bluish. Kept in running water with water plants and tubifex for food and at a temperature as high as 21.5° C., they climbed about actively upon the plants or else remained buried in the ooze.

From some of the larvæ left in a closed aquarium with algal ooze from June 16 to October 2, there remained one survivor five months and a week old that measured 30 mm. in length, 6 mm. in width of thorax, 12 mm. in width of telson-fan, and 25 mm. along the antenna. This crayfish having areas for the ends of the oviducts upon the antepenultimate legs was a female, and it had no appendages upon the first abdominal segment. The color was bright, finely speckled over with brown; the legs lighter; the antennæ dark; the chelæ purplish with red and blue spots and there was still a blue transverse band across the posterior edge of the thorax. The eyes were brown. The shell and flesh were still translucent so that the intestine showed through the dorsal side of the abdomen.

This larva buried itself in the ooze but was so active as to be caught with difficulty. By October 20, it had shed and grown to a length of 34 mm., with antenna 32 mm. long, so that with the food that had been given it it had gained 4 mm. in length in eighteen days. This larva lived till February, 1905, and died when nine months old.

Another lot of larvæ kept in running water from July 16 to October 2, also yielded but one survivor which had increased from less than 26 mm. to 55 mm. and had a telson-fan 25 mm. wide, thorax 13 mm. wide, and antenna 36 mm. long. This fine young crayfish five months and a week old looked like the adult and was a male with well formed male stylets upon its first abdominal somite. The body was opaque and dark; greenish-blue and brown finely speckled; the legs lighter; the chelæ with much blue and with the conspicuous flesh-colored area that the adult has at the angle of the claw. The posterior edge of the carapace was dark blue and the antennæ were bluish at the base fading to brownish at the tip. The under side of the body was pale flesh-color, or colorless with some clear blue.

A third lot of larvæ, 13 mm. long on May 27, and in the third stage, were kept in more favorable conditions, that is, running water in a large tank, with mud, plants, and sunlight, and on October 2 there were six survivors. The measurements of these larvæ, five months and a week old are given in the table below:

Larva	A	B	C	D	E	F
Length	56	60	63	58	58 ?	52
Width	13	15	15	15	15	14
Antenna length . . .	51	52	52	50	55	45
Sex	♂	♀	♀	♀	♀	♂

The males A and F had well formed male organs upon the first abdominal somite while the four females had no appendages there, but the largest females B and C had two blue spots upon that somite that suggested some connection with a possible appendage. The colors of these large young were those of adults, and though all reared in the same tank they showed individual differences in: general color, some being more dark olive, others brown; in size and color of the spot at the angle of the claw, which in one was reduced to a mere light nodule and in others was a very large area; in color of under side of claw which was dark or else bright flaming-red.

The eight young reared to an age of five months and one week thus measured 30, 55, 56, 60, 63, 58, 58, 52 or an average of 54 mm.

Tabulating the facts above recorded as to the size and length of duration of the larval stages as far as they were followed we find the following:

Stage.	Duration.	Length of body.	Habit.
1	4–13 days	9 mm.	Fast to parent.
2	8–10 "	11 mm.	Free and gradually becoming independent.
3	12–14 "	14–15 mm.	Independent.
4	30 "	17 mm.	Independent.
5	?	19–20 mm.	Independent.

The number of moults necessary to increase the larva from the fifth stage when about 20 mm. long to the autumnal larvæ ranging from 30 to 63 and averaging 54 is not known. The amount of increase at each moult above tabulated was about 3 mm. In one case above cited a larva which had grown only to 30 mm. in the autumn, when well fed quickly gained 4 mm. probably in one moult. We might expect then an increment of 3 or 4 mm. at each moult, and growth from the 20 mm. length of the fifth stage to the average autumnal length of 54 mm. may have taken from 8 to 11 moults thus making an estimated total of 12 to 15 moults the first growing season. The size reached was, however, evidently determined in part by food. On such basis it may have taken even more moults to produce the large autumn young 60 and 63 mm. long. And at all events the above larva 30 mm. long having been kept in a closed aquarium should be disregarded in reckoning the average. Rejecting this the average for the seven others reared in running water would be 57. To attain this average size it may well have required at least nine moults after the fifth stage.

It seems then not improbable that this Astacus, under these conditions moulted at least a dozen times while growing to a length of over two inches in the first five months of its life. Four stageswere observed in the first two months when the length had not extended to four-fifths of an inch, and probably twice as many stages were necessary in the following three months to bring the length up to over two inches.

The only previous records of the rate of growth of young Astacus seem to be those of Soubeiran, Chantran, and Steffenberg. Soubeiran ('65) from measurements of a crayfish in a French crayfish farm concluded that they did not moult more than once in the first year, and were 50 mm. long when one year old. Chantran ('70) thought the young crayfish moulted five times in 85 to 100 days of July, August, and September and no more till the end of the next April. The first moult was at ten days after hatching and the other four at intervals of twenty to twenty-five days each. These results were modified by his further studies, also in the laboratory, and later ('71) he stated the number of moults in the first summer was eight and that the temperature influenced the number of moults so that there were six in the second summer, if hot. Finally Steffenberg ('72) gave the lengths of the Astacus larvæ in Sweden as 8.5 mm. at hatching; 11 mm. in the second stage; 13 mm. in the third stage; 15 mm. in the fourth stage.

Astacus leniusculus thus agrees closely with the Astacus of Sweden in the length of the larva in the first, second, third, and fourth stages. As far as the facts go it seems evident that *Astacus leniusculus* probably has more larval stages than have been described for the first year young of the French Astacus, but the differences are probably due more to difference in food and in temperature than to any innate differences in the species.

With this close agreement in larval life between the American and European Astacus and the demonstrated success of rearing in the laboratory the large young from the eggs brought overland, the culture of the American Astacus should be as successful when undertaken as has been crayfish culture in Europe. As elsewhere remarked (Andrews, :06[3]; :06[4]) the introduction of the western *Astacus leniusculus* into Eastern waters might not only prove of economic value but also help to throw light upon the interesting problem of the nature of the causes that have brought about the present remarkable geographical distribution of crayfish. And the geographical distribution of crayfish is intimately connected with the origin of species in this group.

Cambarus affinis.

As elsewhere described (Andrews, :04) this common crayfish of Maryland and adjacent States lays its eggs in the spring, and the development of the young can be followed in the laboratory. Preparatory to laying, the females carefully cleanse the parts of their bodies to which the eggs are to be attached and the eggs flow out of the oviducts into a mucous mass which covers the pleopods upon which, after some special "turning" movements of the female, the eggs are found attached each by its own stalk (Andrews, :06).

The hatching young thus find themselves upon the abdomen of the parent and here, as in Astacus, there are special contrivances which prolong the connection of parent and offspring for some time after hatching so that the attainment of a free and independent existence is a slow and gradual process.

The special arrangements used in the attachment of the egg and of the larvæ in the first and second stages form a series of interesting adjustments between the adult and the next generation. These successive means of association of mother and offspring will be described in what follows.

We will first consider the egg and the maternal appendages.

The eggs, while numerous, three to six hundred according to the size of the female, are small, scarcely 1.5 mm. as compared with 2.5 mm. in *Astacus leniusculus*. Some few become fastened to setæ upon the abdominal sterna but most are fastened to plumose hairs upon the pleopods of the second to fifth somites inclusive, and some account of these pleopods may be given here in connection with questions as to how the eggs and larvæ are attached to the mother.

The posterior face of the fourth left pleopod of a female about to lay is represented in figure 44. It will be noted that the endopodite is longer than the exopodite, and both bear a fringe of long plumose setæ on their right and left edges. The setæ are shorter toward the base of the exopodite and of the endopodite while on the protopodite there are but a few plumose setæ in two tufts upon the inner edge. The long setæ make of the pleopod a wide fan or flat brush since the setæ lie close together and like the wing feathers of a bird form a rather flat firm expanse. The protopodite has a basal part containing several calcified plates in a soft membrane, and a long segment that is well calcified except for a triangular soft area toward its base on the posterior face. The endopodite is made of two segments and the exopodite of one. The endopodite and the exopodite are also somewhat annulated in appearance owing to the grouping of the cement glands. The groups are opaque white and from each side tend to run together across the posterior face. Distally they do not meet but proximally they meet and make cross bands. Still farther toward the base the glands cover the entire surface more and more completely. The non-glandular areas are clear and not opaque, and in the figure are represented dark.

The anterior face differs from the posterior (fig. 44) in a greater development of glands which formed transverse bands more nearly all the way to the tip. As so many of the glands are to the right and left near the setæ, they are well placed to smear their secretion over the setæ.

Toward the tips of the pleopods the exoskeleton is so translucent that with Zeiss 2 D, the striation of the muscle fibers, the branched connective tissue cells, granular blood corpuscles, and the polygonal gland cells may be seen. The gland cells are about the diameter of a muscle fiber and larger than a blood corpuscle.

In most cases the plumose setæ spring from over the glands, and the base of a seta is as thick as two gland cells. The setæ have a large central cavity and a thick wall which is highly refractive and clear and is of unequal thickness so that it projects into the cavity in lumps or waves, and gives the distal part of the axis of the seta a somewhat segmented aspect. At the base each seta is articulated to the exoskeleton, and its central cavity is constricted by a clear refractive thickening of the wall that leaves very little communication between the cavity of the setæ and the cavity of the body.

The side branches of the seta spring out not only along its sides but also, scatteringly, along its posterior face so that the plumose seta is more like a bottle brush than like a flat feather. While the side branches generally make a wide angle with the main axis, toward the tip they become more nearly parallel with it and thus a fine terminal brush is formed by the main axis coming gradually to an acute point in the midst of the surrounding side branches.

The eggs are fastened to these plumose hairs by a secretion that probably comes out of the glands of the pleopods (Andrews, :06^{a}). They then look as in figure 45, which represents the anterior face of a pleopod cut off in the afternoon of April 18, 1905, from a female that had laid the night before. Most of the pleopod is concealed by the eggs which are opaque yellow balls and very elastic. The plumose setæ are all bound together by a common cement or mass of glaire so that the individual setæ are not seen. From this mass a clear, flat, glassy band of material goes out to each egg. Upon separating the eggs these bands are seen as clear, flat stalks, continuous at one end with the mass that binds the setæ together and at the other end with the envelope about the egg. While the shorter bands are flat and wide the longer bands are more string-like and some few are twisted. Though these stalks may cross one another and be more or less intertwined they are not fastened to one another. As the setæ spring chiefly from the side of the pleopod and the eggs are tied to the setæ, the eggs may be combed out, as it were, into groups on each side of the endopodite and of the exopodite. Where the stalk joins the egg it is enlarged as a bell, or tent, full of liquid and its edges are continuous with the outer layer of the egg capsule.

Each egg had then its own separate stalk, though a very few exceptions showed two stalks connected with an egg at different points and with a common extension running over the surface of the egg from one stalk to the other.

Thus very firmly attached to the mother, the eggs are waved back and forth by the mother who regulates the movements of the pleopods in accordance with the oxygen supply in the water, and thus they slowly develop till they hatch. The old egg cases and stalks still remain fast to the pleopods, and are of use to the larva as a means of prolonging its life of dependence upon the mother.

We will next describe the way in which the first larva is connected with the mother.

In hatching, the larva comes slowly out of the egg capsule through a rent along its back, in such a way as to draw out the legs and abdomen last of all as represented in figure 8 in a previous paper (Andrews, :04). In fact the tip of the abdomen remains inside the egg case long after the soft, helpless larva is extruded and left dangling down into the water. And all these newly hatched larvæ would fall to the bottom were it not for a firm attachment of the tip of the abdomen inside the egg case. As it is some time before the respiratory movements become perfect, as the limbs only gradually acquire ability to move, and as the body is globose and the creature cannot stand on its legs, the larva would probably perish but for this temporary fastening of the abdomen that tides it over the weak period till it can reach up and take hold of the egg stalk as indicated in figure 9 of the above paper.

This attachment of the abdomen is the same phenomenon found in Astacus and is brought about by a telson thread; but as the eggs and larvæ of Cambarus are so much smaller and as the tip of the abdomen remains inside the egg capsule the facts are not so readily made out and in a previous notice (Andrews, :04) the telson thread was spoken of as proceeding from the anal region, though further study shows it to be fastened to glandular spines of the telson edge as in Astacus.

In *Cambarus affinis* the tip of the abdomen is fastened by a short thread to a crumpled membrane which lies inside of the spheroidal egg case and is firmly fixed to the egg case on the side near the stalk. The short thread and the membrane together are comparable to the long membranous thread that in Astacus allows the larva to hang far down from the egg case. For convenience we will describe the two parts of the telson thread separately. The short part fastened to the abdomen remains on larvæ 48 hours old though then broken off from the more membranous part inside the egg case. The short part may be whipped up and down in the water like a lash when the larva flaps its abdomen (fig. 50).

At hatching, the telson (fig. 46) is a simple rounded, translucent lobe, with minute spines on each side of the median plane, which formerly fastened it to the telson thread. In this ventral view of a recently hatched larva the pleopods of the fourth and fifth somites are seen free while the sixth somite has its pleopods as lobes inside the telson on each side of the anus. The terminal part of the telson is traversed by radiating lines which point to spines along the edge of the telson. These lines are in reality rows of cells that are to make the plumose setæ of later larval stages and the rest of the translucent flat telson is filled by a parenchymatous mass traversed by blood spaces in which float blood corpuscles.

The telson thread arising from the edge of the telson is a flat band that is readily twisted and shows a striation due to fine wrinkles of the stiff chitin-like material composing this very strong but thin and translucent membrane.

Twenty hours after hatching, the telson had changed form, become more quadrangular and its terminal part was somewhat three lobed (fig. 47). And as the spines to which the telson thread was attached were all on the middle lobe it seemed as if the pull of the telson thread might have aided in making the middle region protrude as a lobe. At this time the cuticle of the larva was separating from the body in preparation for the moult from the first to the second stage.

While the form of the telson is thus so different from that of Astacus (fig. 20), the mode of attachment of the telson thread is fundamentally the same. Figure 48 shows the tip of the telson of a larva torn out of its shell just before hatching; the thread is fastened to five or six spines on each side of the median plane in the same way as in Astacus (fig. 21). Thus nearly the same number of spines are specialized in both crayfish for attachment of the thread though in *Cambarus affinis* the entire number of spines is much less and they are found only on the posterior part of the edge of the telson.

All the spines are glass clear, ice-like in refraction; the lateral ones are bent toward the tip of the telson and the five or six specialized glandular spines converge toward a center as shown in figure 48. The lateral spines toward the posterior end tend to show blunt brushes and secreted lobes at their tips, and thus form somewhat of a transition to the effective specialized spines.

These specialized central spines are much longer and thicker and bent, often at right angles. Some are fused together by their blunt ends and all seem to have flowed out at the tips as a mass which is now fibrous and which binds all of them to each other and to the telson thread. They seem comparable to paste tubes which should squeeze out a myelin-like substance that could coagulate as strong fibrils.

The appearances suggested that the rows of gland cells that later make the plumose setæ of the later larva, had previously, in late embryonic life, secreted a substance which oozed out of the hollow spines and set into a firm cement; but these cells no doubt were also active in making the cuticular walls of the spines themselves, and no sharp line seemed drawn between the substance of the cuticular spines and the material that issued out of their tips. Both are presumably the same exoskeleton and made from ectoderm cells that later make other exoskeletal secretions in the form of plumose setæ. In Astacus (fig. 21) the distinction between spine and secretion was more evident, but in this Cambarus (fig. 48) the spines are so minute that details are not as readily seen.

While the mode of attachment of the telson thread to the telson is thus the same in Astacus and in Cambarus, the thread itself differs in appearance in the two crayfish, in the former being pulled out into a long thread, in the latter being for the most part a wrinkled mass of membrane within the egg case. While in Astacus the thread is apparently a cast off embryonic skin, this is by no means obvious in Cambarus and an interpretation of its meaning was had only from the following facts. When an egg ready to hatch was scratched with a needle the outer egg case came off and the larva popped out alive but still enclosed in a thin spheroidal membrane. This membrane was firmly fastened to the outer egg case by one small area towards which the legs converged and which lay opposite the claws. When the egg case was pulled it remained so fast to the membrane that both were drawn out of shape rather than separate. The part of the egg case attached to the membrane was often near to the stalk of the egg case, which led one to infer that the attachment of egg case and membrane and the making of the egg stalk might have some common cause very early in the life of the egg, but no observations were made to decide this. Left to itself a few minutes, such an embryo removed from the shell burst the membrane without the aid of the egg case. Its telson was fastened by its special glandular spines to the inside of the membrane, and soon it reached about with its claws and seized hold of the membrane. This bag-like membrane was thus the same thing as the telson thread of normal hatching. When dissected from an embryo this membrane was seen to be a bag fast to the telson spines, but with no observed special envelopes for the limbs as would be the case were it a cast skin. Before hatching, the membrane was stretched tightly all over the abdomen except where the two special groups of glandular telson spines were, and there the membrane was raised up as two swellings, one right and one left, much higher than the spines themselves. The space between the membrane and the spines was occupied by a mass of seemingly liquid lumps which in some cases with 4 D showed a finely fibrous material amongst the clear spines which, in places, extended out to the membrane like a fibrous coagulum binding the spines to the membrane. On the median line the membrane was close down against the telson so that the secreted masses right and left seemed to have locally pushed the membrane away from its original connection with the telson.

This membrane was well developed in embryos of stages J to K of Reichenbach but upon dissecting, these embryos dropped out of the membrane, as the telson was then not yet fast to the membrane, though the membrane was firmly fastened to the egg case near the stalk. In the early stage F there was also a membrane over the body and this was loose over the slightly projecting, small abdomen.

It seems probable that the telson thread of Astacus, which is a cuticle formed over the embryo when its limbs are well advanced and thus has tubular outgrowths to cover the limbs, is represented in Cambarus by a telson thread having the form of a sac-like membrane formed so early that the small limbs receive no special envelopes. In both cases there is a special outgrowth to cover the abdomen, but while in Astacus this is a long bag, in Cambarus it is scarcely recognizable as a separate region.

In both, by some unknown process that is imagined to be associated with fertilization phenomena, the membrane is made fast to the outer egg case, and in both the membrane becomes fastened to the embryo by the activity of certain telson glands. A diagram of Astacus would represent it as escaping from a cuticle when hatching, a cuticle fastened to the egg case at one point, and near that point fastened, inside, to the telson of the larva. A diagram of Cambarus would represent it as casting off a membrane at hatching which is fastened as in Astacus but lacks the tubular coverings for the limbs. Here again the small size of Cambarus may have led to misinterpretation of what is plain in Astacus.

Having described this temporary, mechanical association of parent and young we will next consider the more active association that lasts during the rest of the first larval period.

The larvæ, supported for a time by the telson thread, soon established a second connection with the mother by seizing hold of the egg case, the egg stalk, or in many cases the matted pleopod setæ, with their chelæ, and thus, for a time, were fastened both by the telson thread and by the chelæ. While the eggs hung loosely from the pleopod, figure 45, the young crayfish had the habit of reaching in their chelæ as far as possible amongst the egg stalks and pulling themselves close to the pleopods so that they became densely crowded together in a solid mass (fig. 52). In life this mass of young covering the pleopod is a curious sight suggesting mammalian young crowding for maternal milk. Each held itself close to the pleopod, and when disturbed drew itself all the closer as if eager to remain. The part exposed to view is chiefly the rounded head-thorax which is flesh-colored but is conspicuously marked by the enclosed saddle-shaped dark yolk. Here and there the legs and abdomen are seen in profile (fig. 52), but generally the abdomen and legs are under the body, the abdomen being bent somewhat as in a brachyuran (fig. 50) and a full dorsal view shows chiefly the simple head-thorax (fig. 49). The larvæ thus seem egg-like, inert and inactive.

The long-stalked egg cases stand out above the backs of the larvæ as do also a few belated eggs which may hatch some forty-eight hours after the rest (fig. 52). By this time many of the larvæ have broken the telson thread and when disturbed make slight movements with their legs and flap the abdomen to which is fastened, like a small handkerchief, the narrow telson end of the thread, while the membranous sac remains within the egg case.

So closely do the larvæ crowd together that only few of the pleopod setæ can be seen. Figure 52 represents a case in which some of the larvæ had been removed.

While the color of the first larva is light flesh-color to the naked eye, under the microscope the creature is clear, and colorless, except for the scattered, arborescent, vermilion pigment cells over the carapace, abdomen, basal parts of antennæ and some few segments of the legs, and except for the reddish pigment in the eyes and for the large red-brown yolk mass.

The shape of the larva when alive is retained very well in specimens killed in Worcester's liquid, though in many other liquids the head-thorax swells and is abnormally globose, while the branchiostegites roll back and expose the gills.

In neither the dorsal nor the side view (figs. 49, 50) can the rostrum be well seen, but in a front view (fig. 51) it is seen to be pointed, though so bent downward between the eyes as to be of no use as a protection.

The body is thus rounded and embryonic in proportion and lacks all the angularities of adults or of active larvæ.

With the clinging helpless state of the larvæ is associated a lack of ordinary use of the antennæ. The second antennæ, which in larval and adult life of crustacea are carried out in front of the animal, are here folded down under the thorax (fig. 50), between the right and left series of legs. This peculiar position of the antennæ is not found in Astacus and here is brought about at the time of hatching, for in the embryo these antennæ grow backward along the edge of the carapace external to the bases of the limbs. Soon after hatching the legs get astride the antennæ and this apparently useless position of the antennæ is maintained during the rest of the life of the larva in its first stage.

This peculiar position of the antennæ as well as the down bent rostrum were observed in another species of Cambarus, *C. rusticus* by Faxon ('85); and later Steele (:02) described the rostrum as bent down in *C. gracilis* and in other species and the legs, antennæ and abdomen of *C. virilis* as lying under the thorax; thus it seems possible that the first stage of Cambarus in general differs from Astacus in these characteristics of the antenna.

The appendages of *C. affinis* in this first stage resemble those of *Astacus leniusculus* in being without the setæ of later stages, but they differ not only in being very much smaller but in being, in some cases, more simple. Thus the first antenna (fig. 53) has only four segments in the endopodite and in the exopodite in place of five, and the tip of the endopodite bears no sensory club.

The antenna (fig. 54) is remarkably short, as is seen on comparing that figure with figure 7, and figure 50 with figure 3. The filament is bent back and has but twenty-five segments, or about half as many as Astacus. In the adult there may be 150 segments. Carried as it is under the thorax it reaches only to the beginning of the abdomen while in Astacus the antenna if in such a position would reach about to the end of the abdomen when stretched out.

The mandible (fig. 55) has the same simple form as in Astacus (fig. 8).

The first maxilla (fig. 56) is like that of Astacus (fig. 9), but more simple in lacking the few filose setæ and in having fewer spines.

The second maxilla (fig. 57) as in Astacus (fig. 10), has a row of plumose setæ along the entire edge of the scaphognathite and is elsewhere as simple.

The maxillipeds (figs. 58, 59, 60) represent in miniature the structure seen in Astacus (figs. 11, 12, 13) with slight increase in smoothness due to the presence of fewer setæ and spines. There are important simplifications, however, in the gills which in some cases have but half as many side filaments as in Astacus.

The chelæ (figs. 61, 62) have the same recurved tips as in Astacus. Soon after hatching the larva opens its claws widely (fig. 50), and after some failures fastens them to the egg stalk, or to the setæ of the mother's pleopods. Once firmly locked in the hardened secretion that makes the egg stalks and binds the setæ together, these larval chelæ remain fast during the first stage. And even after the larva has escaped from its cuticle and passed into the second stage the old cuticles are left firmly hung to the mother by the cast-off chelæ.

As in Astacus the chela has at first a cutting edge set with a row of few and simple spines, but when the first larva is ready to moult, the loosening of the cuticle reveals the fact that each spine will be replaced by one that is serrated (fig. 62), owing to the presence of flat plates along the posterior face of the new spines. In addition the second stage will have on its claw some spines not represented in the first stage and also near the tips of the claw some long, simple setæ in place of the blunt spines there in the first stage. This figure shows that the recurved tips will be abandoned in the second stage since there are already formed tips that are but slightly curved hooks, to take the place of former recurved tips, one of which was broken off in this specimen.

The chela besides being so small and weak, is inferior to that of Astacus in having its gills less developed, the anterior arthrobranch being very short and simple and with but few side filaments.

In the four walking legs (figs. 63, 64, 65, 66), we find the same proportions as in Astacus but the pleurobranchiæ are absent and the arthrobranchiæ are more simple, especially the anterior ones.

The branchial formula for the first stage is thus the same as in the adult and is as follows:

	Podobranchiæ.	Arthrobranchiæ.		Pleurobranchiæ.	Total.
		Anterior.	Posterior.		
Somite of 2d maxilliped	1	1	0	0	2
Somite of 3d maxilliped	1	1	1	0	3
Somite of chela	1	1	1	0	3
Somite of 1st walking leg	1	1	1	0	3
Somite of 2d walking leg	1	1	1	0	3
Somite of 3d walking leg	1	1	1	0	3
Somite of 4th walking leg	0	0	0	0	0
	6	6	5	0	17

That the pleurobranch of the last thoracic somite of Astacus was absent from *Cambarus rusticus* larvæ 4 mm. long and evidently just out of the egg was observed by Faxon ('85) and it is probable that no members of the genus Cambarus have remnants left in the early larvæ of that pleurobranch still found in Astacus.

As in Astacus the abdomen in the first stage of *C. affinis*, just as in some other species of Cambarus studied by Faxon ('85), has only four pairs of evident pleopods. The sixth pair are but partly formed and enclosed within the telson while the first pair exist here as minute buds readily overlooked and not found in Astacus nor as yet described in other species of Cambarus. The four evident pleopods (fig. 67) have equal exopodites and endopodites in contrast to the proportion found in Astacus (fig. 19). The beginnings of the first pair of pleopods are but minute rounded elevations of the sternal ridge of the first somite (as indicated in fig. 3; Andrews, :06), and contain a small mass of nucleated epidermal cells. The appendages of the sixth somite are large internal buds that cause the side part of the telson to be very thick as they fill all its interior on each side of the anus. As this region is very translucent each pleopod can be seen to have a long outer and a short inner lobe (figs. 46, 47).

The first larva is in several ways more imperfect than the same stage in Astacus, and as it lives inactive and fastened to the maternal pleopods it seems but an extension of the embryonic period in preparation for the second stage, and not at all a self supporting organism. The second stage is made way for by the gradual loosening of the cuticle of the first stage, as above noted in case of the claws of the chelæ, and by the addition within the old cuticle of the new exoskeletal structure of the second stage. This was evident in the telson of a larva twenty hours after hatching, where the old cuticle was raised up the length of the old telson spines and new spines had grown out across this space to enter the hollows of the old spines. Later, just before the moult, the space between the old and new cuticle was twice the length of the old spines, which were still fastened to the remnant of the telson thread, and the new spines still projected across the space into the old hollow spines.

The moulting into the second stage took place after the first stage had lived this dependent and preparatory life for about forty-eight hours and the larva resulting had the form shown in figures 68 and 69. These second larvæ unlike the second stage of Astacus did not gradually become separated from the mother and live isolated, but remained again adhering to the pleopods till a second moult brought them into the third stage which was the first free larval form. Thus the pleopods were still covered with the crowded larvæ. Figure 70 represents a pleopod with only part of its load of second stage larvæ as many had been removed.

In the following description it will be shown that in the second larva also there is a peculiar temporary mechanical connection of young and parent.

Each pleopod in life was covered as with a mass of animated jewels of pink and garnet colors. The flesh-colored larvæ were still strongly marked by the yolk that remained in each as a garnet red mass of saddle-bag shape. No longer firmly fixed by the chelæ, the larvæ soon reached about for firm objects to which to hold, or kicking their legs about, swinging their pleopods and flapping their abdomens formed an animated restless mass quite unlike the inert one seen in the previous period. Thus active, though holding fast, the larvæ were no longer densely crowded in close to the pleopods as in the first stage (fig. 52), but loosely aggregated (fig. 70).

The old larval cases shrivelled and not readily recognizable as more than crumpled membranes, still remained fast by their chelæ and the old egg cases were yet fixed by their stalks to the maternal pleopods. Side by side on old egg stalks were the pairs of living claws and the empty cuticles of old cast off claws. Thus the second larvæ lived amidst a mass of former envelopes,—the ghost-like phantoms of their former selves and the rigid cradles of those selves.

While many larvæ holding fast to the pleopod hairs and to egg stalks tend to pull themselves in close to the pleopod so that they become buried amongst the egg stalks and empty cases, a few larvæ at the periphery of the mass may dangle free in the water, as in the lower right corner of figure 70. These are larvæ which have recently cast off the first cuticle and are still in a soft, helpless condition. Before these larvæ succeed in reaching up and seizing hold of some part of the general mass they are in danger of falling to the bottom where they might be lost, though when they are removed it is found that they can stand and walk, with difficulty. However they seem strongly controlled by an instinct to climb, crawling over one another in heaps when removed from the mother and swimming only when thrown into Perenyi's liquid and possibly many would eventually climb up onto the mother. At all events they are prevented from falling away from the mother by a fine thread which, as indicated in figure 70, passes from the posterior end of the larva to the crumpled, cast-off cuticle which still is firmly fixed to the mother. This thread may be called the anal thread since it actually comes from the anus and not from the rim of the telson as did the supporting thread of the first larva.

But before discussing this anal thread some general features of the second larva may be considered. The abdomen is still carried bent down as seen in figures 69 and 68, but the cephalothorax is more elongated and narrow than in the first stage and ends in a sharp pointed toothed rostrum that projects out between the eyes and is only slightly bent down. The legs are longer and may now be used for walking and the antennæ stand out in front of the animal as if useful feelers, in strong contrast to their apparently useless position in the first larva (fig. 50). This increase in length and change of position of the antennæ gives the mass of young in the second stage (fig. 70) a much more living aspect than was possible in the first stage (fig. 52). The abdomen when straightened out is seen to end still as a simple rounded telson (fig. 71) with the large sixth pleopod still within it on each side the anus and with a terminal part that has its middle lobe set off but slightly from the side lobes. The edge of the telson bears only simple spines as in the first stage (fig. 46), and these spines are not divided into groups (fig. 72), but all seem equally useless since none act as glands and there is no telson thread formed in the second stage. The middle lobe bears spines all along its edge, some sixteen on each side replacing the fewer spines of the first stage (fig. 48). Passing in from each spine there is still a radiating line of cells which is active in making the plumose setæ which we miss in this second stage but which will be expanded in the third stage.

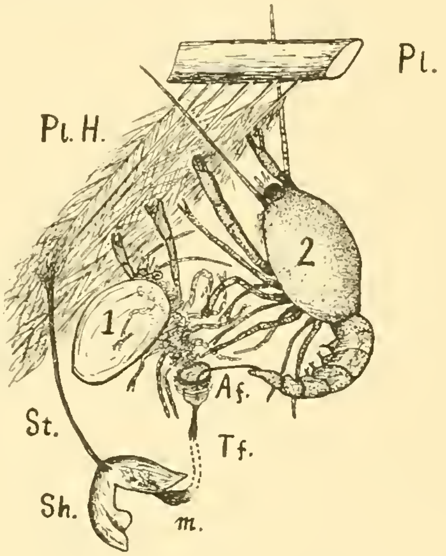
It is to the larva of the above structure that the anal thread is fastened and this may now be considered in connection with this telson that has progressed so little beyond its first form. As seen in figure 71, the anal thread was in life a clear narrow ribbon running from the anus a distance greater than the length of the telson to be fast to a crumpled mass which proved to be the cast-off cuticle. This thread was fast at one end inside the intestine of the larva and at the other was fast to the cast cuticle by being continuous with it at the edge of the cast off anal opening. In fact the anal thread is nothing more nor less than the old cuticular lining of the intestine of the first larva still continuous with the cast-off cuticle of the abdomen and not yet entirely loosened from the intestine of the second larva. An examination of the recently shed larva showed that the cuticle of the larva had become loose all over the body and some distance into the intestine, but that farther in it still adhered to the epithelial lining of the intestine.

When the larva has moulted, the old cuticle of the abdomen is found to be telescoped and its old telson joined by a short cord to the new telson as shown in figure 73; A. If the old cuticle is then pulled with forceps it does not break loose but the thread comes out of the anus of the larva and is thus made longer, as shown in figure 73 B, by a shortening and crumpling of the intestine. There is thus a posterior part of the intestine (y) in which the old cuticle is loose and an anterior part (x) where it is still fast, the region (a) being the first place met with where the cuticle lining of the intestine does not pull away from the intestinal wall. Hence the region (y) is thrown into folds and the region (x) stretched and pulled bodily toward the anus when tension of the anal string pulls the region (a) toward the anus. The anal thread is the loose lining of the intestine as far as it is pulled out of the anus and while in origin a tubular cuticle it is stretched out as a flat ribbon which seems made of clear wire-like fibres, but in reality is only thrown into longitudinal folds due in part to the longitudinal ridges which sections show are present in the intestine. In figure 74 is seen more enlarged the region of the intestine where the loosened cuticle running up from the anus arrives at the region (a) where it is still fast to the epithelial walls, as made out in preparations cleared in Bela Haller's liquid.

Though actual ecdysis was not seen, it is evident that what happens in the moulting of the first larva to the second stage, is that the lining of the intestine for a certain distance up from the anus, delays in casting off its cuticle. The animal bursting out of its head-thorax cuticle and freeing its limbs from their cases would next pull its abdomen out of its old cuticle, but the old cuticular lining of the intestine remains firm where continuous with the outside cuticle at the edges of the anus, and acts like a string tied to the old telson and to the inside of the abdomen far up in the intestine. If the larva then drops out of its cuticle and is too weak to seize hold of the old cuticle, or neighboring firm objects, it will dangle suspended by the anal thread and the tension on this thread will pull it out of the anus as far as possible. By puckering the posterior part of the intestine and by dragging the anterior part of the intestine backward there is thus drawn out of the anus an anal string which, however, is not as long as the abdomen, by any means. The old telson being a stiff plate and the old walls of the abdomen being elsewhere like the bellows of a camera, the pull of the weight of the larva along the telson thread drags the old telson against the cast-off abdominal rings and telescopes the abdominal cuticle as if the front board of a camera were pulled back against the bellows by a string inside. The tendency of the telson string would be to turn the abdominal cuticle of the cast-off case inside out as a hand holding fast to a sleeve would turn the sleeve inside out when the arm was withdrawn, but the presence of a firm, board-like telson at the bottom of the sleeve allows only a telescoping of the cuticle. By this means the old abdominal walls are so shut up that the free anal string from the old anus to new anus is no longer inside the old abdomen, but largely free in the water, as indicated in the diagram on page 54.

Soon after hatching, presumably, the cuticular lining of the intestine becomes loosened along the regions (*a*) and (*x*) and then the anal thread is pulled out from the intestine as is usual in moulting. In the meantime the larva becomes strong enough to reach about and take hold of the old larval skin or of other objects fastened to the pleopods and does not need the anal string as a means of support.

By this delay in the casting off of part of the cuticular lining of the intestine an advantage to the larva seems to result. Both in the first stage and in the second stage the larva has a mechanical means of fixation to its mother during the brief period when it is unable to use its claws for this purpose. Reviewing the life of the crayfish up to the third stage with the aid of a rude diagram (page 54), with reference to the association of mother and offspring, we have seen: the egg fastened to the pleopod setæ by a material that hardens soon after the egg is laid; the larva hung for awhile by its telson thread; then holding by its claws as well as telson thread till the latter breaks when claws alone hold it locked to the mother; then dangled loose as a helpless second stage supported by an anal thread till able to take hold with its claws and cast off the thread, that is, to finish the moulting; finally moulting again and as an active third larva living no longer mechanically bound to the mother, with whom it gradually ceases to associate. The mechanical supports, the telson thread and the anal thread, are left hanging with the egg stalks, egg cases and the other part of the cast off membrane and cuticle; all fast to the pleopod setæ which are bound together in a secreted mass. All this material soon disappears, apparently being eaten up by the third larva before it leaves the mother to hunt other food in wider fields.



Explanation of Diagram.

Pl. = pleopod of mother; Pl. H = setæ of pleopod; 1 = cast cuticle of first larva; St. = egg stalk; Sh. = egg shell; M. = membrane inside shell; Tf. = telson thread, which is broken; Af. = anal thread; — second stage on the mother's pleopods held by anal thread till the claws have taken hold.

Of the two threads which we here describe as mechanical means for preserving the association of the mother and offspring and prolonging the maternal protection beyond the egg stage over larval periods that are especially helpless and not self supporting, the first, the telson thread, is a secretion of glands active before the larva hatches combined with an adherence of the larval envelope to the egg shell that was determined very early in embryonic life. The second thread, the anal thread, is a much more simple and temporary attachment brought about by a delay in casting off the cuticular lining of the intestine and thus utilizing what is cast off as a means of keeping the larva fastened to its old cuticle till the claws can lay hold of some firm object.

When the second larva finally becomes fastened by its claws it remains some six days in a condition of little activity. It is dependent upon the mother for physical support though in a state intermediate between the invariably fixed first larva and the wandering third larva. The shape of the claws (fig. 84) shows that they would not become as firmly locked as did the claws of the first larva (figs. 61, 62), though they might stick firmly into soft material.

When larvæ in the second stage were put into Kleienberg's picrosulphuric they flapped their abdomens for some minutes but did not loosen their claws from the pleopod of the mother; when put into alcohol, however, they dropped off, and when into Worcester's liquid they all broke loose and fell to the bottom where they lay kicking their legs for some time as they were not so readily killed as were the third larvæ.

The second larva lives much as did the first larva and in structure is very like it but it differs not only in the above mentioned characteristics of the telson and mode of fixation to the parent but also in the size, proportions, and amount of armament with setæ of some of the appendages as will be seen when the nineteen pairs of appendages are taken up in sequence.

The first antenna (fig. 76) has grown much longer than it was in the first stage (fig. 53), and the basal segment of the exopodite has divided into two so that there are now five in place of four segments. And as the figure shows there are now a few setæ upon endopodite, exopodite, and protopodite and of these there are five blunt sensory clubs on the inner face of the exopodite. Two of these are close together on the distal end of the fourth segment, two are close together on the swollen basal half of the fifth and the remaining one stands alone on the narrow terminal half of same segment. The ear is still a simple deep pit without as yet any setæ along its edges but with only seven or eight spines or teeth seen with 2 D along its external edge where the second stage of Astacus has plumose setæ.

The second antenna (fig. 77) has greatly grown in length and in perfection of form and as above noted (fig. 69) is no longer carried in the remarkable position it occupied in the first stage (fig. 50). Yet while in a position to be of use as a sense organ the antenna is still markedly lacking in setæ: the exopodite scale bears only a row of few spines and the long endopodite bears but a few acicular setæ toward its tip. With its increase in length there has been also an increase in number of segments in the filament which has now 36 beyond the three large basal segments in place of the 22 of the first larva.

The mandible (fig. 78) has added a row of small acicular setæ along the medial face of the end segment of the palpus, and developed sharp teeth along the heavy cutting edge of its base. When the palpus is folded down into the hollowed face of the mandible two teeth are dorsal and five ventral to the tip of the palpus.

The first maxilla (fig. 79) has changed but little, but its spines are longer and sharper and it has developed a few, minute, acicular setæ.

This stationary state is still more pronounced in the case of the second maxilla (fig. 80), which has only grown sharp setæ in place of the blunt terminal spines. The changes in the first maxilliped are also the development of setæ in place of spines and the addition of a few setæ (fig. 81).

In this second maxilliped (fig. 82) this substitution and addition of setæ is more pronounced but there is a noticeable retrogression in the gill which is more simple, no longer having any lateral filaments.

The third maxilliped (fig. 83) again, as compared with the first stage (fig. 60), has quite long acicular setæ in place of blunt spines, and a few sparsely plumose setæ, noticeably a group at the tip of the exopodite. While the posterior gill is longer the anterior is here also somewhat reduced.

The chela now used as before for clinging to the mother has its tips somewhat recurved (fig. 84), but they are much straighter than in the more firmly fixed first stage (fig. 61). There are added a few acicular setæ and the claw is more like the adult in the development of rasp-like spines along its edges in place of the simple spines of the first stage which, as seen in figure 62, were being replaced during the first stage by the toothed spines of the second stage.

The four walking legs (figs. 85, 86, 87, 88) have changed chiefly in the addition of a few terminal setæ and of a few exopodite, thread-like setæ.

The branchial formula is thus the same in the second as in the first stage.

On the abdomen the four functional pairs of pleopods (fig. 89) are now long and slender but very simple and not yet fringed with setæ, though the spinules on the edges of the exopodite and endopodite are more numerous than in the first stage.

The appendages of the first abdominal somite exist as yet only in the form of minute round knobs (fig. 4; Andrews, :06), but slightly larger than in the first stage. The appendages of the sixth somite are still within the telson (fig. 71). When the larva is nearly ready to moult into a third stage these pleopods make the telson protrude laterally more than in the above figure through the substance of the telson, allowing one to see the form both of the pleopods and their setæ. When they are expanded, at moulting into the third stage, these pleopods have the appearance shown in figure 90.

The second larva remained fastened to the mother for six days, apparently eating nothing, and as the yolk-mass gradually diminished it seems probable that the larva still subsisted upon the original supply of energy taken from the ovary as yolk. Before the moult into the third stage the gastroliths became quite conspicuous as blue areas showing through the body on each side of the stomach.

The actual moult occupied but a few minutes and as usual the head-thorax came out of the old shell first, then the legs were withdrawn from their cases and finally a few flaps of the abdomen freed the larva completely. There being no telson or anal thread this time, the larva at once left its old cuticle and climbed upon the pleopod of the mother. The increased strength and size of the larva with the perfection of its limbs and caudal-fan would make the danger of being lost on falling away from the egg much less than it was in the preceding stages as the larva was now well able to follow its strong instinct to crawl upward and so recover its position on the mother, or, failing that, to live independently, as it soon did.

In the following description of the third larva we will emphasize its manner of association with the parent.

In general form the young crayfish in this third stage (figs. 90, 91) is now for the first time like the adult, yet the great size of the eyes and of the exopodite scales of the antennæ together with the very wide expanse of the tail fan and its long swimming plumes give the larva the aspect of a pelagic larva or of the adult of some lower form of marine decapod. In fact the ability to swim freely in great leaps which the third larva soon exercises and the translucency of the body together with the big eyes and long antennæ and very slender long legs and chelæ make the larva seem much like a small shrimp.

The rostrum is now directed straight forward and is armed with large lateral spines that exaggerate the gothic style of the adult. All the appendages are now provided with long setæ which make them sparsely hirsute as seen under the microscope, but only on the exopodite scale of the antenna and upon the telson and sixth pleopods are the setæ set in rows that suggest a locomotor function. The use of the row of plumes on the scale of the antenna is not obvious but the long plumes all along the edge of the telson fan seem to add to its area effective in locomotion.

The animal was still translucent and within it the liver showed as a narrow green band external to the large mandibular muscle, extending forward a short distance and backward nearly to meet its fellow in the region of the heart.

The sixth pleopods were now no longer inside the telson and the telson had become specialized as in the adult into an anterior and posterior part separated by a distinct movable hinge. Through the clear dorsal exoskeleton was seen the anus and a large mass of muscle on each side in the anterior region and in the posterior part of the telson the old radiating glands, which had eventually perfected the long setæ that a high power showed to be plumose.

The pigment cells represented by dark dots in figures 90 and 91, had become more numerous than before but were still chiefly arborescent red cells, though in many regions there were large blue cells not represented in the above figures though they now altered the ground tone of the animals. Posterior to the eyes the crowded pigment cells formed a streak along the base of the lateral spines and more to the rear a rounded area over the attachment of the great mandibular muscle. This round area on each side was especially conspicuous from the dense crowding there of blue pigment mixed with red. The dark aggregation of pigment cells across the anterior edge of the abdomen still remained. The yolk area and its color were quite gone and on each side of the stomach a blue area indicated the gastrolith. Owing to the fineness of the network of pigment cells on the tips of the chelæ these areas appear conspicuously dark red.

While the young in the third stage still remained on the mother for a while, they were free to move about and soon became more and more independent. A few hours after moulting some of the young were found walking about on the bottom of the aquarium. When disturbed they leaped backward and upward several inches by strong strokes of the abdomen and looked not unlike shrimp, while, when they walked, their habit of holding the anterior part of the body high up in the water as well as the attitude of the slender chelæ gave them the alert, nervous look of shrimp-like creatures and made them look very unlike the adult.

The young climbed about on the pleopods of the mother, over her side and back, upon her mouth parts and eyes and, though at first densely crowded under the abdomen of the mother, more and more frequently they walked off to greater distances, always returning to the abdomen if possible. The same larvæ that at times left the mother in the water, clung fast to her when she was lifted out of the water. But by violently shaking the mother in the water all the young could be shaken off. When two days after moulting into the third stage some sixty larvæ were thus shaken off and left in the same dish with her all but twelve had returned to the mother's pleopods in twenty minutes. As many as a hundred young were seen walking about the aquarium and climbing up onto water plants for a time and later all but a few had returned to the mother.

At first, however, the young did not wander far from the mother and when in a darkened aquarium the mother stayed in one spot for two hours the small fæcal casts of the young over the bottom of the aquarium were almost all very near to the mother.

In about a week this association of mother and offspring was gradually given up and more and more of the young failed to return to the mother.

In nature it is possible that the mother and young separate quite soon, especially if the mother wanders about, but as yet nothing is known of the natural life of this craytish when carrying the young. It may be that the female then lives in holes or cavities and then the young might long remain with her. In captivity the females with eggs will dig holes in the mud and live in them as long as the water is well aerated, but come out when the water is not running. When kept in a small dish the female had no chance to escape from the young and in some cases some of the young remained with the mother and crawled over her three weeks and three days after leaving the egg, but when such females were put into a large tank they walked away and hid themselves, leaving the young scattered about.

Possibly the restricted artificial conditions both prolonged the duration of association of mother and young and lessened the variety of external stimuli so that there was a certain amount of domestication. By close confinement and by supply of abundant food to be given the mother and young without effort on their part, it would appear possible to make of the crayfish a domesticated animal with a more prolonged association of mother and offspring. Such experiments would build upon the ground that the crayfish is preëminently a creature in which embryonic life has been continued on as a series of stages, ancestrally free, but now dependent upon the mother and with special organs to ensure that dependence.

The young that came down from the pleopods took food and eagerly devoured fragments let loose from the mouth parts of the mother when she was feeding. At such times the young climbing on the mouth parts of the mother seemed in danger from those rapidly vibrating appendages but always seemed to be shoved aside and not devoured. When a couple of tubifex were put into the water and seized by a female, the young also took hold and either carried off pieces or continued to hold on while the worm was being dragged into the mouth of the female. Thus the young were drawn up with the food to the mouth of the female, but when between the maxillipeds the young leaped away and none seemed to be injured.

The accompanying illustrations (figs. 92 and 93), being from photographs of living crayfish in water but poorly represent the pinkish mass of active larvæ crowding under the abdomen of the mother or the separate young climbing over the back of the mother or walking about in the dish. They serve, however, to show the crouching attitude of the mother, the size of the young in this third stage and the general character of this active dependence of young upon mother which was long since admired by Roesel von Rosenhof (1775), and might be likened to the clustering of hen and chicks or of sow and pigs. Roesel von Rosenhof's statements regarding the association of the young and parent Astacus are as follows:

"Wenn die Mutter dieser kleinen Krebse, nachdem selbige sich zu bewegen angefangen, zuweilen bei ihrem Futter stille, oder sonst ruhig sitzet, so begeben sich solche von ihr etwas weg und Kriechen um zie herum; merken sie aber nur im geringsten etwas feindliches, oder sonst eine ungewönliche Bewegung im Wasser, so scheinet es, als ob sie die Mutter, sich zuruck zu begeben, durch ein Zeichen erinnerte; indem sie allezusammen geschwind unter den Schwanz zuruck fahren, und sich wieder auf einen Klumpen zusamensetzen, worauf sich die Mutter sammt selbigen mit mögligster Eilfortigkeit, in Sicherheit begiebt, welche sie aber etliche Tage darauf, nach und nach verlassen."

The suggestion of a possible signal to recall the young raises the question as to the nature of the means by which the young associate with the parent.

The interrelation of mother and young in the crayfish would seem a profitable field for study of comparative family life and the following few facts suggest lines of inquiry.

It is not evident that the mother gets any advantage from the clinging of the young to her body, though if in the third stage they eat off the old egg stalks and cases, the cleansing of the pleopods so caused might satisfy in the mother something akin to whatever it may be that causes her to laboriously cleanse that region just before the eggs are laid; but judging from the long endurance of the load of eggs and larvæ and from the frequency of dirt and parasites upon the pleopods it seems hardly probable that the female would feel an instinct gratified when the pleopods are clean again. That the female is at all conscious of the presence of the larvæ remains to be found out by evidence not yet at hand; however, when a lot of young were put into a dish with a male and they climbed over him he cleaned them off from his abdomen and seemed to be annoyed by their climbing over his head, but when the same young were put with a large female that had reared her own young long enough and naturally separated from them some weeks before, they climbed up onto her without her showing any evident sign of being affected by their presence upon her chelæ, thorax and abdomen. When a female was feeding and the young climbed upon her chelæ she did not seem aware of them but reacted eagerly to a tubifex near her chelæ. Whether, then, the young are simply tolerated, [as are the small parasitic leeches over the body of crayfish,] as a continuation of the eggs that are part of the body, or whether the females have special responses to stimuli given by the young is not known, but the former seems not improbable.

The young, on the other hand, act as if they were strongly affected by the mother but this may be due to a few simple reflexes and without any complex visual or other conception of the mother's existence. At all events there is no evidence that the young distinguish one female from another and when two mothers were in the same dish some young of one climbed up onto the other. Even when the young shaken off a female when they were in the third stage were put in a dish with a female carrying her young in the second stage they climbed up amongst the younger larvæ of the strange female and seemed content. When the young were shaken off two females in separate dishes and the females exchanged, the young climbed up onto the strange females; in a few minutes all but three were upon one female and all but seven or eight upon the other though she was moving about. Some young *C. affinis* in the second stage were taken off from the mother and put with some young of *C. Diogenes* of the second stage also removed from the mother and all were then put into a dish with another female *C. Diogenes* bearing young in the second stage. All the young got upon the foster mother and continued there, though the *C. affinis* were scarcely more than one-half the length of the other larvæ. The young that are shaken off dart, swimming, about in the water but soon settle to the bottom and climb up upon one another in heaps or try to climb up at the corners of the dish and upon water plants.

The tendency to climb onto the mother is very strong so that when a female walks along swinging her pleopods laden with young she often gathers up free young that are walking about, as these when touched by a pleopod may not spring away but turn and climb onto the mass. In fact early in the third stage a larva that fell to the bottom, apparently for the first time, stood with head end elevated and quickly responded to the presence of a passing pleopod. Even if lying upon their backs they quickly seize and mount the pleopod of a passing female. A piece of white cheese-cloth, however, did not appear to stimulate them to climb upon it and when a lump of rough cement, a model of a toad, was left in the aquarium very few got on it, most of them preferring the mother.

Possibly the young receive chemical stimulus from the mother that aids them in returning to her. That they responded to some chemical stimuli is most probable and the following facts may be interpreted on this basis. When the mother feeds, the young gather under her mouth and even after the food is gone they remain as if excited by chemical substances coming from the mouth parts of the female. It was also found that while the young climb onto a dead female and even over the exposed surface of the freshly broken abdomen, after some days they remain on the rest of the surface but not upon the broken surface where chemical substances due to decay probably existed.

During the time the larvæ in the third stage associate with the parent the large collections of old egg shells and skins on the pleopods disappear and are probably eaten up by the larvæ since their intestines contain minute setæ that might come from their old cuticle and since in Astacus, Chantran ('71) found that the larvæ eat their shells and cast off cuticles. It is therefore possible that one reason the young remain with the mother is that this food supply on the abdomen acts as a stimulus to them.

However, along with whatever chemotactic movements there may be, there are other factors concerned in the association of the young with the female as indicated by the few following experiments, which tend to show that the young are controlled in part by responses to light and to gravitation and contact. Thus when a small paste-board table was put under the water the young collected on the under side of the horizontal paste-board and remained standing upon it, in an inverted position. When the paste-board was then turned upside down the young scattered in a few minutes so that half were off the paste-board and some were under it in its new position. In crawling under such a table the young reared up and seemed to be trying to reach it above their heads as if influenced by it before they touched it. When a small glass table was used the young also collected under it and reached up as if trying to climb up to it. When dark paste-board was laid on part of the glass, above, twenty-two larvæ had collected under that part of the table shaded by the paste-board, in two hours, and none under the clear part.

It may be imagined from these indications that the larvæ in the third stage have a tendency to climb upward due to negative geotactic responses, that they prefer the shade as being photophobic and that they come to rest standing upon a solid object as being thigmotactic. Assuming some such responses together with some chemotactic phenomena, possibly all the habits of the young in reference to the mother may be explained; possibly not.

The association of the young and the mother, however brought about, endures in *Cambarus affinis* during two larval stages and a part of a third. In *Astacus leniusculus,* however, it is the second and not the third stage which gives up the association with the mother. Whether this is a generic difference cannot be determined without extensive observations, as almost no data are yet at hand. That Cambarus in general have three dependent stages seems probable from the following few facts that have been recorded.

Faxon ('85) saw specimens of *C. Clarkii* 7 mm. long upon the abdomen of the mother (as previously recorded by Hagen, '70), in which the tail-fan was perfect so that with the ability to lead a free existence there was still the habit of associating with the mother. In *C. affinis* larvæ in the first stage are 4 mm., in the second 5 mm., and in the third 7-8 mm. long, and it seems probable that the above recorded *C. Clarkii* were also in a third stage. The same author saw upon the mother *C. gracilis* 9 mm. and *C. Bartonii* 10 mm. long, with perfect tail fan. These two species may well have three stages of association as in *C. affinis*. Also he records *C. rusticus* just hatched and 4 mm. long as being so embryonic that we may assume they would remain with the mother as long as *C. affinis* does. On the other hand Steele (:02), who first observed the *living* larvæ of Cambarus associated with the mother, records *C. gracilis* 7 to 8 mm. long with a bent rostrum as if in the first stage though so large. And in a more detailed study of *C. virilis* she describes the first stage and then a second stage nine days old with the tail fan complete and other features of the third stage of *C. affinis*, but as she says the larva six days old could swim it seems probable that in both these species as in *C. affinis* there are three stages in the period of association, the second of which is easily overlooked.

There is then no obstacle to assuming that we may expect to find in Cambarus that the larvæ remain with the mother through a first, a second and part of a third larval stage and that in Astacus they remain through the first and part of the second only.

The active third larvæ becoming independent lived some eighteen days in all before moulting again to pass into a fourth stage and these in turn were followed through more stages till eventually adults were reared in the laboratory. Without describing the gradual changes of the early larvæ to the details of adult form we may now give a more complete record of the rates of growth of young crayfish than has hitherto been possible as a number of new observations have been added to those previously published, Andrews (:04), and certain points as to the period of sexual maturity determined. We will give certain facts as to the number of moults, as to the rate of growth, as to the development of the external male organs, as to the ratio of the sexes and as to the arrival of sexual maturity and the ability to breed in captivity.

Observations made upon the young of a single female which laid March 28, 1903, and whose eggs hatched May 18, 1903, gave the times of moulting and rates of growth of the larvæ represented in the following table:

Stages.	Dates.	Duration.	Size.	Increase.	Habit.
1st stage.	May 18–May 20	2 days	4 mm.	. . .	Attached to mother.
2d stage.	May 20–May 26	6 days	5 mm.	1 mm.	Attached to mother.
3d stage.	May 26–June 13	18 days	8 mm.	3 mm.	Associated with mother for about one week and then free.
4th stage.	June 13–July 1	17 days	12 mm.	4 mm.	Free.
5th stage.	July 1–July 6	5 days	15–18 mm.	3–6 mm.	Free.
6th stage.	July 6–July 17	11 days	21 mm.	3–6 mm.	Free.
7th stage.	July 17– ?	?	29 mm.	8 mm.	Free.

These same young were kept till October 6, 1903, without observation and the eight survivors then measured as follows: 62, 55, 53, 49, 50, 45, 43, 41 mm. in length. The average is nearly 50 and as far as can be judged from the above table such a large larva as that measuring 29 mm. in the seventh stage would probably have passed through at least four or five moults to become the large one 62 mm. long and smaller larvæ would have required as many or more moults if the increment was as large as in passing from the sixth to the seventh stage; but if the increase was the average for the above seven stages, scarcely 4 mm., then at least six more moults may have taken place. Other data show that the rate of growth is very different in individuals and in some cases seemed to depend directly upon food supply so that the number of moults during the first summer is probably not by any means constant but different in individuals. However, we are sure that at least seven stages may be passed through and probably eleven to thirteen larval stages may occur in the first summer of the creature's life outside the egg. Yet data given below show that the larvæ may remain but 20 mm. long in the fall, owing, probably, to insufficient food arresting them when in the sixth stage.

After October there were no moults till the following warm season, the lengths remaining constant during the winter. Just as the growth in the first summer was restricted to the five months of May, June, July, August, and September, so in the second summer there was an increase of 25 mm. during that time and though the moults were not observed there may well have been four or five during this second summer. In a few exceptional cases a moult took place in the early spring before May and a gain of 6 mm. was observed then. After a second winter of no moults there followed a third summer of growth in which a single observation showed that a specimen 70 mm. long December, 1902, was 76 mm. long July 1, 1903, an increase of 6 mm. probably due to one moult. As this same individual increased to 90 mm. by October, 1903, it probably moulted two or three times or in all three or four times during this third summer.

We thus have evidence for seven and probably as many as twelve moults the first summer, four or five in the second summer, three or four in the third summer, and in the fourth summer perhaps only one or two moults to judge from a single case of 8 mm. increase.

Without reference to the number of moults, observations upon the amount of growth of young crayfish hatched from eggs laid in the laboratory and kept under various artificial conditions in the laboratory, were made and are recorded below as a substitute for data never yet obtained as to the rate of growth of American crayfish in the open.

The following list gives the length in millimeters from tip of rostrum to end of telson of 101 young hatched in May, kept in six different tanks in different years and under somewhat different conditions and measured in October when four months old.

I. 62, 53, 53, 49, 50, 45, 43, 41.

II. 60, 59, 52, 52, 45, 39, 40, 33, 30, 22.

III. 41, 38, 24, 56, 32, 44, 43, 39, 39, 33, 35, 36, 32, 34, 30, 23, 30, 29, 27, 32.

IV. 47, 39, 33, 27, 20, 23, 31, 38, 30, 31, 28, 30, 35, 35, 35, 34, 36, 42, 46, 52, 46, 45, 46, 41, 39, 40, 36.

V. 43, 51, 41, 49, 43, 37, 38.

VI. 55, 43, 55, 48, 38, 50, 40, 40, 53, 46, 40, 42, 40, 43, 50, 45, 44, 48, 50, 49, 37, 57, 44, 45, 43, 46, 46, 36, 38, 38.

It is obvious that there was great individual difference in size attained in the first four months of life both under different conditions and when kept in apparently the same conditions, but of course subject to different chances of food supply even in one tank.

The first group of eight survivors ranged from 41 to 62, with an average of nearly 50.

The second group of 10 survivors ranged from 22 to 62 with an average of 43.

The third group of 20 ranged from 23 to 56 with an average of 35.

The fourth group of 26 ranged from 20 to 47 with an average of 36.

The fifth group of only 7 ranged from 37 to 51 with an average of 43.

The sixth group of 30 ranged from 36 to 57 with an average of 45.

The large size of the crayfish in the first group was undoubtedly due to greater care taken to feed them and the differences in other groups were probably due to differences in food supply and also in temperature.

Judging from the above 101 measurements the young four months old may vary in length from 20 to 62 mm. but while the average of all was 41 mm. the average of different experiments ranged from 35 to 50.

We may then expect this crayfish to be nearly two inches long in the autumn of its first year of life.

Measurements made in the autumn and again in the next spring showed that there was no growth from October to May, except in rare cases in which a moult occurred in early spring. The crayfish thus started in their second summer of life with a length of nearly two inches and were the same size when twelve months old as when four months old.

The rate of growth in this second summer may be inferred from some few measurements made in October upon crayfish reared from eggs laid in the laboratory and measured then, when sixteen months old. Of five larvæ measuring May 26, 1904, 62, 55, 53, 50, 62 mm. the three survivors in October, 1904, measured 75, 80, and 72 mm., an average of 76 mm. From the average, 58, of the above five to the average 76 of the three survivors there was an increase of 18 mm., or a gain of 30 per cent in length in this second summer. And records showed that one of these larvæ had grown from 62 to either 75 or to 82, that is added 13 or else 20 mm. to its length, or increased 21 per cent or else 32 per cent.

Another group of young left three survivors of 56, 70, 75 mm., or on the average 67 mm. when 16 months old to represent the seven which were 40-45 mm. long when twelve months old; they had thus probably added 25 mm. or gained more than 50 per cent in the second summer.

A third group of young, twenty in number, ranging from 23 to 56 mm. when twelve months old, left only two survivors at sixteen months, which measured 70 and 79 mm., or an average of 74: there was thus an increase from the average 35, of 39 mm. But records of the individuals showed that the few survivors were probably 43 and 56 mm. long in the spring and had grown only 23 and 27 mm. in each case which would be an increase of 53 per cent and of 63 per cent.

The above few data indicate a growth in the second summer of sometimes 50 per cent of the length; that is a crayfish two inches long the end of the first summer may be expected to be three inches long the end of the second summer, when sixteen months old. But here again the individual differences are very great.

In the second winter there was probably no growth; two crayfish 75 and 80 mm. long in October, 1904, were the same length in May, 1905, and, in general, moulting during the early spring was rarely observed.

The only observation upon the growth of crayfish reared from the egg and kept during the third summer was the following: two individuals 70 and 79 mm. long when twenty-four months old left one survivor 90 mm. long in October, 1903, when 28 months old. It had thus increased either 11 or else 20 mm. in the third summer, that is, it added only 14 per cent or 20 per cent to its length.

Probably then a crayfish may grow in the third summer from a length of three inches to be somewhat short of four inches.

The one young crayfish kept during its third winter did not change but measured 90 mm. in October, 1903, and the same again in May, 1904.

In its fourth summer this crayfish grew to a length of 98 mm. by October but died then when three years and four months old, having grown but 8 mm. or barely 9 per cent in this summer. This may indicate a great diminution in rapidity of growth as the maximum size is approached so that the crayfish one hundred and twenty millimeters long that are taken in the Potomac may well be six or seven years old; but from one specimen we cannot say that the rate is naturally lessened in the fourth year and a possible yearly increment of one inch would make the large crayfish of five inches only four years old.

The age of *Cambarus affinis* would seem to be roughly determinable from the formula $A = L - V$, where $A =$ the age in years ending in May, $L =$ the length in inches and $V =$ one, in conditions of maximum favorableness, but in unfavorable conditions V may become zero and in very old large crayfish V may be a negative quantity.

Soubeiran ('65) gave the length of Astacus in France as 50 mm., 70 mm., 90 mm., 110 mm., 125 mm., in the first to fifth years inclusive, that is with an annual increment of 20 mm., which, however, became less in the fifth year, so that he could not tell the age of crayfish 160 mm. long nor of any very old ones 190 mm. long.

Compared with this Astacus, *C. affinis* starting as a much smaller egg caught up in size in the first summer and for two years showed just about that same increment of 20 mm. annually, but then probably began to grow with more diminished speed than did the French Astacus.

The sexes of these young crayfish are early determined and in the third larval stage the female shows the beginning of the annulus and the male the external openings of the deferent ducts, as elsewhere described (Andrews, :06). But the difference between the appendages of the first abdominal somite in male and in female are first well seen in the fourth stage when the female still bears minute tubercles and the male long papillæ to represent the appendages of this somite. From that time on to the autumn the distinctive characters of the sexes become perfected so that the annulus of the female is much like that of the old crayfish, and the first abdominal appendages, or stylets, of the male are also much like those of the full grown crayfish. It is thus very easy to recognize the sexes by external characters when they are four months old. The actual length in millimeters of the male stylets in crayfish of four months is given in the following table:

Length of body . . .	55	53	49	45	43	60	52	52	45	39	40	33	30
Length of 1st stylet .	9	9	9	8	7	10	9	9	7	6	6	5	4
Length of 2d stylet .	10	10	9	7	11	10	10	8	7	7	5	4	

The second stylets are thus longer than the first and as much as 18 per cent to 20 per cent of the length of the body so that the stylets are in about the proportions they will be in larger crayfish since specimens 115 mm. long have stylets 18 and 22 mm. long.

Some examinations of various catches of adult crayfish indicated that there is no great disparity in number of males and females and though it is not known whether one sex or the other is subject to greater mortality in early larval life, the following observations tend to show that the sexes are about equal when four months old so that it may be that the eggs are about equally male and female. Observed at four months: of 26, there were 15 male and 11 female; of thirty, 11 were male and 19 female; of 7, 4 were male and 3 female; of 19, 10 male and 9 female; of 10, 8 male and 2 female; of 8, 5 male and 3 female. Of the entire 100, 53 were male and 47 female. With no marked disparity in numbers and with well formed external organs the two sexes when four months old and about two inches long often have well developed sexual instincts. Thus in October a male 55 mm. long, 15 mm. wide, with tail fan 22 mm. wide, antennæ 48 and 51 mm. long and entire expanse from tip of chelæ to end of telson only 75 mm., was seen to try to conjugate with a sister 62 mm. long when four months eighteen days old. Another female had a mass of sperm transferred to its annulus by a male of like age when four months old and 57 mm. long. Many cases were seen in which the four months young had conjugated, thus of 19 females four months old, in one aquarium, five bore sperm given by males of like age. Though the sperm transferred by these young males was apparently perfect it seemed doubtful if these unions would lead to fertile eggs but when a number of four months females thus provided with sperm by males of like age were kept isolated from all males during the winter they laid eggs in the spring which developed and thus demonstrated not only that the females could lay eggs when but a year old but also that these eggs would develop after union with males of the same age, union which moreover took place in the previous autumn so that these experiments also showed that the sperm got in the autumn and kept all winter would fertilize the eggs, parthenogenesis being, supposedly, out of the question. In Astacus, Chantran stated that the eggs were laid only ten to forty-five days after union but in *Cambarus affinis* as many as 230 days may elapse. The data on which the conclusions rest are as follows. A crayfish 62 mm. long laid eggs when forty-seven weeks old, and these eggs hatched eight days after the mother's birthday; this female received sperm the preceding autumn from a male of like age and after that was kept isolated. Three other females were supplied with sperm in the autumn and laid eggs in the spring when one year old and kept isolated from males. Another female 57 mm. long laid eggs May 26, 1904, when one year old, having hatched May 18, 1903, and after being kept isolated after conjugation with a male of like age in the autumn of 1903. Another female only 50 mm. long laid eggs when about eleven months old, April 29, 1905.

It thus seems demonstrated that a crayfish growing the first summer to the length of about two inches and receiving sperm from a male of like age in the autumn may lay fertile eggs the next spring when scarcely a year old.

When older, 16 months old and about three inches long, that is in the second autumn of their lives, crayfish were seen to conjugate and to lay fertile eggs the following spring when two years old. In one case it was shown that a female which laid eggs when 62 mm. long and not quite one year old again laid eggs the next spring when 80 mm. long and but a few days over two years of age.

Though it is possible that artificial conditions may have made these crayfish that reproduce when a year old precocious, it is probable that this Cambarus comes to sexual maturity much sooner than does the Astacus of Europe of which both Soubeiran ('65) and Chantran ('70) state that it reproduces first in its fourth year, though the latter says the males were ready for conjugation at the beginning of their third year.

The fact that one female *Cambarus affinis* laid in two successive years is in contrast to the statement credited to Steffenberg ('72) that the female Astacus in Sweden hiding away during the winter, if fecundated, breeds only every other year.

It is finally to be noted that not only did the young of *C. affinis* reared in captivity lay fertile eggs but the young of the next generation also, so that there would seem to be no obstacle to the establishment of a permanent race of domesticated crayfish bred in captivity.

COMPARISONS AND CONCLUSIONS.

The chief differences between the young of *Astacus leniusculus* and those of *Cambarus affinis* are to be found in the first and second stages and are differences in size, in habit, and in structure.

The differences above described may be enumerated as follows. In *Cambarus affinis* the larva coming from a small egg about 1.75 mm. in diameter is about 4 mm. long and lives only two days before moulting. In *Astacus leniusculus* the larva coming from a very large egg, 2.5 mm. in diameter, is about 9 mm. long and lives four or more days before moulting. The first larval stage in Cambarus has a simplified telson not well armed but having only 26 spines which are upon its posterior edge only, while the Astacus has 66 spines that are set along the lateral as well as the posterior edges. The abdominal appendages differ in that the first pair are absent in Astacus while barely recognizable in Cambarus and the four following have equal exopodites and endopodites in Cambarus while in Astacus the exopodite is longer. The telson thread is short in Cambarus and long in Astacus, and in Cambarus there seems no part of it a recent cuticle cast off by the embryo with well developed limbs as is the case in Astacus. The first antenna in Cambarus is more simple in having only four in place of five segments in its exopodite and in its endopodite and in lacking the sense-hair of Astacus. The second antenna in Cambarus has 25 segments while Astacus has 50; moreover, Cambarus carries this antenna bent backward close to the body between the legs while Astacus carries it forward, but depressed. In Cambarus the first maxilla lacks the few plumose setæ of Astacus and has fewer spines; and the maxillipeds have fewer setæ and spines, as well as gills of more simple structure. The gill formula of Cambarus is already that of the adult and is therefore more simple than that of Astacus, but besides this generic difference the gills of Cambarus are more simple in structure, in this first larval stage, in many cases, especially the anterior arthrobranchs of the pereiopods.

In the second larval stage the habits of the two are different in that the young Cambarus still remain inactively fixed upon the mother and are aided in doing so by an anal thread, while the young of Astacus soon wander away from the mother. The former are about 5 mm. long and live about six days before moulting while the latter are 11 mm. long and live 8 to 10 days before moulting. In Cambarus the rostrum is more bent and not so efficient as a protection and the setæ over the entire animal are much less developed. The abdomen of Cambarus has only weak spines upon its telson and these are along its posterior edge only, while in the active Astacus there is a complete fringe of long plumose setæ on all the edges of the telson. In Cambarus the first antenna is less perfected; in having only 5 segments in its exopodite and 4 in its endopodite while Astacus has 6 in each; in having but 5 sensory hairs in place of 8 in Astacus which has advanced further as is shown by the arrangement of these hairs, and in having the ear pit still bare while in Astacus it is guarded by a fringe of plumose setæ along its edge. In Cambarus the second antenna has 39 segments and its scale has a row of a few spines only while in Astacus there are 54 segments and the scale is fringed with plumose setæ. In Cambarus the maxillæ and maxillipeds have but few setæ and no plumose ones except on the tip of the last maxilliped and the edge of the scaphognathite, while in Astacus the plumes are conspicuous and show a tendency to extend out to the cutting edges of the protopodites and to thus replace the simple setæ by highly specialized forms of setæ with lateral barbs. The scaphognathite in Cambarus is more simple in lacking the peculiar long plume-like setæ at its posterior end. The chelæ are used by Cambarus to hold fast to the mother and their tips are somewhat less straight than in Astacus. In Cambarus also the remarkably long exopoditic setæ of Astacus are not developed.

The first two stages in which the larvæ of these crayfish differ most are also the stages in which crayfish are peculiar in having an intimate association of larvæ with parent. From the generally accepted standpoint that crayfish have been evolved from marine ancestors which had pelagic, or at least, active larvæ that left the mother as soon as they were hatched, the association in the crayfish is a new acquisition. The differences between the larvæ are also presumably of recent origin since they make the early stages more unlike than later stages, while if there were a common ancestor the greater divergence would be in the most remote descendants and stages, until some newer change modified the early larvæ and thus "falsified" the record.

Some of the new modifications in structure that go along with the new habits of association of larvæ and mother may be recognized as distinct from the small size and other characters that might belong to active larvæ. The characters in the first and second stages that seem inimical to free larval life and to be adapted to the parasite-like life upon the mother are; partly those negative traits which an embryo might have in protected sedentary life and which here may be in fact but the lingering on outside the egg of conditions formerly found only within the egg; and partly directly adapted additional characters that are peculiar to this life of larval dependence upon the pleopods of the mother, and of no use elsewhere.

The embryo-like characters of the first larval stage are as follows. The spheroidal head-thorax and accompanying position of limbs and of abdomen that make walking and true swimming impossible and force the creature to lie upon its side if removed from its natural attachment to the mother. The weak, imperfect state of the locomotor organs; slender legs, simple telson, absence of utilizable sixth pleopods. The lack of useful defensive organs, that is the bending down of the rostrum between the eyes and the small number and insignificance of the telson spines. The imperfect state of the sense organs; namely the short eye stalks and incomplete eyes, the open unguarded ear-pit, the complete or nearly complete absence of sense setæ on the first antenna and the naked character of the other appendages and whole body over which only a few simple spines take the place of the innumerable sensory and locomotor setæ of active larval stages. The lack of development and of use of the first and sixth pairs of abdominal appendages; the imperfect development and shortness of the first and second antennæ; the lack of teeth on the edge of the mandible and the apparent lack of use of any of the numerous mouth parts and appendages concerned in later stages in getting and eating food. The passive habit as a fixed dependant with physiology like that in the embryo, except for the addition of active respiratory movements; the pose of the body with the limbs and abdomen beneath the thorax and antennæ depressed.

The special characters of the first larva that are neither embryonic nor such as a free larva would have are the two means of attachment to the mother. The first is the existence of recurved tips on the long strong chelæ that, combined with the instinct of the larva, enable it to seize hold of and become locked to the material on the mother's pleopods. The second is the telson-thread that holds the larva to the mother till it can get locked with its claws. This contrivance is formed in advance of its use both by early adhesions of membranes and by later special secretions of telson glands so that its usefulness is dependent upon a series of modifications of the ancestral history.

In brief the first larval stage is embryonic in proportions and activities and in lack of the perfection of sensory, feeding, locomotor, and defensive organs to be expected in a free larva. It is actively specialized for its peculiar association with the parent by the locking claws and telson thread.

The second larval stage is transitional in structure from an embryonic to a free larval state and in habit it remains still a fixed dependant in Cambarus though in Astacus gradually becoming but loosely associated with the parent. In both crayfish the second larva is still imperfect in lacking the sixth pleopods and is embryonic in still containing yolk. It also has imperfections in sensory and locomotor setæ that may be interpreted as retrogressions from a more perfect ancestral state toward a yet more simple state like that of the first larva; presumably the association with the mother was first acquired in the first stage and has later extended, as yet, less thoroughly through the second stage.

Supposing the ancestors of crayfish to have hatched as active larva the first and second stages at present are new, in so far as they are specialized for attachment to the mother and in that they are inactive and imperfect, while the third stage may be compared more directly with ancestral larvæ and is older in its general structure.

While the absence of the locomotor sixth pleopods in the first and second stages of crayfish young might be regarded as indicating that these stages had never been represented by free ancestral forms but were merely embryos prematurely removed from the egg to live a pseudo-larval life upon the mother's pleopods, yet the near marine relative of the crayfish, the lobster, likewise has no available sixth pleopods in its first and second stages though free and even pelagic, and we are free to assume that the first stages of the crayfish are modified representatives of free ancestral larvæ.

Such ancestors may have been much like the lobster and at present the third larval stage of the lobster is like the third in the crayfish in that the sixth pleopods are then first expanded; but it is not till the fourth larval stage in the lobster that the length of antennæ and perfection of tail-fan is developed enough to be comparable to the third stage in the crayfish. While the first and second stages of the crayfish are well adjusted to life upon the mother's pleopods, the first, second, and third stages of the lobster are well fitted for pelagic life in retaining the locomotor exopodite of the pereiopods and short antennæ. The fourth stage of the lobster first acquires long antennæ, perfect tail fan and reduced exopodites, and is in the main very like the third stage of the crayfish; in fact the adult state is rather suddenly imitated in the third stage of the crayfish and in the fourth stage of the lobster. If these two stages are supposed to be homologous we may suppose that the process of reduction of metamorphoses that has already gone so far in the lobster (Herrick, '95), has advanced a little more in the crayfish so that only two larval stages exist where there used to be three.

The greater length of the antennæ in the earlier stages of the crayfish and the earlier presence of the 2nd-5th pleopods may be imagined as secondary changes from the lobster-like state, possibly connected with development of crawling habits and abandonment of pelagic life, for the long antennæ would be of more use to a creeping animal and the pleopods perhaps of more use in connection with respiration and sensory examination of water to an animal living on the bottom, or possibly in holes, and needing a supply of water to the gill region and information of the nature of the material beneath the abdomen.

In the departure of crayfish from marine lobster-like ancestors the changes have been in the abolition of most of the free swimming contrivances, the acquisition of some arrangements better fitted for a crawling life and finally the retention of embryonic states along with special new adjustments in connection with a life of quasi-parasitism upon the mother.

We imagine the ancestral crayfish to have given up pelagic larvæ, to have developed crawling larvæ, and with these to have lately begun an association of larva and parent that forms an early phase in family life. If continued in the same lines there might ultimately result a crowding back of hatching nearer to the time of egg laying and a retention of embryo-like larvæ upon the mother along with reduction in number of larval stages, that would allow for a long family life and protection of young nearly to the adult state.

That Cambarus has departed from the ancestral state more than has Astacus is shown by the following considerations. In *C. affinis* the telson is more reduced, that is its shape is less like that of an ancestral swimming organ and its protecting spines are only upon the posterior edge and not along the side as well, and, moreover, there are but 32 as compared with 66 in *A. leniusculus* or, probably, 50 in one Astacus of Europe. *Cambarus affinis* holds its second antennæ bent back under the thorax out of the way of jostling neighbors upon the pleopods but in a position of no use as a feeling organ. This antenna is also very short and has but 25 segments as against 50 in Astacus. In Cambarus the appendages of the first abdominal segment, which will ultimately be sexual organs in the male, are started in the first stage though lacking till much later in Astacus, as far as known. And the young develop to sexual maturity within four months, thus shortening the period of non-sexual life remarkably. Rathke ('29) found no signs of stylets in male Astacus 1 inch 3-4 lines long while we find them 0.1 mm. long in *C. affinis* 17 mm. in length. The telson thread of Cambarus seems made less evidently from a recent larval skin and is apparently of earlier origin than in Astacus, as it seems to arise further back in the embryonic life; or we should say the larval history of Astacus is the more primitive in having a more complete representation of a lost larval stage still evident in a complete cast cuticle within the egg. But while there is a cuticle cast off near the time of hatching in both Astacus and the lobster we may assume from comparison of these larvæ that the first stage of the lobster is represented within the egg of the crayfish and that therefore the cuticles cast at hatching are not homologous.

In the second stage of Cambarus there are also signs of further recession from ancestral states. Thus the rostrum is less developed and not as efficient as a defense as it is in the more active Astacus. The second larva of Cambarus still lacks most of the plumose setæ that are present in the second Astacus and is thereby less fit for free life and is also more like an embryo. The second stage of Cambarus lives upon the mother while in Astacus it becomes free: in Cambarus it is fast by its chelæ and when it moults a delay in casting off the cuticular lining of the intestine makes an anal thread that mechanically continues the attachment of the young to the mother beyond what is found in Astacus. The telson of *Cambarus affinis,* even in the second stage, has only spines in place of the locomotor plumes of Astacus and is thus evidently unfit for free life. Cambarus also has not yet developed sense setæ upon the second segment of the exopodite of the second antenna and is thus not as advanced as Astacus is; and the ear pit is less perfected in not having the setæ along its edge. The second antenna is less perfect in having only 39 in place of 54 segments and in still having only spines in place of plumes upon its scale. In Cambarus also the second stage is notably lacking in almost all plumose setæ and is thus further removed from fitness for free active life.

The third stage of Cambarus though rivaling Astacus in perfection of locomotor and sensory apparatus still associates longer with the mother and thus suggests a future period when the larval dependence may be extended so that more than two larval stages may remain upon the mother.

Though the young of Cambarus are better fitted to stay with the mother, and do so for a longer period of their life as reckoned in stages, the actual number of days in which the association continues is not essentially different in Cambarus and in Astacus. In the former the larvæ is fixed on the mother for a week and then remains in association for another week or more. In the latter the larva is fixed to the mother four to fourteen days and then is associated for only a few days more, as far as was made out in laboratory culture of *A. leniusculus*, while Chantran ('70) states the young of a European species are fixed for ten days and then go and come for ten days more.

The conclusion that Cambarus has advanced further than Astacus in the adaptation of its young to a life of association with the mother is in harmony with the relative positions of these two genera as determined by anatomy and geographical distribution. The absence of the pleurobranchiæ in Cambarus and the presence of a specialized sperm receptacle, the so-called annulus ventralis, as well as the corresponding specialization of the male stylets, are some of the important characters that show the adult Cambarus to be more highly evolved than Astacus, and Ortmann (:02) has shown how the evolution of all the species of Cambarus may have taken place since divergence from Astacus like ancestors in the region of Mexico.

We may therefore suppose that as Cambarus has migrated over the middle and eastern United States it has become split up into the sixty odd species now found and in some as in *C. affinis* has made more perfect the association of young and parent already present in the Astacus ancestor.

As all the crayfish are primarily fresh water or land dwellers it is natural to seek to connect their possession of an elementary family state with their departure from their ancestral marine life and it is easy to imagine that the species might be benefited by the young being protected by the mother when either living in holes or moving from place to place till of larger size and more perfect structure. But it is not obvious that the advantage would be greater in fresh water than in salt water life, and as we know the lobster has already greatly shortened its ancestral series of metamorphoses and that the crayfish family-life is possible only after such shortening of metamorphoses, we seem, in the lack of evidence as to when the association found in the crayfish really began, to have no grounds for connecting fresh-water life with these peculiarities of crayfish. The marine ancestors of crayfish may have already acquired some connection of young and parent before leaving the sea and in fact the life in bays and estuaries would be one in which the dangers of loss of young if set free early and swept out to sea, would make an attachment to the parent especially valuable! And, later, the main advance of crayfish ancestors having been presumably up rivers and across country from river to river, the advantage of having the young not set free early when they might more easily drift down stream or be devoured, but when they were large enough and able to crawl and to hold to the bottom, would perhaps lead to a continuance and perfection of family life.

But while it is easy to speculate on the origin of the characters of crayfish on the assumption of utility and the working of natural selection, the conclusions are of doubtful value in our present relative ignorance of their actual life. Moreover, the nature and the amount of differences in the hard parts and in the larval history that distinguish one kind of crayfish from another are such as to raise the question whether utility and natural selection have played any part in their formation or in their perfection. All the specific and generic characters of crayfish may be as useless as color differences, and they may have suddenly arisen perfected as we see them, or they may have progressed in certain lines for long periods of time independent of external agencies. We need more evidence from observation and from breeding experiments before concluding that such characters as the shape of stylets and annulus or of rostrum and of spines, absence or presence of one gill filament more or less, or the behavior of telson glands and the presence of feathered setæ instead of simple spines, have ever in any manner been connected with utility to the species or with the survival or the extinction of individuals. Until the contrary is proven we may regard these as the unmeaning by-products of unknown activities in the living protoplasm.

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EXPLANATION OF PLATES.

All figures drawn with camera lucida with Zeiss lenses specified, with few exceptions noted. They are printed one-third the diameter of the drawings, except Figs. 92 and 93, which are nearly life size.

ASTACUS LENIUSCULUS.

PLATE I.

Figure 1. Larva issuing from egg-shell. 290 mm., aa.
2. Pantograph enlargement of photograph of living female to show young, several hours after hatching, crowded upon the under side of abdomen of mother.
3. Right side of living larva soon after hatching. 290 mm., aa.
4. Dorsal view of living larva just hatched, showing split egg-case and long filament connecting it to telson of larva. 290 mm., aa.
5. Front and oblique side views of eyes and rostrum to show its curvature. 2. aa.
6. Dorsal face of left antennule of first stage. 2. A.
7. Under face of left antenna of first stage. 2. A.
8. Outer face of left mandible of first stage. 2. A.
9. Outer face of first maxilla of first stage. 2. A.
10. Outer face of second maxilla of first stage. 2. A.
11. Outer face of first maxilliped of first stage. 2. A.
12[1]. Outer face of second maxilliped of first stage. 2. A.

PLATE II.

Figure 13. Outer face of third maxilliped of first stage. 2. A.
14. Posterior face of left chela of first stage. 2. A.
15. Posterior face of left second walking leg, first stage. 2. A.
16. Posterior face of left third walking leg, first stage. 2. A.
17. Posterior face of left fourth walking leg, first stage. 2. A.
18. Posterior face of left fifth walking leg, first stage. 2. A.
19. Anterior face of one of left pleopods of first stage. 2. A.

PLATE III.

Figure 20. Dorsal face of telson of first stage, showing internal radiations, marginal spines, and attachment of telson thread. 2. A.
21. Enlarged views of attachment of telson-thread to certain glandular spines on the posterior edge of the telson of first stage. 2. D.
22. Detail of three such glandular telson spines still covered by cuticle of embryo. From a larva just hatched, but not yet shed. 4. D.
23. Dorsal view of living larva in second stage. 290 mm., aa.
24. Left side of living larva in second stage. 290 mm., aa.
25. Upper face of left antennule of second stage. 2. A.
26. Under face of left antenna of second stage, with flagellum represented in two isolated parts. 2. A.

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[1] In this and the subsequent five figures the anterior arthrobranch has been dotted for distinctness.

Plate IV.

Figure 27. Outer face of left mandible of second stage. 2. A.
28. Inner face of left mandible of second stage. 2. A.
29. Outer face of left first maxilla of second stage. 2. A.
30. Outer face of second maxilla of second stage. 2. A.
31. Outer face of first maxilliped of second stage. 2. A.
32[1]. Outer face of left second maxilliped of second stage. 2. A.
33. Outer face of left third maxilliped of second stage. 2. A.
34. Posterior face of left chela of second stage. 2. A.

Plate V.

Figure 35. Posterior face of left second walking leg, second stage. 2. A.
36. Posterior face of left third walking leg, second stage. 2. A.
37. Posterior face of left fourth walking leg, second stage. 2. A.
38. Posterior face of left fifth walking leg and pleuro branch. 2. A.
39. Posterior face of a left pleopod of second stage. 2. A.

Plate VI.

Figure 40. Dorsal aspect of living larva in the third stage in normal attitude which makes the telson fore-shortened. 290 mm., aa.
41. Side view of living third-stage larva kept quiet by alcohol. 290 mm., aa.
42. Dorsal aspect of the left newly expanded pleopod of the sixth segment of the third-stage larva. 2. A.
43. Dorsal aspect of the telson of third-stage larva. 2. A.

Cambarus affinis.

Plate VII.

Figure 44. Posterior face of fourth left pleopod of adult female. 290 mm., aa.
45. Eggs attached to pleopod of adult female about twenty hours after being laid. 290 mm., aa.
46. Ventral aspect of posterior part of abdomen of first larva, showing attachment of telson thread, the concealed sixth and free fifth and fourth pleopods. From a recently hatched larva. 2. A.
47. Dorsal aspect of telson and sixth abdominal somite of first larva twenty hours after hatching. 2. A.
48. Ventral aspect of terminal middle part of telson of first larva dissected out of egg-shell, showing attachment of telson thread to certain spines. 2. D.
49. Dorsal aspect of first larva as seen in Worcester's liquid. 290 mm., aa.
50. Right side of first larva, seen in Worcester's liquid. 290 mm., aa.
51. Front view of eyes and rostrum of first larva, seen in Worcester's liquid. 2. aa.
52. Pleopod covered by larvæ in the first stage and 48 hours old; alive; some few removed. Camera lucida on dissecting stand, Steinheil Aplanatic, No. 9.
53. Dorsal aspect of left antennule of first stage. 2. A.
54. Lower face of left antenna of first stage. 2. A.
55. Outer face of left mandible of first stage. 2. A.
56. Outer face of left first maxilla of first stage. 2. A.
57. Outer face of left second maxilla of first stage. 2. A.

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[1] In Figs. 32 to 37 the anterior arthrobranch is dotted for distinctness.

Figure 58. Outer face of left first maxilliped of first stage. 2. A.
59. Outer face of left second maxilliped of first stage. 2. A.
60. Outer face of left third maxilliped of first stage. 2. A.

PLATE VIII.

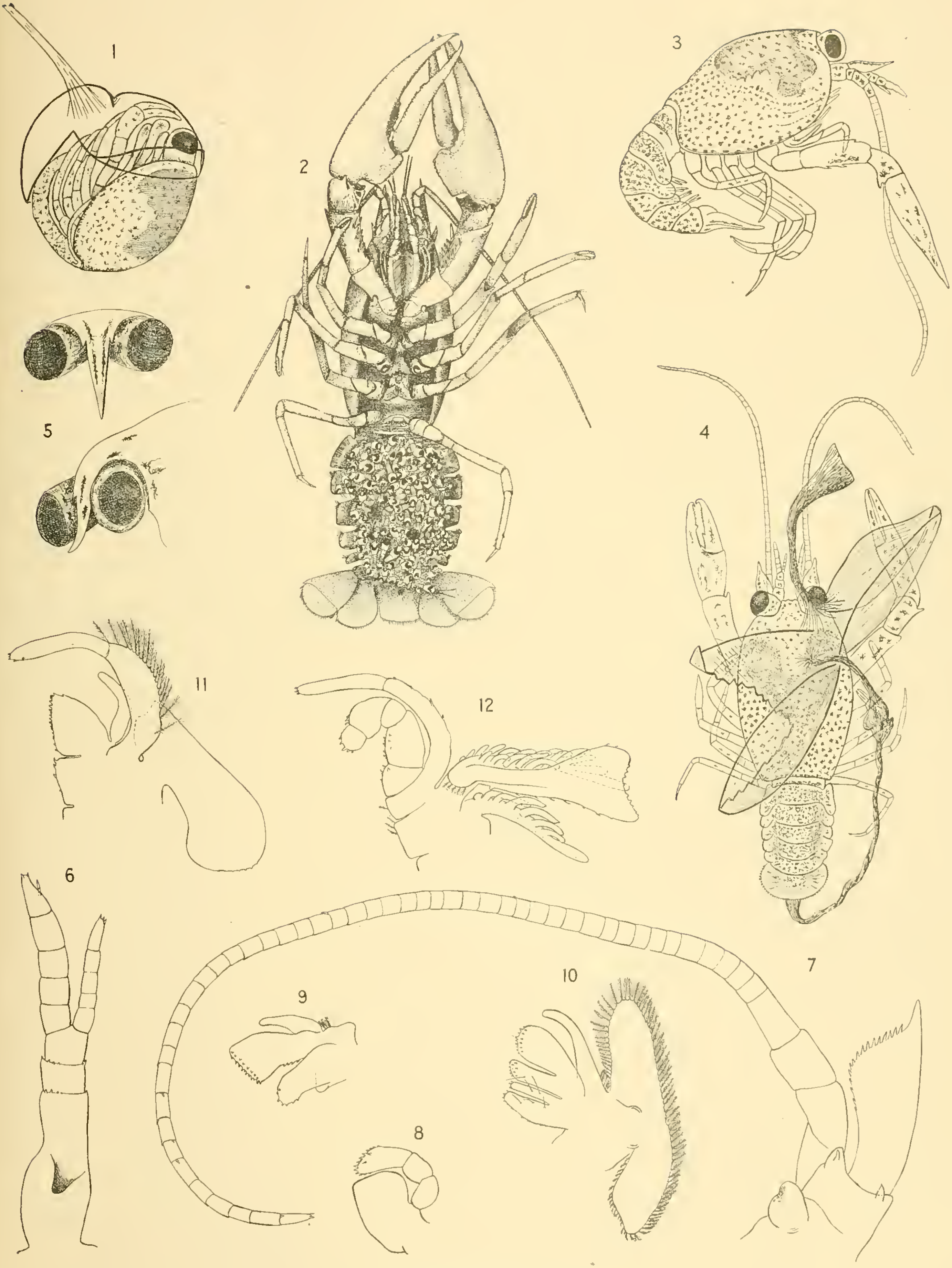
Figure 61. Posterior face of left chela of first stage. 2. A.
62. End of chela of first stage, showing new cuticle and spines within old. 2. D.
63. Posterior face of left second walking leg of first stage. 2. A.
64. Posterior face of left third walking leg of first stage. 2. A.
65. Posterior face of left fourth walking leg of first stage. 2. A.
66. Posterior face of left fifth walking leg of first stage. 2. A.
67. Posterior face of left pleopod of first stage. 2. A.
68. Dorsal aspect of second larva, in Worcester's liquid. 290 mm., A.
69. Left side of second larva, living, copied from Andrews, '04.
70. Part of pleopod with some young in second stage left upon it. Drawn living, with dissecting stand and Steinheil Aplanatic, No. 9.
71. Ventral aspect of telson of second stage with included sixth pleopods and anal thread issuing from anus: living. 2. A.
72. Ventral view of right half of telson of second stage to show marginal papillæ. 2. D.
73. Telson and part of intestine removed, with attached anal thread and portion of cast shell, ventral views. In A normal relation is shown; in B the puckering of the intestine when the cast telson shell is pulled away from the telson. 290 mm., A.
74. Portion of intestines and chitinous lining, made transparent to show the limit of the cast-off lining (*y*) and the region (*x*) where still attached. 2. D.
76. Dorsal aspect of left antennule of second stage. 2. A.
77. Under face of left antenna of second larva. 2. A.

PLATE IX.

Figure 78. Outer face of left mandible of second larva. 2. A.
79. Outer face of left first maxilla of second larva. 2. A.
80. Outer face of left second maxilla of second larva. 2. A.
81. Outer face of left first maxilliped of second larva. 2. A.
82. Outer face of left second maxilliped of second larva. 2. A.
83. Outer face of left third maxilliped of second stage. 2. A.
84. Posterior face of left chela of second stage. 2. A.
85. Posterior face of left second walking leg, second stage. 2. A.
86. Posterior face of left third walking leg, second stage. 2. A.
87. Posterior face of left fourth walking leg. 2. A.
88. Posterior face of left fifth walking leg, second stage. 2. A.
89. Posterior face of left pleopod of second stage. 2. A.
90. Dorsal aspect of living larva in third stage. 290 mm., aa.
91. Left side of living larva in third stage, reduced ½ from 2 aa.

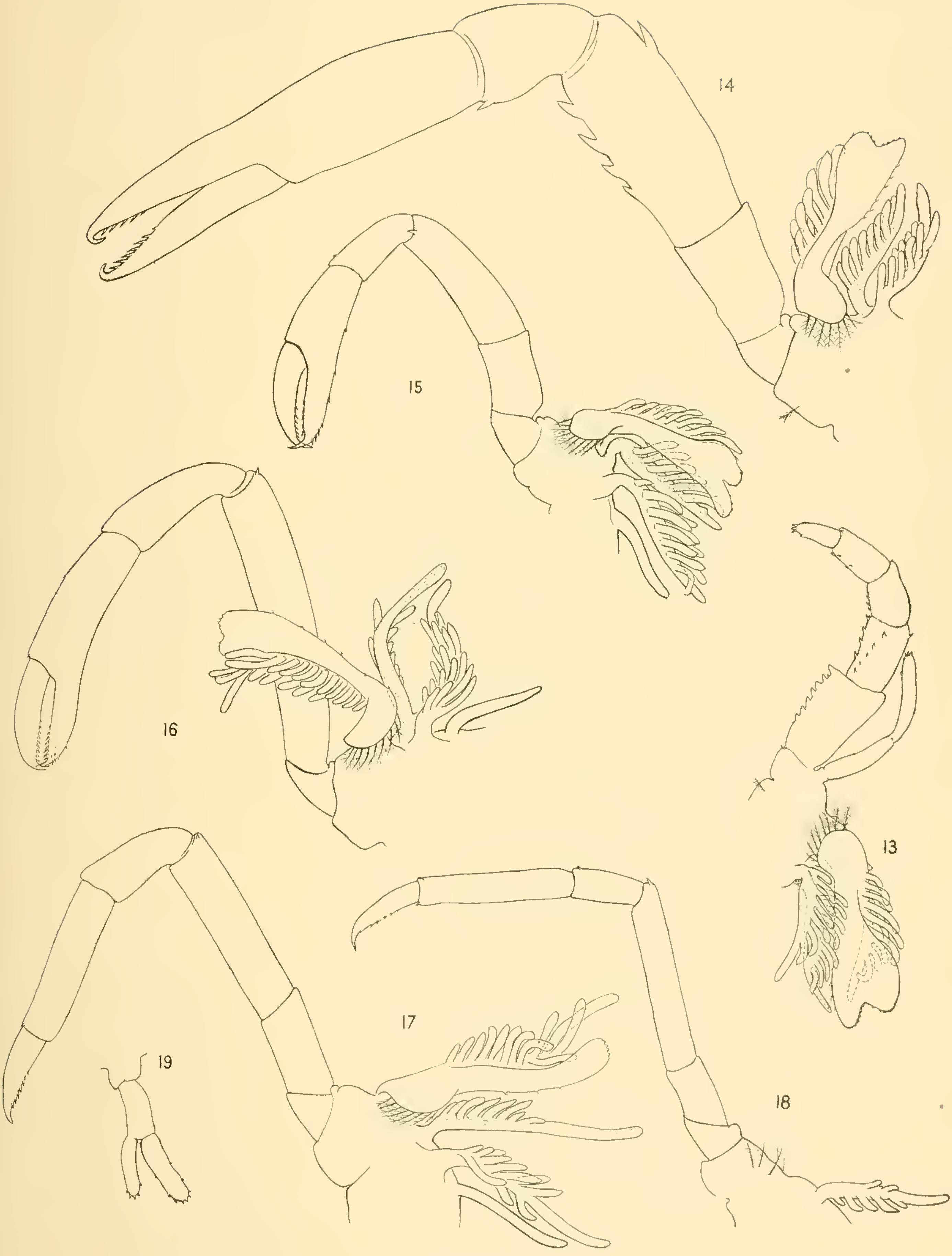
PLATE X.

Figure 92. Photograph of side view of adult female and its young in third stage climbing under and about the body.
93. Photograph of dorsal side of adult female, with its young in third stage climbing over its back.



ASTACUS LENIUSCULUS: FIRST STAGE

E. A. ANDREWS, del.



ASTACUS LENIUSCULUS: FIRST STAGE

E. A. ANDREWS, del.

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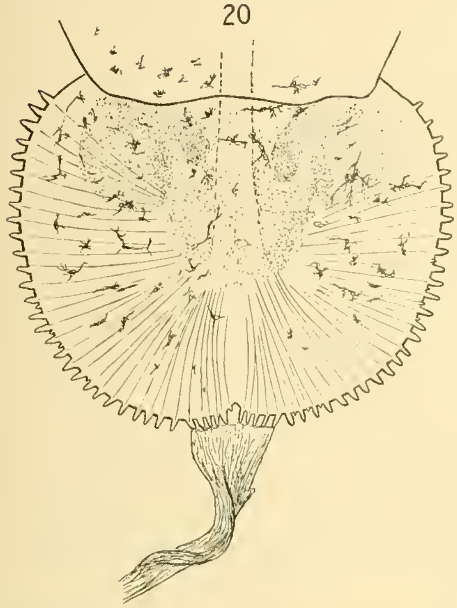

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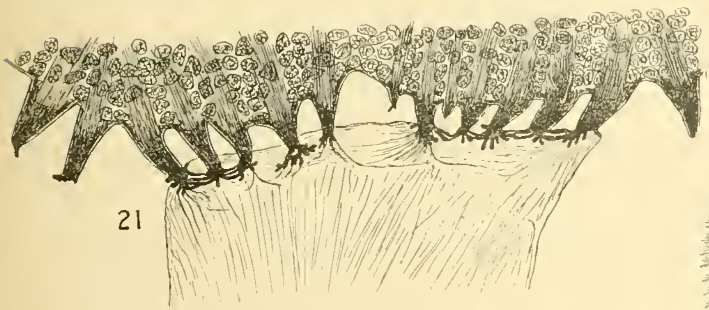

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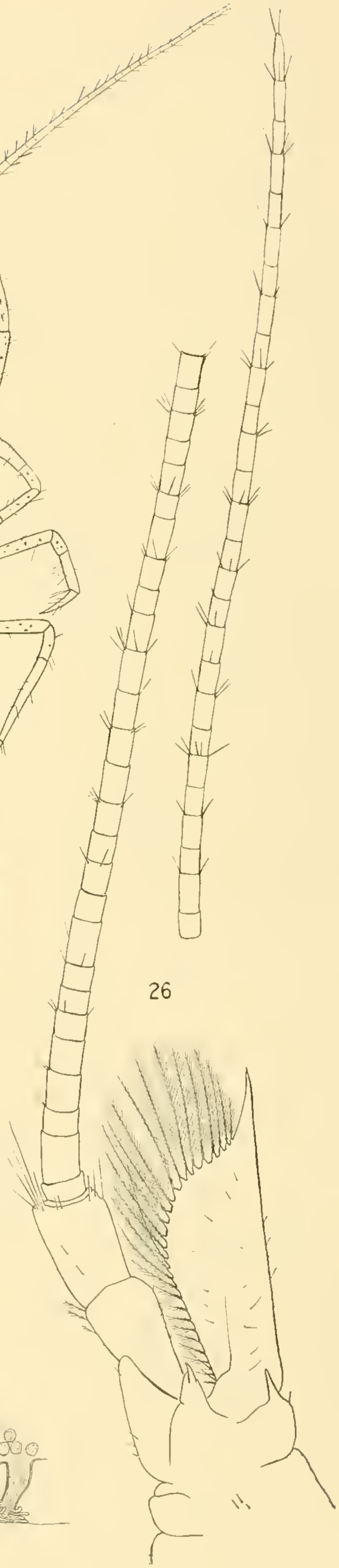

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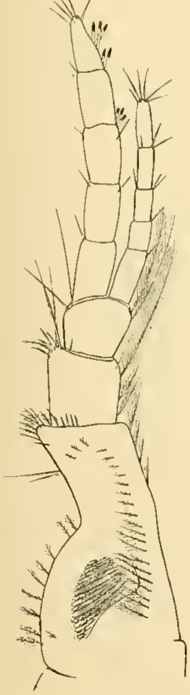

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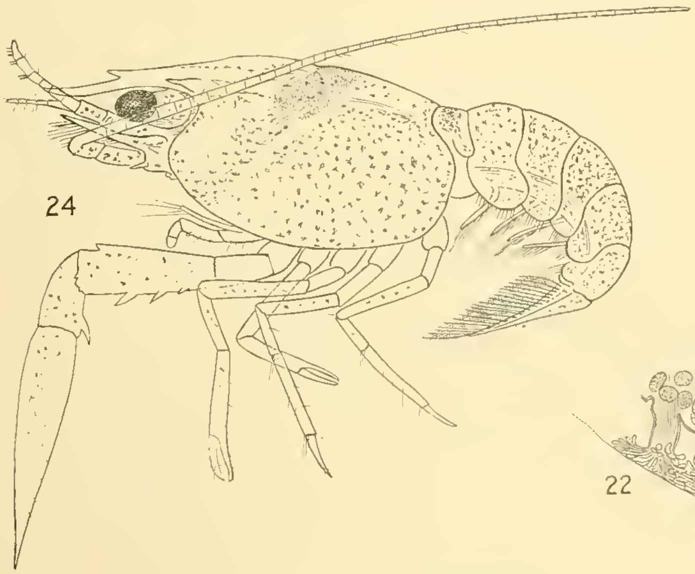

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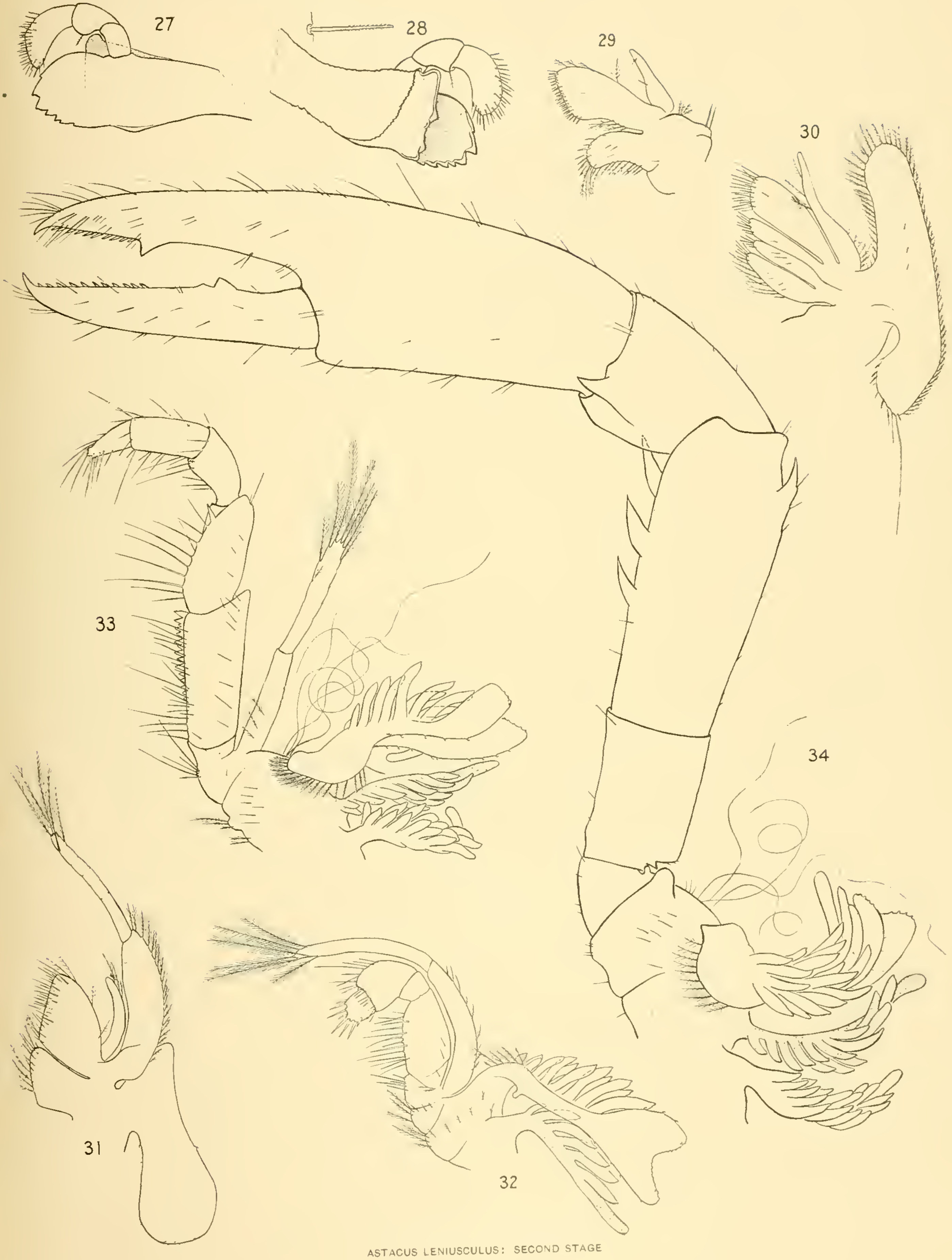
ASTACUS LENIUSCULUS: SECOND STAGE

E. A. ANDREWS, del.



ASTACUS LENIUSCULUS: SECOND STAGE

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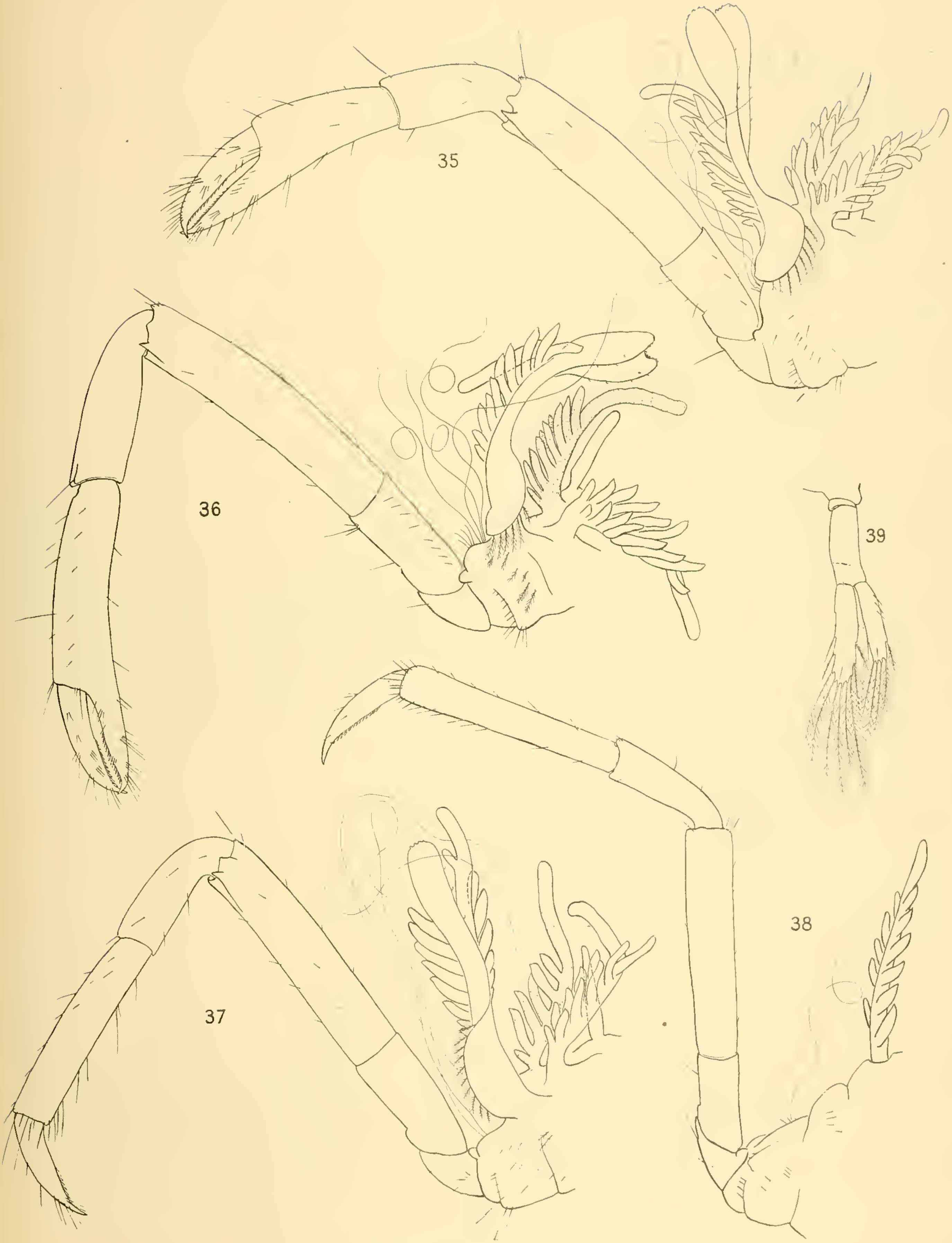
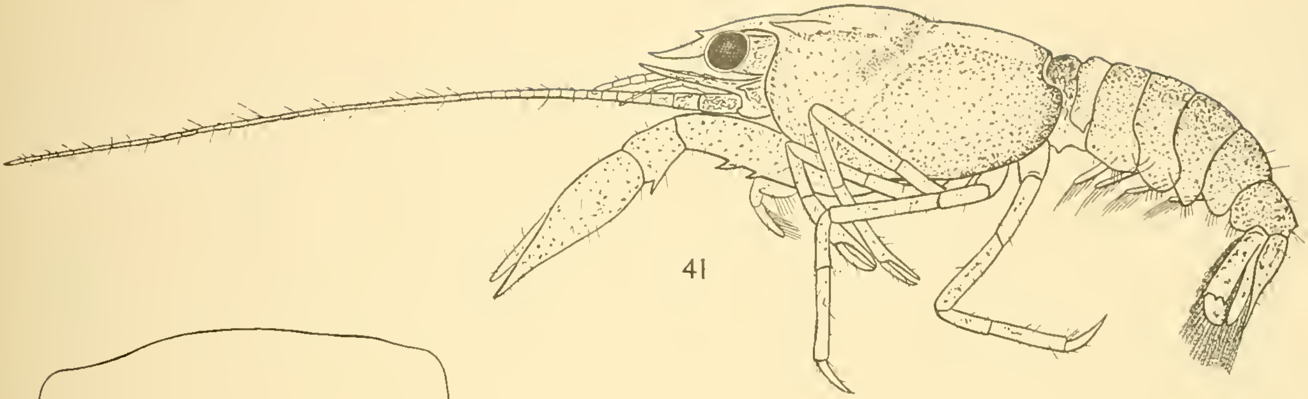


ASTACUS LENIUSCULUS: SECOND STAGE

E. A. Andrews, del.



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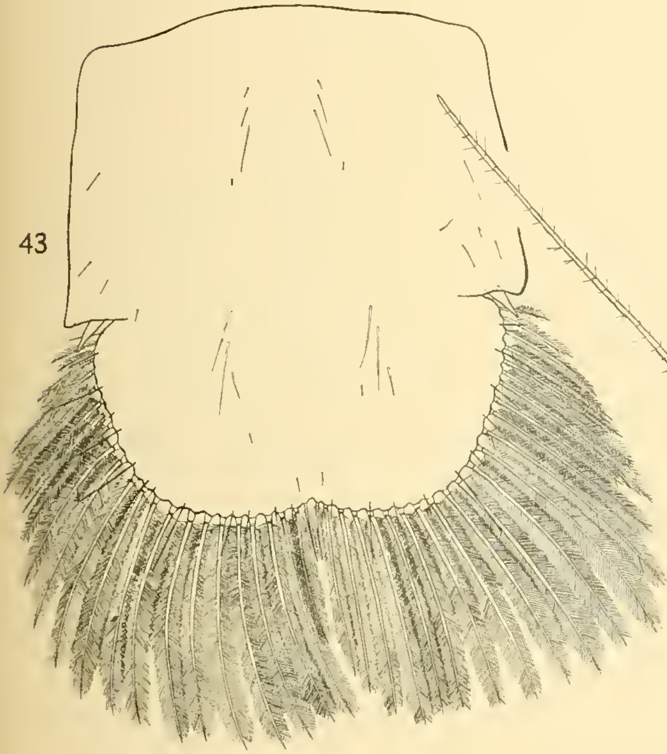

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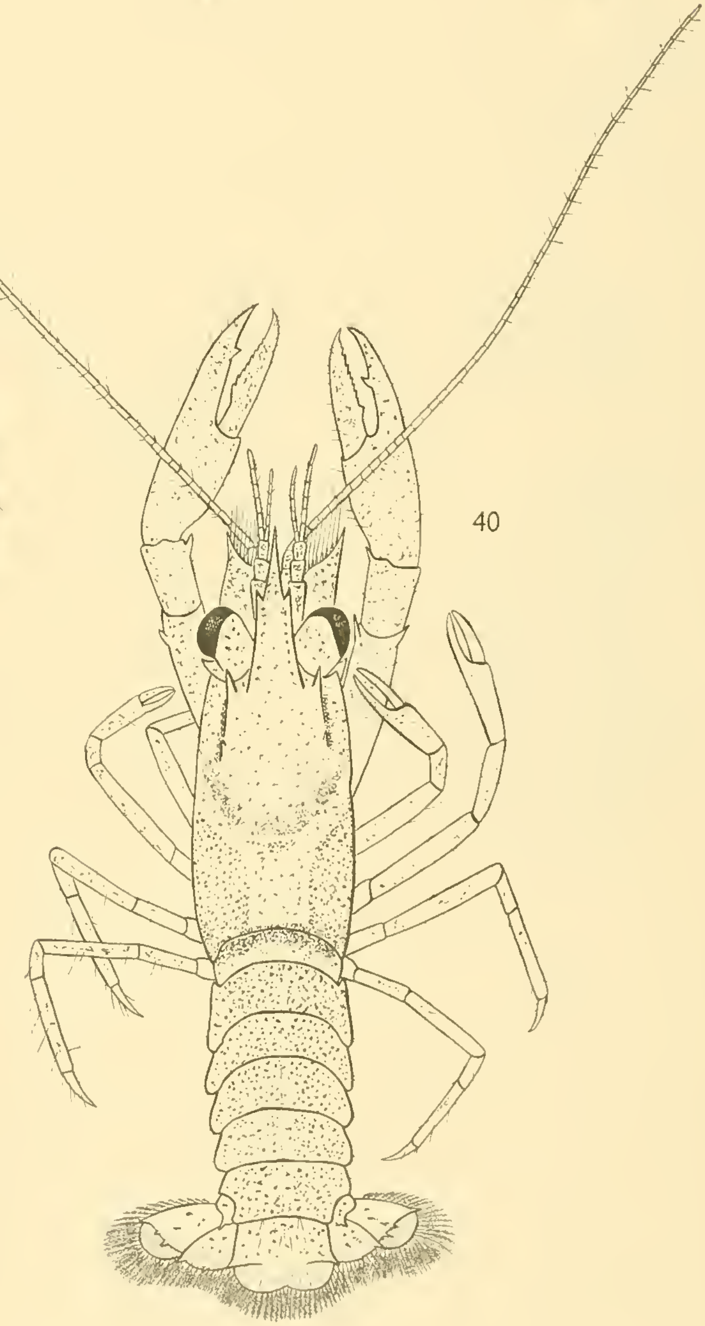

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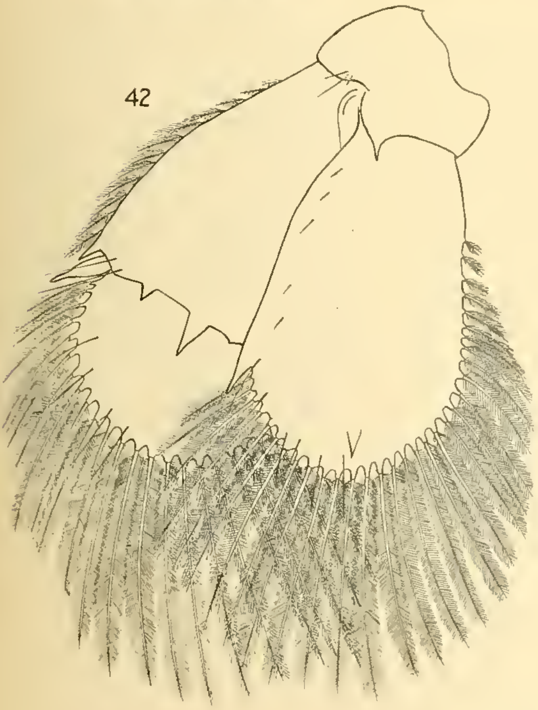
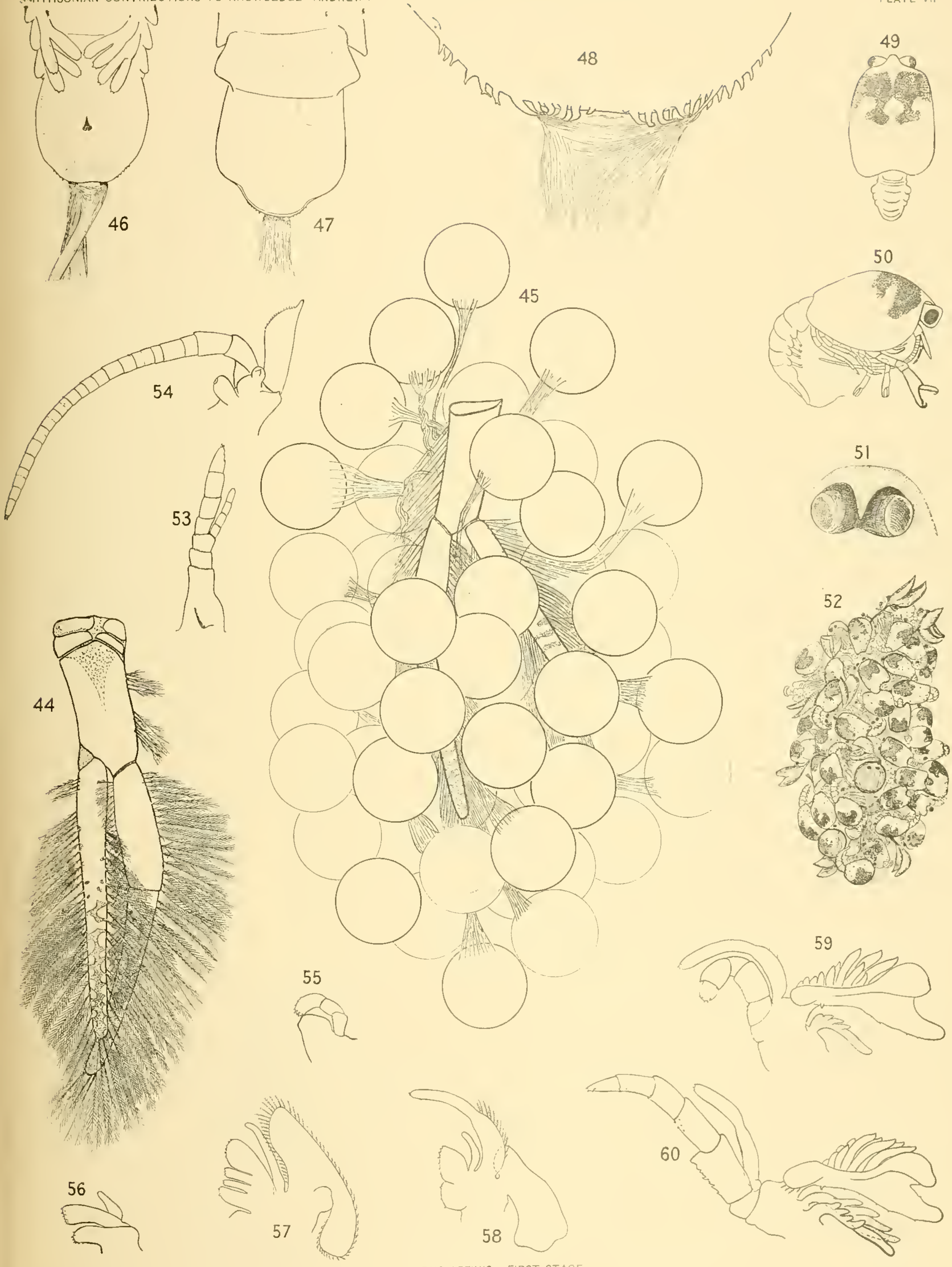


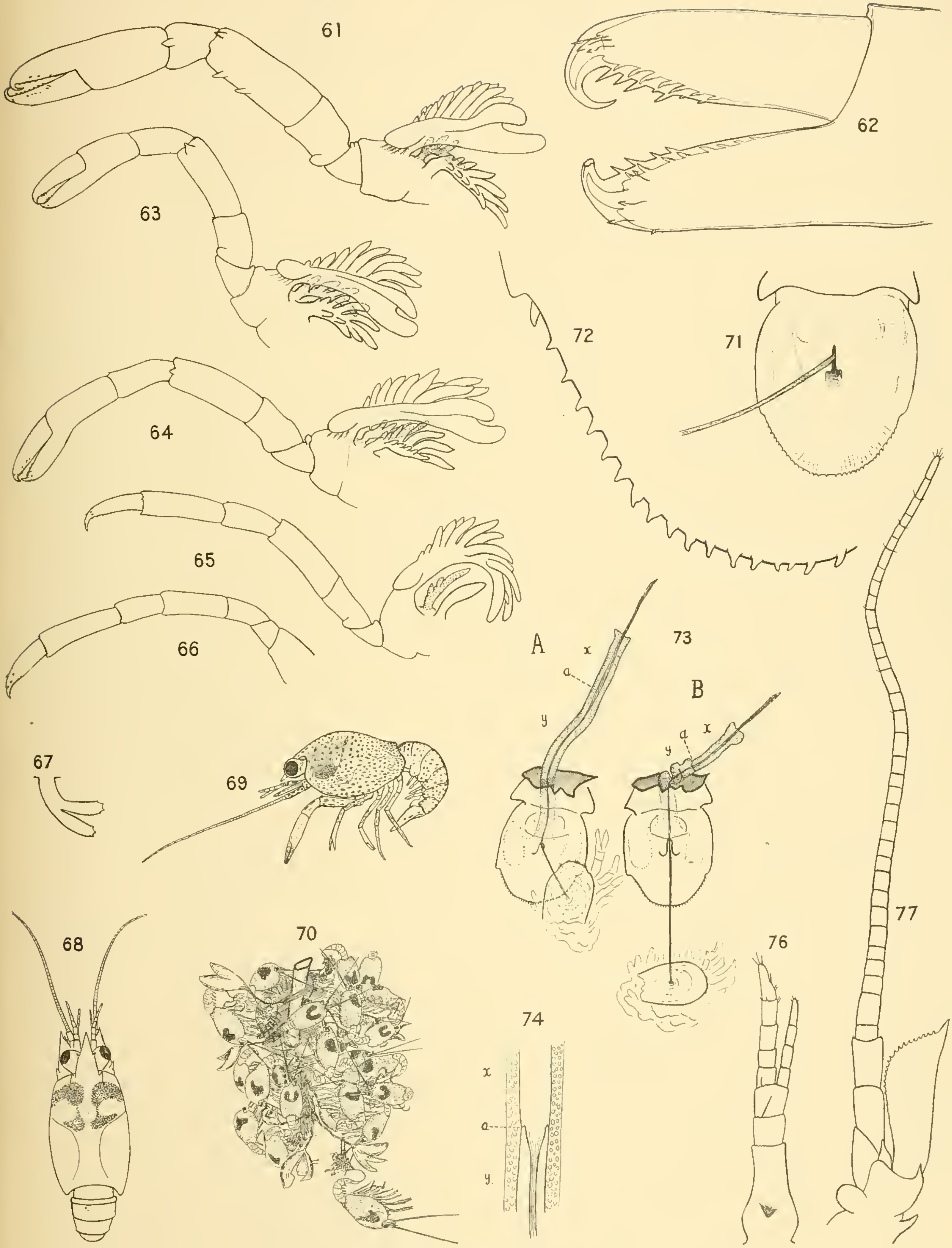
ASTACUS LENIUSCULUS: THIRD STAGE

E. A. Andrews, del.



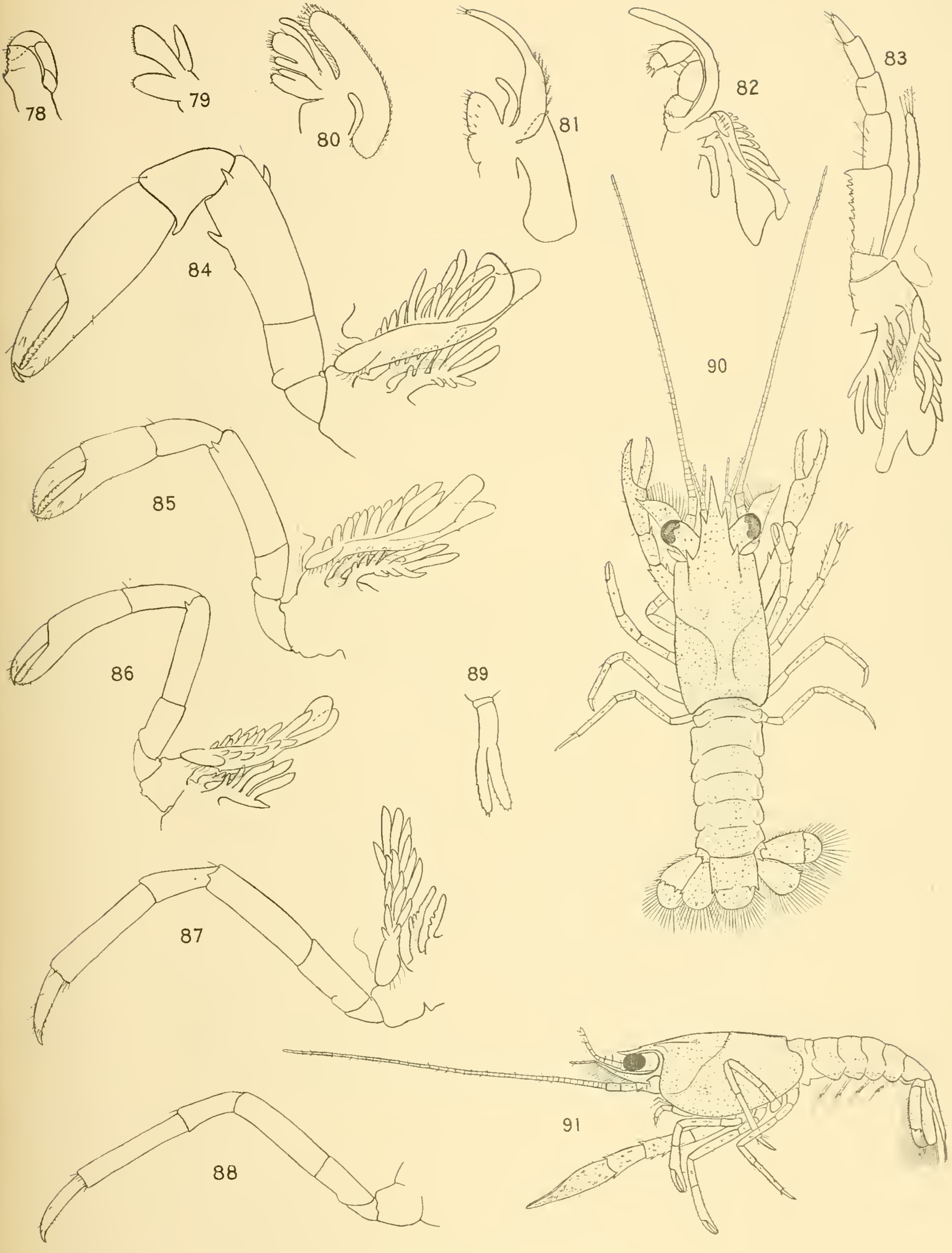
CAMBARUS AFFINIS: FIRST STAGE

E. A. ANDREWS, del.



CAMBARUS AFFINIS: FIRST AND SECOND STAGES

E. A. ANDREWS, del.



CAMBARUS AFFINIS: SECOND AND THIRD STAGES

E. A. ANDREWS, del.

FIGURE 92

FIGURE 93

CAMBARUS AFFINIS: THIRD STAGE

E. A. ANDREWS, photo.

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE
PART OF VOLUME XXXV

THE APODOUS HOLOTHURIANS

A MONOGRAPH
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BY

HUBERT LYMAN CLARK

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ADVERTISEMENT.

The present memoir by Dr. Hubert Lyman Clark, of the Museum of Comparative Zoölogy, in Cambridge, Massachusetts, on "The Apodous Holothurians," sea-cucumbers or trepangs, forms part of Volume XXXV of the Smithsonian Contributions to Knowledge.

In this memoir the attempt has been made to give a complete summary of our present knowledge of the two families of sea-cucumbers which lack tube-feet. As a system of classification is the essential foundation upon which any discussion of structure, habits or relationships must be built, the first section is devoted to a discussion of the history of the classification of the two families (Synaptidæ and Molpadiidæ), with comments on the principles involved and a final summary of the system adopted. Most of the original investigations having been based on material in the collections of the United States National Museum, the second section is an annotated catalogue of the Apodous Holothurians of that institution. The third section deals with the family Synaptidæ, and takes up in regular sequence, so far as our present knowledge permits, the structure, physiology, development, habits and classification of these animals. In the last subdivision of this section, each species, recognized as valid, is treated separately in some detail. In the fourth section, the family Molpadiidæ is treated in the same way.

The most important feature of the work is the recognition of the changes taking place in the maturing and senescence of individual holothurians, particularly in the family Molpadiidæ. As a result of this, radical changes in nomenclature have been necessary, but every effort has been made to have the system adopted accord with the most widely accepted codes, and thus be as stable as possible. Special attention has been given to geographical distribution, but the work in this line is chiefly of value as a summary of our present very inadequate knowledge. Artificial keys to genera and species have been freely used with the intention of making the work as useful as possible to all subsequent investigators, and the numerous figures, most of which are copied from other writers, are given with the same end in view.

In accordance with the rule adopted by the Institution, the work has been submitted to a commission consisting of Prof. A. E. Verrill, of Yale University, and Prof. W. K. Brooks, of the Johns Hopkins University, who recommended its publication in the present series.

Chas. D. Walcott,
Secretary.

Smithsonian Institution,
Washington, *June*, 1907.

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INTRODUCTION.

Early in the spring of 1909 the collection of apodous holothurians of the United States National Museum was placed in my hands for identification. This collection consisted of nearly 1,000 specimens from various localities along the American coast, both east and west, from the Banks of Newfoundland and the Aleutian Islands to the Strait of Magellan. It was rich in Molpadiidæ, and furnished an excellent basis for the revision of that family, but it was poor in Synaptidæ, though many of the American species were represented by numerous specimens. Owing, however, to the great need of a revision of the Synaptids, it was thought best to take the opportunity of making it, and the present paper was intended to be a complete account of all the footless holothurians known to science. After the manuscript was completed, in 1906, a supplementary collection from the National Museum, containing over 1,200 specimens, was placed in my hands, and the examination of this additional material has proved of great value, not only by enabling me to test and correct the artificial keys, but by throwing much additional light on the validity of a number of doubtful forms. This report, as it now stands, is intended to include all species described prior to January 1, 1907, and to furnish a means for their ready identification. The synonymy of each species has received careful attention, but no attempt has been made to include every writer who has mentioned the form, unless he has in some way modified or qualified the name in use. The bibliography is thought to include every paper which contains any matter of importance relating to the two families, but a number of papers are omitted which simply contain casual references to, or familiar facts concerning, some of the well-known species.

As a matter of convenience, the classification of the two families is discussed first, and this is followed by an annotated list of the species in the collections of the National Museum, including descriptions of new genera and species. The remaining space is occupied by an account of the morphology, embryology, physiology, ecology, and taxology of the two families, with artificial keys and an account of each species, especial attention being given to the geographical distribution. The figures are intended to illustrate not only the new forms described, but also previously known species that have not been figured, and some others, figures of which will be of service to the student of these animals. A synonymic index is also given, to aid in finding any species referred to by previous writers. A sincere effort has been made to place the nomenclature on as firm a basis as possible, by the use of the now very generally accepted principles laid down in the International Code. This has involved a number of changes which, however unwelcome, were bound to be made sooner or later. The author lays no claim to infallibility, however, and does not expect that no errors will be found in his results. Lack of knowledge or poor judgment on his part, coupled with the inadequate descriptions of early writers, afford many loopholes for mistakes.

In conclusion, I desire to express the great obligation I am under to Mr. Richard Rathbun, the Assistant Secretary of the Smithsonian Institution, for his unfailing courtesy and many helpful suggestions, and to Miss Mary J. Rathbun, for much kind assistance in connection with nomenclature and illustrations. My friend, Professor L. T. Larsen, of Olivet College, has afforded me invaluable assistance in my effort to have philologically correct the new names I have been obliged to coin. I am also greatly indebted to Dr. Hjalmar Östergren, of Upsala, who by his letters and kindness in sending me specimens, as well as by his publications on the Synaptidæ, has proved an invaluable aid.

Finally, Dr. W. K. Fisher has very kindly permitted me to have advance sheets of his valuable memoir on Hawaiian Holothurians, and these have enabled me to include his work herein.

Cambridge, Mass., *April* 1, 1907.

PLATE I.

Synapta maculata (Chamisso and Eysenhardt).

Figure 1. Anterior end of adult, with verrucæ, natural size. (From Semper, 1868.)
2. Anterior end of adult, without verrucæ, natural size.

1. 2.

Synapta maculata Chamisso and Eysenhardt.

PART I.

THE CLASSIFICATION OF THE APODOUS HOLOTHURIANS.

The first writer on Holothurians who recognized the presence or absence of feet (pedicels) as an important character in the classification of the group was J. F. Brandt ('35), in his account of the animals observed by H. Mertens. He divided the group Holothuriæ, which he ranked as a family, into two great subdivisions, the Pedatæ and the Apodes. Unfortunately, however, he failed to distinguish accurately the apodous from the pedate forms, and consequently, as Ludwig ('81*b*) has shown, many really apodous forms occur in the Pedatæ. He divided the Apodes into the Pneumonophoræ and the Apneumones, according to the presence or absence of respiratory trees. But here again his observations were not exact, and some forms without respiratory trees are placed in his Pneumonophoræ. Burmeister ('37) ranked the holothurians as an order including several families, one of which, called by him Synaptidæ, was equivalent to Brandt's Apodes. Grube ('40) called the same group Chiridotæ, Forbes ('41) called them Synaptæ, Gray ('48) Synaptidæ, and Siebold ('48) Synaptinæ. Johannes Müller ('50) considered the possession of respiratory trees as the important point in holothurian anatomy, and accordingly he divided the order into "lungenlose" and "lungentragende" groups; the latter were divided into the "fusslose" and "fussige," and the "fusslose" were christened Molpadiidæ. Bronn ('60) recognized the position of the holothurians as a class, and divided it into two orders, the first of which contained only the extraordinary Rhopalodina, while the second was divided into two suborders, Apodia and Eupodia, the Apodia equivalent to Brandt's Apodes. Under the Apodia were placed two families, the Synaptidæ (without respiratory trees; four genera, Synapta, Synaptula, Chiridota, Myriotrochus) and the Liodermatidæ (with respiratory trees; three genera, Lioderma, Haplodactyla, Molpadia), Müller's Molpadiidæ.

With the publication of Selenka's monograph ('67) the study of the holothurians really began, from a modern systematist's point of view. He divided the class Holothurioidea into two orders, the Pneumonophora and the Apneumona, the former with three families, the last of which, the Liosomatidæ, was equivalent to Müller's Molpadiidæ. Selenka's classification of the footless forms may be tabulated thus:

Orders.	Families.	Genera.
PNEUMONOPHORA . .	Liosomatidæ . .	Molpadia, Liosoma, Haplodactyla, Caudina, Embolus.
APNEUMONA	Synaptidæ . . .	Synapta, Synaptula, Chirodota, Myriotrochus, Eupyrgus, Rhabdomolgus.

In the Liosomatidæ, Selenka included nine species, of which one was described for the first time. In the Synaptidæ were included 44 species, of which 29 were placed in the genus Synapta and 10 in Chirodota.

The notable monograph of Semper ('68) used essentially the same classification, but he called the family of footless Pneumonophora, Molpadiidæ, and in it he placed a new genus Echinosoma. He also described a new Haplodactyla, *H. molpadioides*, with two varieties, *pellucida* and *sinensis*. Under the Apneumona he placed two new families, the EUPYRGIDÆ and ONCINOLABIDÆ, each with one genus, but he expressed strong doubts as to the validity of these families, and regarded the genus Eupyrgus as probably belonging to the Molpadiidæ, and Oncinolabes as synonymous with Synapta. Under the Synaptidæ he placed a new genus, Anapta, containing one species. He also added 10 new species of Synapta and admitted 23 others; five new Chirodotas, and admitted 12 others; and he recognized three other genera each with one species. Semper therefore listed 68 species of apodous holothurians as against Selenka's 53.

Seventeen years later, Lampert ('85) returned to the classification of Brandt and recognized the order Apoda, with its two suborders each with a single family. His arrangement was as follows:

Suborders.	Families.	Genera.	No.	No. of valid species.	New species.	Doubtful.	Total.
Apneumona	Synaptidæ . .	Synapta, Anapta, Chirodota, Myriotrochus, Trochoderma, Acanthotrochus, Rhabdomolgus.	7	78	0	4	82
Pneumonophora . .	Molpadiidæ .	Haplodactyla, Molpadia, Liosoma, Caudina, Trochostoma, Ankyroderma, Eupyrgus.	7	24	0	1	25
			14	102	0	5	107

The next great monograph on holothurians, that by Théel ('86 *a*) adopts the same classification, except that Embolus is admitted among the Molpadiidæ and Liosoma is not. Owing to the description of 11 new species, the total number treated is 118, of which 26 are regarded as of doubtful standing. The classic work of Ludwig (*'92b*) in Bronn's Thierreich introduces an entirely new basis of classification and breaks up the suborder Apoda. Ludwig shows that the embryology of the Synaptidæ sets them apart as a distinct group from the other holothurians, and he therefore divides the class HOLOTHURIOIDEA into two orders, the ACTINOPODA and the PARACTINOPODA, distinguished by the place of origin of the circumoral tentacles. The Actinopoda include four families, of which the last is the Molpadiidæ, containing the footless species. The Paractinopoda includes the single family Synaptidæ. Ludwig's arrangement of genera is as follows:

Molpadiidæ = Molpadia (2 species), Eupyrgus (1), Haplodactyla (5), Caudina (4), Trochostoma (12), Ankyroderma (8).
6 genera, 32 species.
Synaptidæ = Synapta (51 species), Anapta (5), Chiridota (20), Trochodota (2), Trochoderma (1), Myriotrochus (1), Acanthotrochus (1).
7 genera, 81 species.
Total, 13 genera, 113 species.

The last important paper of the nineteenth century dealing with the classification of the footless holothurians is Östergren's (*'98b*) admirable revision of the Synaptidæ. He proposes to divide the family into three subfamilies, chiefly because of differences in the calcareous deposits: Synaptinæ with anchors and plates, or occasionally (Anapta) only miliary granules; Chiridotinæ with 6-spoked wheels, or sigmoid or bracket-shaped particles, never anchors; Myriotrochinæ with wheels having 8 or more spokes, never collected in papillæ. Under the Synaptinæ, he places Anapta and five other genera, made from the old genus Synapta, as follows: Euapta, Chondrocloea, Synapta, Labidoplax, Protankyra. These genera are distinguished from each other mainly by the shape of the tentacles and anchors and anchor-plates. Under the Chiridotinæ are placed two genera, Sigmodota and Chiridota, while Myriotrochus, Trochoderma, and Acanthotrochus make up the third subfamily. Altogether Östergren recognizes 81 species of Synaptidæ, the same number listed by Ludwig six years before.

The report on the holothurians of the "Travailleur" and "Talisman," by Rémy Perrier (:03), returns to the old arrangement of Brandt again, but is notable for the relative rank given previously recognized groups. He considers the apodous holothurians a natural assemblage, and ranks them as a subclass, the Apodes. This subclass includes two orders, the ANACTINOPODA[1] with one family, the Molpadiidæ, and the PARACTINOPODA with three families, the Synaptidæ, Chirodotidæ, and Myriotrochidæ. Thus Östergren's subfamilies are here raised to full family rank. Delage and Herouard (:04) recognize two orders, ACTINOPODIDA and PARACTINOPODIDA, under the first of which they place

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[1] Spelled Anactipoda on page 261, where first introduced; elsewhere spelled as above given.

the Molpadiidæ as a distinct suborder, with the usual single family and six genera. Their classification of the Paractinopodida is most confusing, for no subordinate groups are given save genera, of which 14 are recognized, two being known only from fossil remains. Moreover, although several references are made to Östergren's work, these only add to the confusion, for blunders are made in attempting to indicate the subfamilies proposed by him, and an obvious slip of the pen concerning the Chiridotinæ makes matters still worse. MacBride (:06), ignoring Ludwig's important embryological work, divides the holothurians into six orders, of which the last two are the MOLPADIIDA and SYNAPTIDA, each containing a single family and six genera. Such a classification is certainly no contribution to our knowledge of the group! Fisher (:07) recognizes the classifications used by Ludwig and by Östergren, at the same time calling attention to some points of nomenclature in which the latter seems to be in error. He adds a new genus (Opheodesoma) which is practically section B of Östergren's Euapta, and gives a very full account of the type species. He also describes four other new forms of Synaptidæ.

In arranging any scheme of classification, the first point to be determined is the relative value of characters upon which to base specific, generic, and family differences. In the holothurians, the characters which best determine family limits are the presence or absence of true retractor muscles and respiratory trees, the number and form of the tentacles, and the presence or absence of other ambulacral appendages. Since the ambulacral appendages, except tentacles, vary greatly in number, size, and arrangement, even in a single species, the characteristic features of the internal anatomy carry more weight. The group of apodous holothurians therefore cannot be accepted as a natural group, especially since the genera Himasthlephora and Gephyrothuria form an obvious connecting link with the pedate forms. The absence of respiratory trees is, however, a constant and remarkable character, and, combined as it is with the absence of pedicels and papillæ and the presence of unbroken circular muscles, marks out the Synaptidæ as a well-defined family, aside from its ordinal characters. The other apodous holothurians are less susceptible of satisfactory definition, aside from the lack of pedicels, but the shape of the body usually terminating in a more or less evident caudal portion, the peculiar, short tentacles, combined with the presence of respiratory trees, are really quite characteristic for the Molpadiidæ. These two families may therefore be accepted as including all known apodous holothurians (except the remarkable and unique Pelagothuriidæ), but there is no intention of implying any necessarily close connection between them. Perrier's (:03) reëstablishment of the group Apodes seems to be an attempt to base the classification on an obvious, external character, because it is convenient and easy to note, rather than an effort to reach a natural arrangement. No new arguments are advanced in favor of the Apodes, and the evidence is certainly against their standing as a subclass.

In discussing the classification of the Synaptidæ, the question naturally arises whether the subfamilies suggested by Östergren ('98*b*) are worthy of recognition. Subfamilies may be quite as natural groups as families, but if they are simply artificial assemblages they needlessly complicate the classification, unless the number of genera is unusually large, which is certainly not the case with the Synaptidæ. That Östergren's subfamily Synaptinæ is a natural group seems very probable, the genera contained in it being evidently related to each other. There is more room for question whether the Chiridotinæ and Myriotrochinæ can be properly separated from each other, but the calcareous particles are certainly strikingly different in the two groups, and it is at least probable that no violence is done in separating them. But Perrier's (:03) proposition to make full families of these subdivisions of the Synaptidæ cannot be approved without exaggerating their differences.

In attempting to define genera or species in the Synaptinæ, we are met with the difficulty that many are known from a single specimen or at most a few, and nothing is recorded of their life histories. Especially is this true of the various East Indian species, and since, in those species whose life history has been studied, it is known that the number of tentacles gradually increases as the animal approaches maturity, it is very probable that some of the 10- and 13-tentacled species will prove to be the young of other 12- or 15-tentacled forms. Moreover, many species have been described from fragments, the anterior end of the body being missing, and consequently the species are based wholly on the calcareous particles, which is of course unfortunate; for it ought to be clearly understood that the calcareous particles in the skin of Synaptids (as in all holothurians) are more or less variable, and while each species usually has its own distinct sort, yet there is a very wide range of diversity, even in one individual, and exact conformity to a given type must not be expected or looked for. The six genera proposed by Östergren appear in the main to be natural groups, and will doubtless be quite generally accepted. But unfortunately in selecting his names, Östergren overlooked or ignored some of his predecessors. The name Synapta was proposed by Eschscholtz ('29) for a species which he called *mammillosa*, and he also states that *Holothuria maculata* Chamisso and Eysenhardt is congeneric. There can be little question that these two species are the same, in spite of the extraordinary difference in the colored figures given (see page 79), and it is further reasonably sure that they are no other than the species well known as *beselii* Jäger. The name Synapta must therefore be retained for this species, which Östergren puts in his genus Chondrocloea. Owing to its unique anchor-plates, and some other peculiarities, it is better to regard it as *sui generis*, and let the other members of "Chondrocloea" stand apart. They cannot, however, be called by Östergren's name, for among them is "*vivipara*" (=*hydriformis* Lesueur), which was made the type of the genus Synaptula by Oersted in 1849, and they must therefore be called by the earlier name, of which Chondroclœa is obviously a synonym. One species of this group, however (*kefersteinii*), is so distinct from the others in its large number of tentacles that it may well be considered as the representative of another genus, for which I would suggest the name Polyplectana (see page 76). Östergren's other genera Anapta, Euapta, Labidoplax, and Protankyra are all valid and may be accepted without further discussion. His genus Synapta, however, must bear the name Leptosynapta, proposed for it by Verrill in 1867.[1] To these genera it is now necessary to add the recently rediscovered Rhabdomolgus Keferstein. It is also necessary to recognize a new genus, Dactylapta (see page 111), for a remarkable species from the Indian Ocean. Fisher's (:07) division of Euapta into two genera seems to me of doubtful value, but the two groups are as easy to distinguish from each other as they are from Synaptula, and we may therefore recognize Opheodesoma, for the present at least, without doing violence to any natural relationships. We thus recognize 11 genera of Synaptinæ.

When we come to the Chiridotinæ we must first of all determine to what characters we will give the most weight. The number of tentacles offers an obvious and tempting character, but one which must be used guardedly; it does not seem to be natural or justifiable to separate forms with 10 tentacles from those with 12, solely on that ground. Of course, where the difference in number is greater, the character has more weight. It is probable that Ludwig is right in putting the emphasis on the distribution of the calcareous wheels, while the presence or absence of the sigmoid bodies may be regarded as the feature of second importance. With these principles in mind, we find the classification of this subfamily quite simple. Östergren divides it into two genera, Sigmodota and Chiridota. The former genus was suggested by Studer ('76) for species having calcareous particles in the form of sigmoid bodies. Östergren proposes to include in Sigmodota all the species with sigmoid bodies, whether they have wheels or not, restricting Chiridota to species having no sigmoid bodies, and with the wheels in papillæ. The genera Toxodora Verrill ('82) and Trochodota Ludwig ('92*b*) are thus included in Sigmodota by Östergren, though he recognizes three distinct groups in the genus. Ludwig (92*b*) puts Toxodora under Anapta and bases Trochodota on the species with 10 tentacles, the wheels scattered (*i. e.*, not in papillæ), and sigmoid bodies present. The tentacles of Toxodora, however, are peltato-digitate, whereas those of Anapta are pinnate; the calcareous particles are also of essentially different types; it is hardly legitimate, therefore, to unite the two groups, for there is no reason to believe that they have a common ancestry or any close genetic connection. Verrill's genus appears to be valid and may be defined as

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[1] Fisher (:07) has already called attention to these necessary modifications of Östergren's names.

Chiridotinæ without wheels, but with small C- or bracket-shaped bodies. It is thus very closely allied to Chiridota. The genus Trochodota is a natural group, well characterized by several morphological features. At first sight it might seem that Ludwig's name is antedated by Studer's Sigmodota, but although Studer states that his type species is Lesson's *purpurea,* a perfectly recognizable species which Ludwig makes the type of Trochodota, he incorrectly identified the Chiridotinæ before him and in spite of their having 12 tentacles, called them *purpurea;* consequently he states that Sigmodota has 12 tentacles. (It has been generally assumed that he says further there are no wheels in Sigmodota; as a matter of fact, he says nothing whatever on that point.) Ludwig ('98*b*) has shown that the species Studer had in hand was undoubtedly *Chiridota contorta* Ludw., and as his generic diagnosis fits that species, *contorta* becomes the type of Sigmodota. But even though it is thus clear that Sigmodota and Trochodota are not synonyms, the former name cannot be used; for in 1868 Semper suggested that the peculiarities of *Chiridota australiana* Stimpson warranted its being made the type of a new genus to which he gave the name Tæniogyrus. This seems to be a natural and acceptable course to follow; but the genus, which is characterized by the presence of wheels collected in papillæ and numerous scattered sigmoid bodies, includes besides the type-species, *C. contorta* Ludwig and consequently Sigmodota Studer is a synonym of Tæniogyrus Semper. The interesting species, *C. japonica* v. Marenzeller, bears the same relation to Tæniogyrus that Toxodora does to Chiridota, and therefore is best treated as the type of a new genus, Scoliodota (see page 125). There are still left about a dozen species to make up the genus Chiridota, but one of these, the widespread *C. rufescens* Brandt, is so distinct from the others that it is entitled to generic rank, and we may call the genus Polycheira (see page 120). It is clear, I think, that *Anapta inermis* Fisher is one of the Chiridotinæ, and must, therefore, be made the type of a new genus which may well be called Achiridota (see page 126). There are thus seven genera of Chiridotinæ which it seems proper to recognize, instead of the two given by Östergren. However much multiplicity of genera is to be deplored, it cannot be avoided in this subfamily if our classification is to show natural relationships. In the Myriotrochinæ there are three well-marked genera, universally recognized, based on the form of the calcareous wheels; Myriotrochus, with wheels having 10-25 spokes and 17-35 large teeth extending horizontally inward from the rim; Trochoderma, with wheels having 10-16 spokes, and the rim with large, scattered, sharp knobs, but no horizontal teeth; Acanthotrochus, with two distinct kinds of wheels.

Turning now to the Molpadiidæ, we are confronted by only about half as many species as in the Synaptidæ, but with even more difficulty in arranging them in genera. No suggestion of subfamilies needs consideration in this group, the genera are so closely allied. Of the 10 genera which have been proposed, six are universally accepted: Ankyroderma, Caudina, Eupyrgus, Haplodactyla, Molpadia, and Trochostoma. Embolus Selenka is now regarded only as a synonym of Trochostoma; Echinosoma Semper corresponds to Eupyrgus; Microdactyla Sluiter is best treated as a synonym of Caudina; and Liosoma Brandt (Lioderma, Bronn), used by Stimpson for a Trochostoma, is really a synonym of Chiridota. But generic limits in this family are not sharply drawn and the evidence now to be presented breaks down all possible distinction between Ankyroderma and Trochostoma. As generally defined, the former is distinguished from the latter by the presence of rosettes of racquet-shaped rods, from the center of which there extends outward a conspicuous anchor. These anchors have a long shaft and serrate flukes, so that if they are numerous, the body surface is very rough, and it is not remarkable that Ankyroderma has been considered a clearly defined genus. I have had the opportunity of studying more than 350 specimens of these two genera, and a careful, long-continued examination has convinced me that the presence of the anchors and rosettes of racquet-shaped rods cannot be regarded as even a constant specific character. The first intimation I received of this fact came when comparing some specimens of "*Ankyroderma danielsseni* Théel" with others which I had identified as "*Trochostoma violaceum* (Studer)." I was struck by the similarity in general appearance and in the calcareous deposits of the body-wall, and my faith in the distinction between the two genera was shaken when I found some of the racquet-shaped rods in a specimen of what I had called Trochostoma. This led me to make numerous preparations from nearly all the specimens, and the longer I compared them, the more I became convinced that they all belong to a single species. Some are perfectly distinct specimens of *T. violaceum,* and show not a trace of anchors or racquet-shaped rods, and others agree perfectly with Théel's ('86*a*) description and figures of *A. danielsseni.* Between these two extremes, however, there are several specimens which at first sight would pass for *T. violaceum*, but of which a careful examination shows that here and there are scattered more or less imperfect groups of racquet-shaped rods, and occasionally there is evidence of an anchor having been present. My suspicion that Ankyroderma was untenable was thus confirmed, but it was made a certainty when I came to study the 150 or more specimens of Ludwig's *T. intermedium.* These varied in length from 17 to 180 mm. and showed all sorts of intermediate stages in the condition of the racquet-shaped-rod rosettes. The smaller specimens (those under 60 mm.) all have a very thin skin in which the colored bodies are light yellowish brown and the rosettes with anchors are numerous. They are clearly Ankyrodermas and I at first supposed they represented a new species of that genus. The largest specimens (those from 100 mm. up) have the body-wall rather thick and firm, the colored bodies in the skin very numerous and deep red or brown, and, with one exception, no anchors or rosettes. The specimens intermediate in size differ greatly in the texture of the skin, in the quantity and shade of the colored bodies, and in the presence, number, and condition of the rosettes. As a rule, it is undoubtedly true that the larger the specimen, the thicker the skin, the fewer and more imperfect the rosettes, and the darker and more numerous the colored bodies. But there are many exceptions: some rather small specimens show no trace of the rosettes, while some large specimens have the rosettes quite common and occasionally nearly complete. It is noticeable that as the rosettes begin to disappear, the number of rods become reduced and they begin to be transformed into colored bodies. Théel ('86*a*), Ludwig ('94), and others have referred to this transformation of calcareous particles into colored bodies, but in the specimens of *intermedium* before me, it is unusually well shown by the racquet-shaped rods. The gradual disintegration of a complete rosette with anchor into a heap of rounded colored bodies can be easily traced, and is well shown in figures 5 to 12, Plate XII. Ludwig ('94) in his account of *T. intermedium* refers to the occasional presence of peculiar, scattered, racquet-shaped rods, and figures one; so that it is clear his experience was not greatly different from mine. Moreover, in speaking of *Ankyroderma danielsseni*, Ludwig ('94, pp. 164-170) refers to the difficulty of deciding without very careful examination whether a given specimen is an Ankyroderma or a Trochostoma, so rare are the rosettes and anchors in some cases. As to the significance of these facts, our knowledge is as yet too imperfect to draw any clear conclusions. Chemical analysis of the deposits (see page 143) shows that the colored bodies are radically different from the ordinary deposits in the skin. Both are possibly connected with the process of excretion; but why one should replace the other, it is certainly hard to say. That the change is closely connected with the age of the individual seems to me almost certain, though it must be remembered that size in Echinoderms is not a sure criterion of age. It is interesting to note that most of the species of Ankyroderma described have been less than 60 mm. long, while many of the Trochostomas range over 75. The discovery that the presence of anchors and rosettes is not a constant feature of even a given species, combined with the fact that in Trochostoma the calcareous plates and tables are more variable and show greater individual diversity than in any other genus of holothurians, makes the proper classification of the genus at the present time almost hopeless. There may be some species in which the anchors are present throughout life and there may be species in which they are never present. In determining species, therefore, the presence or absence of anchors and rosettes can only be considered as a secondary character, even if it can wisely be taken into account at all. The name Trochostoma antedates Ankyroderma by two years and must therefore have the preference if either be used, but as a matter of fact both are synonyms of Cuvier's Molpadia. Although Cuvier's diagnosis is very brief and is also erroneous, there can be no doubt that the animal he had in hand was a specimen of what has since been called Trochostoma; for he says it was from the Atlantic Ocean, and none of the other genera to which his description might apply occur there. If we do not use Molpadia in this sense, it cannot be used at all, and the name of the family would consequently have to be changed. Since I have no doubt as to the group of holothurians to which Cuvier intended to apply Molpadia, I should not consider myself justified in rejecting his name.

As regards the remaining genera we are in difficulty, because of the very incomplete characterization given them by their original describers and the subsequent extensive emendations of later writers. The loss of the type specimens increases the trouble. The small genus Eupyrgus is the best characterized of all and seems to be a natural group. In 1840, Grube described Haplodactyla, a genus which he characterized as having simple tentacles without digits. Curiously enough, as Ludwig has shown, his type seems to have been a specimen of *M. musculus* Risso, and consequently Haplodactyla is a synonym of Molpadia. In 1868, Semper described a holothurian to which he very naturally applied the name Haplodactyla, but unfortunately Grube's name cannot be so used, if we are to observe the modern rules of zoölogical nomenclature, and consequently Semper's species and its allies are without a generic name. As the tentacles lack digits, we may call the group Aphelodactyla. In 1841, Gould described, under the name *Chirodota arenata,* a remarkable holothurian from the coast of Massachusetts, which Stimpson ('53) later made the type of a new genus Caudina. Unfortunately, Stimpson makes no attempt to define this genus or to show how it differs from Molpadia, referring simply to Ayres' ('52*a*) description, which contains some glaring errors. However, owing to the type species being well known, Caudina has been very generally accepted, and several other species have been added to the genus. In 1850, Müller described an interesting holothurian which he called *Molpadia chilensis,* and in 1868 Semper added *M. australis.* The latter gave a revised diagnosis of the genus, based on his own and Müller's work, and widely different from the original one of Cuvier. As defined by Semper, Molpadia was distinguished from Caudina chiefly by the presence of "retractor" muscles. As that character is one of very doubtful importance among the apodous holothurians (see pages 52 and 144), the species included by Semper and later writers in Molpadia belong rather in Caudina. One important exception to this statement must be made, however, for Sluiter's (:01) species, *M. demissa,* is evidently quite unlike the others, and must be made the type of a new genus, which may well be called Acaudina, from the absence of a caudal appendage.

Although many new species of apodous holothurians have been described in the past 20 years, no new genera ascribed to either family have been named, except in the rearrangement of the Synaptidæ referred to above. It is remarkable, therefore, that the collection from the National Museum should afford examples of two holothurians so extraordinary that they cannot be placed in any known genus, and the definition of the Molpadiidæ will have to be altered to make it possible to enter them in that family. In order to lay out clearly the plan of classification adopted in the present paper, it is necessary to introduce these new genera at this point. The descriptions will be found later on (see pages 39 and 40). One of these genera is based on four specimens from the Western Atlantic Ocean, of which the largest is only 28 mm. long. Owing to some curious lash-like dorsal papillæ, I have given the name Himasthlephora to this remarkable holothurian. It bears a striking resemblance to Gephyrothuria Koehler and Vaney (:05), which is regarded by its describers as representing a new family (Gephyrothuridæ) of Aspidochirotæ. A careful comparison of Himasthlephora with the descriptions and figures of Gephyrothuria convinces me that the two genera are very closely allied, if not identical. But it seems clear to me that they are Molpadiidæ and that the new family is quite uncalled for. On account of the differences in the tentacles and the caudal appendage, it seems best to keep the two genera separate for the present. The other genus to be described is based on three specimens from Bering Sea, the general appearance of which is not unlike "Trochostoma;" but the tentacles are extraordinarily different, and the name of the genus (Ceraplectana) is based on this character. There are, therefore, eight genera of Molpadiidæ recognized in the present report.

The following table shows in outline the classification herein adopted and the number of species recognized in each genus:

Families.	Subfamilies.	Genera.	Type species.	No. of species herein recognized.
Synaptidæ Burmeister. 21 genera, 88 species.	Synaptinæ Östergren. 11 genera, 60 species.	*Synapta* Eschscholtz.	*maculata* Chamisso & Eysenhardt.	1
		Euapta Östergren.	*godeffroyi* Semper.	2
		Opheodesoma Fisher.	*spectabilis* Fisher.	4
		Polyplectana, gen. nov.	*kefersteinii* Selenka.	1
		Synaptula Oersted.	*hydriformis* Lesueur.	8
		Leptosynapta Verrill.	*inhærens* O. F. Muller.	9
		Labidoplax Östergren	*buskii* McIntosh.	5
		Protankyra Östergren.	*abyssicola* Théel.	25
		Anapta Semper.	*gracilis* Semper.	3
		Dactylapta, gen. nov.	*dubiosa* Koehler & Vaney.	1
		Rhabdomolgus Keferstein.	*ruber* Keferstein.	1
	Chiridotinæ Östergren. 7 genera, 22 species.	*Chiridota* Eschscholtz.	*discolor* Eschscholtz.	13
		Polycheira, gen. nov.	*rufescens* Brandt.	1
		Tæniogyrus Semper.	*australianus* Stimpson.	2
		Trochodota Ludwig.	*purpurea* Lesson.	3
		Scoliodota, gen. nov.	*japonica* v. Marenzeller.	1
		Toxodora Verrill.	*ferruginea* Verrill.	1
		Achiridota, gen. nov.	*inermis* Fisher.	1
	Myriotrochinæ Östergren. 3 genera, 6 species.	*Myriotrochus* Steenstrup.	*rinkii* Steenstrup.	4
		Trochoderma Théel.	*elegans* Théel.	1
		Acanthotrochus Danielssen & Koren.	*mirabilis* Danielssen & Koren.	1
Molpadiidæ J. Müller. 8 genera, 46 species.	....	*Molpadia* Cuvier.	*holothurioides* Cuvier.	27
		Caudina Stimpson.	*arenata* Gould.	8
		Acaudina, gen. nov.	*demissa* Sluiter.	1
		Aphelodactyla, nom. nov.	*molpadioides* Semper.	5
		Eupyrgus Lütken.	*scaber* Lütken.	2
		Ceraplectana, gen. nov.	*trachyderma*, sp. nov.	1
		Himasthlephora, gen. nov.	*glauca*, sp. nov.	1
		Gephyrothuria Koehler & Vaney.	*alcocki* Koehler & Vaney.	1

Finally, in conclusion of this section, it may be stated that no subspecies or varieties are accepted. In some cases proposed subspecies, when well characterized, have been raised to full specific rank, while more commonly no attempt is made to distinguish them at all. The wide-ranging species are so variable and our knowledge is at present so incomplete, genuine subspecies cannot be positively determined. Until our collections are far more extensive and have been studied with great care, we cannot profitably make use of subspecific or varietal names.

PART II.

THE APODOUS HOLOTHURIANS OF THE UNITED STATES NATIONAL MUSEUM.

The collection contains about 2,200 specimens, representing 43 species, of which 23 are Synaptidæ and 20 are Molpadiidæ. There seem to be eight species which have never been described, two of these representing new genera. The collection is almost wholly from the American coast, and chiefly from the Pacific coast of North America. Most of the specimens are in good condition, but many of the Chiridotas, especially those from deep water, are almost worthless. The large series of specimens of *Chiridota lævis* and *discolor,* and of *Molpadia musculus* and *intermedia* have been of the greatest value in attempting to solve the problems connected with those perplexing genera. The following are the species represented in the collection:

SYNAPTIDÆ.

SYNAPTA MACULATA (Chamisso and Eysenhardt).

There is a single specimen in excellent condition, collected at Cebu, Philippines, by the "Challenger."

EUAPTA LAPPA (Müller).

There are two large specimens from Great Sound, Bermudas, which are of interest as the only specimens yet recorded from those islands.

SYNAPTULA HYDRIFORMIS (Lesueur).

There is a single small specimen of this species from Watling's Island, W. I.

LEPTOSYNAPTA DOLABRIFERA (Stimpson).

There are six good specimens of this interesting species, from Port Jackson, New South Wales, the locality where Stimpson's type was taken. There have been no records of, or notes on, this species published since Stimpson's original description; consequently these specimens are of the greatest value in determining the relationships of the species.

LEPTOSYNAPTA INHÆRENS (O. F. Müller).

There are some 130 specimens from Woods Hole, Mass., and vicinity, 10 from New Haven, Conn., 155 from Newport, R. I., and 8 from Provincetown, Mass. There are four specimens from Point Loma, California, which show no characters by which they can be distinguished from specimens from the

Atlantic coast. There are also two fragments of a Synapta from Sitka, Alaska (Eastern harbor, 16 meters, green mud), which is probably a young individual of this species. These fragments are about 2 mm. in diameter, yellowish, with scattered minute red spots. One is an anterior end and has 10 pinnate tentacles, each with 7, 9, or 11 digits and 2 or 3 sense-cups. The calcareous ring and particles in skin are like those of *inhærens*, except that the anchor arms are smooth. All of these peculiarities seem to me to indicate immaturity, but the specimen is strikingly suggestive of Östergren's *Synapta decaria* (*q. v.*). An anterior end of a similar small synaptid with 11 tentacles is in the collection labeled simply "Alaska," and confirms the opinion that the one from Sitka is a young *inhærens*. There is also a nicely preserved specimen from Bergen, Norway. I am unable to distinguish satisfactorily between the specimens from Alaska, California, Massachusetts, and Norway.

Leptosynapta ooplax (v. Marenzeller).

There are 18 specimens from Funafuti, of which the largest is about 200 cms. long. The calcareous particles are like those of Bedford's variety *lævis* from the Loyalty Islands, but there is no little diversity even in a single individual.

Labidoplax digitata (Montague).

There are two specimens from Trieste, Austria, of small size, but notable for the large size of the anchors and plates near the posterior end of the body. Many of the anchors are half a millimeter or more in length, but they do not resemble the so-called "giant" anchors of this species. Sense-cups are present on the tentacles, but I failed to detect a "giant" anchor anywhere.

Labidoplax dubia (Semper).

There are five specimens of this species taken off the coast of Japan by the "Albatross" (Stations 3723, 3724, and 3770) in 23-81 m. They agree perfectly with the specimens called "*incerta* var. *variabilis*," by Théel ('86*a*) collected near Japan by the "Challenger." I fail to distinguish them from *dubia* Semper in any other way than by the presence of sense-cups on the tentacles, which Semper says were lacking in *dubia*. As he only had a single, mutilated specimen, however, I cannot consider this difference of great importance. The specimens before me are 60-70 mm. long and about 4 mm. in diameter, and are of a dirty whitish color, though one specimen shows an evident reddish tint dorsally. There are 5 or 6 sense-cups on each of the 12 tentacles, and 4 digits. The anchors and plates are abundant; the former are 200-265 μ long; the latter, 180-235 μ. The miliary granules are very scarce and usually have the ends little, if at all, bent.

LABIDOPLAX THOMSONII (Herapath).

A decalcified synaptid from Naples lacks sense-cups on the tentacles and seems to be referable to this species.

PROTANKYRA ABYSSICOLA (Théel).

PLATE IV, FIGS. 8-11.

A single strongly contracted individual of this species is in the collection, dredged by the "Albatross" in 2,260 m. (St. 2382) in the Gulf of Mexico, lat. 28° 19′ 45″ N., long. 88° 01′ 30″ W. Fortunately the anterior end is uninjured, and it is possible, therefore, to figure one of the tentacles and the calcareous deposits. These agree essentially with those described by Ludwig ('94) for the closely allied species *pacifica*. The specimen is 65 mm. long and 5 mm. in diameter, and the color is dark yellowish, with considerable reddish pigment at base of tentacles, on the inner side. Anchors and plates are numerous on the bivium, but are almost wanting on the trivium near the middle of the body, though somewhat more common posteriorly. There are 7 polian vessels, slender and nearly equal. The stone canal was not found. The genital glands are small and somewhat branched. The anchors (700 μ long) have the teeth on the flukes sharp, and not blunt, as figured by Théel. The plates (550 μ) have the holes rather smooth or with several teeth. No miliary granules were found.

PROTANKYRA PACIFICA (Ludwig).

The type and co-type of Ludwig's *Synapta abyssicola* var. *pacifica* from "Albatross" Stations 3360 and 3381, off Panama, 3,009-3,189 m., are in the collection. They are quite different from *abyssicola* and are entitled to full specific rank.

PROTANKYRA BRYCHIA (Verrill).

PLATE IV, FIGS. 12-14.

There is a single headless fragment of this species, from 1,688 m. off Cape Hatteras ("Albatross" Station 2111), lat. 35° 9′ 50″ N., long. 74° 57′ 40″ W. Although not labeled, I suspect this is Verrill's type, as it is from the same locality and answers his description exactly. It is gray, 100 mm. long and about 9 mm. in diameter. There are two polian vessels and long branched genital glands. The anchors and plates are similar to those in the preceding species, but are much larger, a full mm. or more in length, and the flukes of the anchors are more slender. Miliary granules in the shape of simple elongated discs or oval rods occur along the radii. The anchors and plates are in approximately three longitudinal rows in each interradius.

Protankyra duodactyla, sp. nov.

(δύω, two + δάκτυλα (poetic plural), fingers; in reference to the number of digits.)

Plate IV, Figs. 1-7.

Tentacles 12, well expanded, each with only 2 digits. Calcareous ring narrow, 1 mm. high, the radial pieces slightly higher and perforated for passage of the nerve. Cartilaginous ring wanting. Polian vessels only 2. Stone-canal single, of moderate size. Genital glands long and branched. Body rather stout, cylindrical. Anchors 360 μ long, similar to those of *inhærens,* though the base is somewhat wider. Plates 300 μ long, unlike those of any known synapta, perfectly flat, usually with no bow, and with smooth holes. Two holes are much larger and more elongated than the others, and lie side by side, with the smaller holes more or less symmetrically arranged at the two ends of the plate. One end usually has many more holes than the other, and no two of the plates are exactly alike; many seem to be only partly developed. Miliary granules wanting, but there are numerous branched rods and perforated plates in the tentacles. Color, uniform gray. Length, 60 mm. Diameter, 8 mm.

The specimen just described (type, Cat. No. 19,829, U. S. N. M.) was taken at "Albatross" Station 2871, in 1,006 m., lat. 46° 55′ N., long. 125° 11′ W., about 60 miles off Gray's Harbor, Washington. A second specimen, in very poor condition, is in the collection, from lat. 54° 11′ 30″ N., long. 167° 25′ W., 1,777 m. In this specimen the plates are only 250 μ long, and many of them have a more or less incomplete bow on that end of the plate which has the more numerous holes (fig. 5). The presence of only 2 digits allies this species to *P. bicornis* (p. 101), but the plates are very different from those of that or any other species.

Anapta fallax Lampert.

There are 2 incomplete specimens from off the southern coast of Chile, "Albatross" Station 2784, lat. 48° 41′ S., long. 74° 24′ W., 350 m. Both are anterior ends of small individuals, the oral discs being only 3 mm. in diameter. Each has 12 tentacles with 7 or 9 digits. The minute elliptical rods are most numerous along the radii, and the tentacles are richly supplied with slightly curved rods, which are either smooth or rough. The color of these specimens is pale yellowish brown.

Chiridota discolor Eschscholtz.

There are considerably more than 600 Chiridotas in the collection, which almost defy classification, for though the largest specimens are easily separated from the smallest, not only by size, but by color and general appearance, there are almost all possible intergradations between the extremes. The largest specimens are all from Alaska or Siberia, and are distinctly gray or creamy whitish in color. In life, the largest must have been over 30 cm. long and about 15 mm. in diameter, but most of the specimens of approximately the same color and general appearance are much smaller, 10-15 cm. in length. The wheel-papillæ are usually in a single row, and that is apparently in the mid-dorsal interambulacrum. These specimens, I believe, represent Eschscholtz's species *discolor,* as shown by the habits as well as the habitat, for they are said to be "common in mud, under rocks." Eschscholtz, however, says that *discolor* has 15 tentacles, 12 large and 3 small, while all the specimens I have examined (save 1 with 9) have 12 tentacles. Moreover, he says that there is on each of 3 interradii a single row of large white spots (the wheel-papillæ, doubtless); while most of the specimens before me have only one, many have none, a few have 2, several 3, and one 5. In spite of these differences, the fact that this seems to be the abundant littoral chiridota of Alaska makes it very probable that it is the species Eschscholtz was describing. I have accordingly referred the following 207 specimens to *discolor:*

1	specimen	from	Arctic Ocean.		
11	specimens	from	Alaska.		
16	“	“	Nazan Bay, Atka, Alaska.		
20	“	“	Atka Island, Alaska.		
3	“	“	Port Etches, Alaska.		
4	“	“	Robben Island, Siberia, 50 m.		
1	specimen	from	Bering Island.		
7	specimens	from	lat. 65° 25′ 28″ N., long. 171° 11′ 26″ W.		
18	“	“	“Albatross”	Station	2852, lat. 55° 15′ N., long. 170° 33′ W., 74 m.
1	specimen	“	“	“	2853, lat. 56° N., long. 154° 20′ W., 286 m.
2	specimens	“	“	“	2871, lat. 46° 55′ N., long. 125° 11′ W., 1,006 m.
2	“	“	“	“	2928, lat. 32° 47′ 30″ N., long. 118° 10′ W., 750 m.
4	“	“	“	“	3077, lat. 55° 46′ N., long. 132° 24′ W., 580 m.
30	“	“	“	“	3227, lat. 54° 36′ 30″ N., long. 166° 54′ W., 405 m.
11	“	“	“	“	3310, lat. 53° 56′ 51″ N., long. 166° 28′ 53″ W., 104 m.
5	“	“	“	“	3324, lat. 53° 33′ 50″ N., long. 167° 46′ 50″ W., 196 m.
2	“	“	“	“	3326, lat. 53° 40′ 25″ N., long. 167° 41′ 40″ W., 1,037 m.
2	“	“	“	“	3329, lat. 53° 56′ 50″ N., long. 167° 8′ 15″ W., 720 m.
20	“	“	“	“	3439, lat. 57° 06′ N., long. 170° 33′ W., 74 m.
2	“	“	“	“	4227, near Naha Bay, Alaska, 111-117 m.
45	“	with no label.			
207	“	from 21 stations.			

Many of these specimens are in poor condition, some so very poor as to make positive identification impossible. It is not unreasonable to suppose that if this great mass of material could have been carefully studied when living, it would have been possible to distinguish at least two species, but at present such division would be hazardous and of no advantage.

CHIRIDOTA REGALIS, sp. nov.

(*regalis*, royal; in reference to the color.)

Similar in general appearance to *discolor*, but distinguishable at once by the purple color. In some specimens the color is pale, but in most it is quite deep, and in some it is a rich royal purple. The wheel-papillæ are rather numerous, but are confined almost wholly to the mid-dorsal interambulacrum, although anteriorly a very few may occur in the lateral interambulacra. Aside from the color, this handsome species differs from *discolor* and *lævis* in the presence of C-shaped deposits along the ambulacra. These deposits are similar to those shown in figure 27, plate VII, and seem to be constantly present, although not always abundant. They are not confined to the area of the longitudinal muscles, but occur in the skin along each side of that region. The largest of the specimens in the collection is upward of 200 mm. long.

26 specimens from "Albatross" Station 3695, south coast of Honshu Island, Japan, 198-428 m.
3 " " " " 3737, Suruga Gulf, Honshu Island, Japan, 290-300 m.
—
26 " " 2 stations.

CHIRIDOTA LÆVIS (Fabricius).

Of the more than 400 Chiridotas remaining, there are some which are very clearly representatives of Fabricius's species, but there are others which are quite different, although there are numerous connecting examples. The condition of the specimens makes a careful separation of species out of the question. There are, however, 4 sorts of individuals which are fairly recognizable, though not always so. The typical form is small, soft, pinkish, more or less translucent, and has the wheel-papillæ in 3 rows dorsally, with some scattered ones anteriorly on the ventral interambulacra. These are from water 5 or 7 m. deep, between Nantucket Island and High Duck (Grand Manan), off the Atlantic coast of America. Others resemble these in the arrangement of the wheel-papillæ, but are much larger and are cream-colored or light gray; they are from the Bay of Fundy, Labrador, and Anticosti. Still others have the body-wall generally stiffer, and the color is more or less dirty brownish. These are all from the Pacific coast of America, and may prove to be a distinct species from those of the North Atlantic. The fourth sort are similar to the latter, but have the wheel-papillæ in a single row. They are also all from the North Pacific. Since the Atlantic forms answer well to Duncan's and Sladen's description of Fabricius's species, I feel justified in calling them *lævis,* and as I am not able to find any constant distinguishing characters, I have referred all of the following specimens to that species:

1	specimen	from	Anticosti.		
3	specimens	from	Labrador.		
40	“	“	the Bay of Fundy.		
26	“	“	between Nantucket (N. B.) and High Duck, in 5-7 m.		
1	specimen	from	“Albatross”	Station	2866, lat. 48° 09′ N., long. 125° 3′ W., 308 m.
1	“	“	“	“	2922, lat. 32° 27′ 15″ N., long. 119° 5′ 15″ W., 85 m.
3	specimens	“	“	“	3070, lat. 47° 29′ 30″ N., long. 125° 43′ W., 1,145 m.
50	“	“	“	“	3193, lat. 35° 25′ 50″ N., long. 121° 9′ 10″ W., 288 m.
250	“	“	“	“	3196, lat. 35° 2′ 55″ N., long. 120° 59′ 40″ W., 360 m.
2	“	“	“	“	3210, lat. 54° N., long. 162° 40′ 30″ W., 869 m.
3	“	“	“	“	3326, lat. 53° 40′ 25″ N., long. 167° 41′ 40″ W., 1,037 m.
10	“	“	“	“	3329, lat. 53° 56′ 50″ N., long. 167° 08′ 15″ W., 720 m.
10	“	“	“	“	3330, lat. 54° 0′ 45″ N., long. 166° 53′ 50″ W., 632 m.
2	“	“	“	“	3340, lat. 55° 26′ N., long. 155° 56′ W., 250 m.
4	“	“	“	“	3343, lat. 47° 40′ 40″ N., long. 125° 20′ W., 929 m.
9	“	“	“	“	3603, lat. 55° 23′ N., 170° 31′ W., 3,188 m.
4	“	“	“	“	3607, lat. 54° 11′ 30″ N., long. 167° 25′ W., 1,776 m.
419	“	“	17 different stations, mostly collected by the “Albatross.”		

Many of these specimens are in very poor condition, a large majority having the calcareous deposits dissolved. It is practically out of the question to separate them and make more than a single species from the lot, although it seems almost certain that there are at least three species included in this mass of material.

CHIRIDOTA PISANII Ludwig.

There are three specimens from Gregory Bay, Strait of Magellan. The wheel-papillæ are very few, but there are many miliary granules along the radii.

CHIRIDOTA ROTIFERA (Pourtales).

From Key West there are 9 small specimens of this common tropical species.

TÆNIOGYRUS AUSTRALIANUS (Stimpson).

There are five excellent specimens of this very interesting species in the collection from Port Jackson, New South Wales. They show that Stimpson's description is correct as far as it goes, and that the species is entirely distinct from either *contortus* Ludwig or *dunedinensis* Parker. The specimens are yellowish, 30-50 mm. long and each has 10 tentacles, with 5-6 pairs of digits. The genital glands are distinctly branched, and there is a single polian vessel.

The calcareous ring is very narrow, much as Dendy ('97) figures it for *dunedinensis.* The wheel-papillæ are conspicuous in the three dorsal interradii, especially anteriorly. The sigmoid bodies are also collected, on the dorsal side, into little groups which appear to the naked eye as numerous small whitish papillæ.

TÆNIOGYRUS CONTORTUS (Ludwig).

There are 3 specimens of this species from the Strait of Magellan, "Albatross" Station 2771, lat. 51° 34′ S., long. 68° W. They were dredged in 91 m., and measure 40-45 mm. long.

SCOLIODOTA JAPONICA (v. Marenzeller).

There is a single specimen in the collection. one of those taken by the "Challenger" at Port Jackson, New South Wales. and already described by Théel. There can be no doubt that wheels are entirely wanting.

MYRIOTROCHUS RINKII Steenstrup.

There are rather more than 600 specimens of this little holothurian in the collection, from 10 widely separated points: Point Belcher, Arctic Ocean, 16 m., sand; off the banks of Newfoundland, lat. 45° 35′ N., long. 55° 01′ W., 121 m.; Barden Bay, Inglefield Gulf, 18-72 m.; Norway; Cape Smyth, Alaska; Aberdore Channel, east of Alger Island; Point Barrow, Alaska; Greenland; Kara Sea; and "Albatross" Station 3440, Bering Sea, lat. 57° 05′ N., long. 170° 41′ W., 86 m. The abundance of material from Bering Sea and the banks of Newfoundland led me to make a comparison of the calcareous wheels of the specimens from those points. These measure 164 to 328 μ in diameter, but average about 245 μ, and the very great majority are near that figure. The wheels of specimens from the banks average 16.5 spokes and 26.5 teeth on the rim; the number of spokes, therefore, is about 0.62 that of the teeth. In specimens from Bering Sea the average was 17 spokes and only 23.7 teeth, or about 0.71. This difference was found in counting 10 wheels chosen at random in each of 10 specimens from each locality. It is not probable, however, that it really has any significance, as the number of spokes and teeth shows such great diversity, and there is apparently no correlation between the two; for although the wheel with the smallest number of spokes (12) had the smallest number of teeth (16) and the wheel with the largest number of spokes (22) had the largest number of teeth (30), wheels with only 15 spokes had as many as 29 teeth—that is, a ratio of only 0.51—while others with 17 spokes had only 18 teeth, or a ration of 0.94. In every case, however, there were more teeth than spokes. It is interesting to compare these figures with those given by Östergen (:03). He says the wheels of specimens from eastern Siberia average from 240 to 260 μ, while those of Norwegian specimens averaged 208-

220; the American material is thus seen to be very similar in this particular to the Siberian. The Siberian specimens, however, averaged about 20 spokes to the wheel, while those from Norway had about 16; so, in this particular, American specimens are more like the Norwegian. The average number of teeth, as given by Östergren, is 26.5–29.3, which is decidedly more than in the American material. The number of spokes is about 57 per cent of the number of teeth in Norwegian specimens, about 62 per cent in Newfoundland specimens, about 71 per cent in Bering Sea material, and about 76 per cent in high Arctic specimens. It seems quite possible, judging from these figures, to draw the conclusion that the number of spokes tends to decrease toward the southern limit of the range of *Myriotrochus rinkii.*

MOLPADIIDÆ.

Molpadia affinis (Danielssen and Koren).

In the same bottle with the two specimens of *arctica* from the Kara Sea, labeled "*boreale*" (see page 32), was a third specimen, 75 mm. long, with a few scattered colored bodies and numerous calcareous tables exactly like those figured by Danielssen and Koren ('82) for *affinis;* there are, however, no anchors or rosettes. Although the status of *affinis* is not beyond question, this specimen must for the present be referred to that species.

Molpadia amorpha, sp. nov.

(ἄμορφος, misshapen; in reference to the imperfectly formed calcareous tables.)

Plate XIII, Figs. 14-22.

Body rather stout, the caudal region short; skin thin, but not delicate. Ground color, gray, more or less spotted, flecked or blotched with dark purplish; in some specimens the purplish predominates, especially toward the anterior end, which may become almost uniformly dark; the oral disc and tail are, however, always gray. Tentacles 15 (in two specimens there were only 14), each with 3 terminal digits. Calcareous ring as usual. Deposits of two kinds, elliptical phosphatic bodies, and calcareous tables; elliptical bodies small and dark purplish red, though some very small, yellowish-brown ones also occur; tables small and irregular, widely scattered in body-wall, but common though not crowded, in the caudal region. They are very abortive, twisted and incomplete, and it is upon this fact that I have based the name.

3 specimens from "Albatross" Station 2779, lat. 56° 6′ S., long. 70° 40′ 30″ W., 138 m.
1 specimen " " " 2783, lat. 51° 2′ 30″ S., long. 74° 8′ 30″ W., 220 m.
20 specimens " " " 2784, lat. 48° 41′ S., long. 74° 24′ W., 349 m. Types and co-types, Cat. No. 19,866, U. S. N. M.
—
24 " " 3 stations.

The largest specimen is 140 mm. long (10 mm. is "tail") and 45 mm. in diameter; the smallest is 52 mm. long and 20 mm. in diameter. The specimens from Station 2779 are very large and very deep purplish-red, excepting only the oral disc and tail; they thus bear a striking resemblance to some specimens of *oölitica*.

The general appearance of most of the specimens, in form, color, and texture of skin, distinguish them at once from any other species which I have seen, and the scattered, very imperfect tables are also quite characteristic. The species is probably most nearly related to *Molpadia intermedia* (Ludwig), but the specimens from Stations 2783 and 2784 are easily distinguished from any specimen of that species which has come under my notice, while those from Station 2779 were identifiable by means of the infrequent, scattered misshapen tables of the body-wall.

Molpadia antarctica (Théel).

There are numerous specimens of this species, all but two from the vicinity of Wellington Island, off the coast of Chile. The largest is 92 mm. long, while the smallest is only 14. They all agree in having a very thin and delicate skin, gray in color, but generally somewhat blotched with yellowish-brown, especially dorsally and anteriorly; in some specimens there is a tinge of brown around the caudal region. There are numerous calcareous deposits in the small specimens, but in those over 30 mm. long, they are confined to the caudal region, and in a specimen 35 mm. long they are scarce even there. In the large specimens no trace of calcareous bodies could be found in any part of the skin. The deposits are similar to those in the following species; the disc is in most cases regular, and the spire is longest in the smallest specimens, where it sometimes has as many as 7 cross-bars; in older specimens the spire of the tables is shorter and it may be wanting.

3	specimens	from	"Albatross"	Station	2782, lat. 51° 12′ S., long. 74° 13′ 30″ W., 464 m.
5	"	"	"	"	2783, lat. 51° 02′ 30″ S., long. 74° 08′ 30″ W., 220 m.
18	"	"	"	"	2784, lat. 48° 41′ S., long. 74° 24′ W., 349 m.
2	"	"	"	"	2791, lat. 38° 8′ S., long. 75° 53′ W., 1,218 m.
28	"	"	4 stations.		

Molpadia arctica (v. Marenzeller).

Of this species there are three specimens before me, two of which are labeled "*Trochostoma boreale*, Kara Sea," while the third is labeled "*Trochostoma arcticum*, Norway." These specimens all agree in the entire absence of colored bodies in the skin, and although the tables are simpler and less crowded in the specimen from Norway than in the others, I am not able to separate them satisfactorily. They have the thin skin characteristic of *arctica*, and I have no hesitation in referring them all to that species. Whether *arctica* is really distinct from *borealis* (*oölitica*) is still an unsettled point; so far as I know, connecting forms have not been recorded as yet.

MOLPADIA ARENICOLA (Stimpson).

PLATE XII, FIGS. 1, 2.

There are 8 specimens of this species in the collection, and they agree perfectly with Stimpson's description, except that the calcareous ring consists of the usual 10 pieces found in the Molpadiidæ. The largest is about 120 mm. long and 35 mm. in diameter, and the caudal portion is not abruptly narrowed, though it is only 5 mm. thick at the extremity; although there are no deposits in the skin of the body, there are numerous small, much-branched rods and perforated plates in the skin of the tail. In the smallest specimens, the calcareous particles are more abundant. The specimens are from San Pedro and San Diego, California, and "Southern California." Some, if not all, were picked up on the beach after storms.

MOLPADIA BLAKEI (Théel).

There is a single specimen of this very well characterized form, from "Albatross" Station 2383, Gulf of Mexico, lat. 28° 32′ N. and long. 88° 6′ W., 2,126 m. It is of a light grayish-brown color and about 50 mm. long. The caudal appendage is very short, there are no colored bodies, and the remarkable tables are very abundant, though not crowded.

MOLPADIA GRANULATA (Ludwig).

Ludwig's type and three co-types, from "Albatross" Stations 3361 and 3399, off Panama, 2,648-3,132 m., are in the collection, but there are no other specimens.

MOLPADIA INTERMEDIA (Ludwig).

PLATE XII, FIGS. 5-15.

This is apparently the common Molpadia of the eastern Pacific, for there are no less than 143 specimens before me, collected at various points from the 28th to the 56th parallel, and at depths ranging from 52 to 2,925 m. They vary in length from 17 to 105 mm., with corresponding variety in form, texture of skin, and color. The smallest specimens are gray, and the yellowish-brown ellipses in the skin are so small and scattered they only become visible under the microscope; the skin is very thin and delicate and abundantly supplied with calcareous bodies, the tables characteristic of the species, and the rosettes and anchors supposedly characteristic of Ankyroderma. The largest specimens have the ground color gray, but this is more or less completely hidden by the reddish-brown color, caused by the very numerous "ellipses"; the skin is moderately thin but firm; the calcareous bodies are in nearly all cases simply the tables, but not infrequently the last browning remnants of a rosette are found, and occasionally more or less complete rosettes and anchors occur. Between the two extremes all possible intergradations occur, and it seems almost beyond question that the small specimens are the young, the large specimens the adults. Ludwig had only 5 specimens before him for his description, and all were over 48 mm. long, but he speaks of the very thin skin of the smallest and of the presence of rare, scattered, perforated rods, like those which make up the rosettes of Ankyroderma, though he did not find any rosettes or anchors.

13	specimens	from	“Albatross”	Station	2838, lat. 28° 12′ N., long. 115° 09′ W., 79 m.
8	“	“	“	“	2902, lat. 34° 06′ N., long. 120° 02′ W., 95 m.
1	specimen	“	“	“	2971, lat. 34° 20′ 30″ N., long. 119° 37′ 50″ W., 48 m.
12	specimens	“	“	“	2972, lat. 34° 18′ 30″ N., long. 119° 41′ W., 110 m.
10	“	“	“	“	2973, lat. 34° 19′ 30″ N., long. 119° 44′ 15″ W., 122 m.
50	“	“	“	“	3068, lat. 47° 55′ 30″ N., long. 122° 27′ W., 243 m.
1	specimen	“	“	“	3193, lat. 35° 25′ 50″ N., long. 121° 09′ 10″ W., 288 m.
5	specimens	“	“	“	3195, lat. 35° 14′ N., long. 127° 07′ W., 454 m.
2	“	“	“	“	3196, lat. 35° 02′ 55″ N., long. 120° 59′ 40″ W., 48 m.
6	“	“	“	“	3307, lat. 53° 55′ N., long. 170° 50′ W., 1,859 m.
11	“	“	“	“	3308, lat. 56° 12′ N., long. 172° 07′ W., 2,925 m.
1	specimen	“	“	“	3331, lat. 54° 1′ 40″ N., long. 166° 48′ 50″ W., 630 m.
2	specimens	“	“	“	3395, lat. 7° 30′ 36″ N., long. 78° 39′ W., 1,314 m.
2	“	“	“	“	3431, lat. 23° 59′ N., long. 108° 40′ W., 1,791 m.
2	“	“	“	“	3478, lat. 36° 44′ 45″ N., long. 120° 57′ W., 122 m.
3	“	“	“	“	3604, lat. 54° 54′ N., long. 168° 59′ W., 2,522 m.
1	specimen	“	“	“	3666, lat. 36° 45′ N., long. 121° 53′, 122 m.
1	“	“	“	“	3667, lat. 36° 45′ N., long. 121° 52′, 162 m.
1	“	“	“	“	3676; no record.
4	specimens	“	“	“	3737, off Honshu Island, Japan, 295 m.
1	specimen	“	“	“	3738, off Honshu Island, Japan, 300 m.
2	specimens	“	“	“	3775, off Honshu Island, Japan, 103 m.
4	“	No locality.			
143	“	“	23 stations.		

Molpadia musculus Risso.

Plate XI.

Besides Ludwig's type and two co-types, from Stations 3382, 3392, and 3432, off Panama and in the Gulf of California, 2,286–3,230 m., there are three small specimens (27, 43, and 65 mm. in length) of a Molpadia from "Albatross" Station 2393, lat. 28° 43′ N., long. 87° 14′ 30″ W., 945 m., which answer well to his description of *Ankyroderma spinosum*, except for color. All these specimens are very spiny, and the anchors and rosettes are numerous. The color is pale brown, but under the microscope a considerable number of the small reddish-brown ellipses are to be seen. A fourth specimen from "Albatross'' Station 2925, lat. 32° 32′ 30″ N., long. 117° 24′ W., 610 m., is only 18 mm. long, but, unlike Ludwig's specimen of the same size, it is well supplied with anchors. Koehler and Vaney (:05) are convinced that Ludwig's *spinosum* is only a form of the widespread *musculus,* and although I think there is room for doubt on the point, I defer to their opinion, as they have had more material for study.

The form of *musculus* known as *violacea* Studer seems to occupy in the Southern Pacific the place that *M. intermedia* does in the northern, but has an even more extended range, as there are specimens before me from lat. 32° 44′ N. and nearly 52° S., and not less than 16 intermediate stations, at depths of 220–3,229 m. These specimens vary in size from 20 x 8 mm. to 100 x 20, and in color from pale gray, with a few small scattered reddish or purplish spots, to deep wine red, though all the specimens have the oral disc and tail pale gray. There is also great diversity in the shape, abundance, and arrangement of the calcareous bodies; they are most irregular and scattered in the smallest specimen and most regular and transversely arranged in the largest. A few of the specimens seem to have no rosettes and anchors and correspond exactly to the descriptions of *violacea;* others have the browned remains of rosettes, and many others have more or less complete rosettes and anchors present and correspond admirably to Théel's description of *Ankyroderma danielsseni.* I am therefore led to the conclusion that the ankyroderma individuals are probably the young, losing their calcareous particles as they grow older; but the evidence is not indubitably convincing.

6	specimens	from	"Albatross"	Station	2781, lat. 51° 52′ S., long. 73° 41′ W., 626 m.
1	specimen	"	"	"	2782, lat. 51° 12′ S., long. 74° 13′ 30″ W., 464 m.
7	specimens	"	"	"	2783, lat. 51° 02′ 30″ S., long. 74° 08′ 30″ W., 220 m.
39	"	"	"	"	2784, lat. 48° 41′ S., long. 74° 24′ W., 349 m.
1	specimen	"	"	"	2923, lat. 32° 40′ 30″ N., long. 117° 31′ 30″ W., 1,480 m.
1	"	"	"	"	2925, lat. 32° 32′ 30″ N., long. 117° 24′ W., 610 m.
6	specimens	"	"	"	3361, lat. 6° 10′ N., long. 83° 6′ W., 2,648 m.
1	specimen	"	"	"	3362, lat. 5° 56′ N., long. 85° 10′ 30″ W., 2,115 m.
1	"	"	"	"	3366, lat. 5° 30′ N., long. 86° 45′ W., 1,921 m.
4	specimens	"	"	"	3381, lat. 4° 56′ N., long. 80° 52′ 30″ W., 3,190 m.
1	specimen	"	"	"	3382, lat. 6° 21′ N., long. 80° 41′ W., 3,229 m.
2	specimens	"	"	"	3392, lat. 7° 5′ 30″ N., long. 79° 40′ W., 2,286 m.
8	"	"	"	"	3398, lat. 1° 7′ N., long. 80° 21′ W., 2,831 m.
5	"	"	"	"	3399, lat. 1° 7′ N., long. 81° 4′ W., 3,132 m.
1	specimen	"	"	"	3407, lat. 0° 4′ S., long. 90° 24′ 30″ W., 1,593 m.
1	"	"	"	"	3418, lat. 16° 33′ N., long. 99° 52′ 30″ W., 1,188 m.
1	"	"	"	"	3429, lat. 22° 30′ 30″ N., long. 107° 1′ W., 1,654 m.
1	"	"	"	"	3627, lat. 32° 44′ N., long. 119° 32′ W., 1,397 m.

87 specimens from 18 stations.

Molpadia oölitica Pourtales.

There are three specimens of a Molpadia in the collection, which answer admirably to Pourtales' description of *oölitica,* of which *borealis* Sars is almost certainly a synonym. It is probably true in this species, as in others, that the older the specimen, the more elliptical bodies and the fewer tables it will have. The specimens before me are all large, 100, 110, and 122 mm. in length, and dark-colored; one is reddish with small gray patches; another is very dark reddish, with very little gray, and the third is so dark a red it is almost black. In all, the oral disc and the tail are almost white, as they are free from the elliptical bodies which give the color to the body. There are apparently no tables present. The three specimens were all taken by fishermen from Gloucester, on the banks of Newfoundland. There is also in the collection a small molpadid, labeled "*Ankyroderma jeffreysii*. Norway," which has at some time been completely desiccated. It is impossible now to determine its identity, but if it is correctly labeled it may be included here, as *jeffreysii* is very probably the young of *oölitica.*

Molpadia parva (Théel).

The thin-skinned molpadids from the Caribbean Sea, referred by Théel to *antarctica*, and two varieties of *arctica,* are represented in the National Museum collection by nine specimens. While their relationship to *arctica* is obvious, they seem to be clearly and constantly different, and I therefore adopt for them the first of the varietal names suggested by Théel. I do not think, however, that the variety *cærulea* is sufficiently well marked or constant to warrant its separation.

1 specimen from "Albatross" Station 2106, lat. 37° 41′ 20″ N., long. 73° 3′ 20″ W., 2.695 m.
8 specimens " " " 2144, lat. 9° 49′ N., long. 79° 31′ 30″ W., 1,613 m.

Caudina arenata (Gould).

There are 3 specimens of this well-known species from off Cuttyhunk Island (Mass.), in 33 m., the largest 50 mm. long. There are 173 specimens of all sizes, labeled simply "Massachusetts Bay," and a single greatly contracted specimen from "Fish Hawk" Station 1617. From "Albatross" Station 3767, off the coast of Japan, 25-32 m., there is a completely desiccated molpadid, the calcareous particles of which are exactly like those of *arenata.* I am unable to avoid the suspicion that there is some mistake about the label. If not, *arenata* or a very closely allied species occurs in Japanese waters.

Caudina albicans (Théel).

There are 3 specimens from "Albatross" Station 2111, 35° 9′ 50″ N. and 74° 57′ 40″ W., 1,678 m.; 1 from Station 2677, 32° 39′ N. and 76° 50′ 30″ W., 860 m.; and 1 from Station 2682, 39° 38′ N. and 70° 22′ W., 1,807 m. As no connecting links between this well-marked form and the preceding are known, it is hard to see why *albicans* should not rank as a distinct species, instead of a variety (*armata*) of *arenata*, as Théel ('86*b*) described it. The specimen from Station 2682 is labeled "*Trochostoma albicans*, det. A. E. Verrill." The identification appears to be correct, but I am unable to find any satisfactory ground upon which that species can be distinguished from *Caudina arenata armata*; certainly the calcareous particles are identical. The name *albicans* antedates *armata*.

Caudina californica Ludwig.

Besides the type specimen from "Albatross" Station 3434, Gulf of California, 2,858 m., a larger molpadid, labeled "Southern California probably," is in the collection, which is doubtfully referred to this species; it is in poor condition and the calcareous deposits are mostly dissolved. There is also a much smaller specimen, from Station 2838, off Lower California, 85 m., which seems to be a young *californica*. The numerous plates are smaller, more symmetrical and with fewer perforations than in the type, but they are distinctly knobbed or provided with blunt spines. The differences seem to me such as might be expected between the plates of a young and an old individual.

Caudina planapertura, sp. nov.

(*plana*, even, + *apertura*, openings; in reference to the smooth calcareous plates.)

Plate IX, Figs. 6-8.

Tentacles 15, each with 4 long digits. Calcareous ring not very stout, the posterior prolongations of the radial pieces not very prominent and rather pointed. Polian vessel single, long. Stone-canal single, lying in the dorsal mesentery. Respiratory trees long and delicate. Genital glands branched and containing very large ova. Body elongated, tapering into the slender tail, which is more than one-third of the total length. Calcareous particles in the skin smooth, or slightly knobbed, plates perforated with many smooth holes. Color gray, with minute light brown blotches, which are so numerous on the back as to give a faint brown tinge to the dorsal side. Length, 67 mm., of which the caudal portion is 27; diameter of body, 12 mm.; of tail, 3.

This species resembles *C. arenata* superficially, but is easily distinguished by the very characteristic plates in the skin. It differs from *C. californica* in having the plates smaller, much less numerous, and nearly or quite smooth.

There are 4 specimens (Cat. No. 19825, U. S. N. M.), collected by the "Albatross" (Station 2784) near the southern part of Wellington Island, Chile, lat. 48° 41′ S., long. 74° 24′ W., 349 m.

CAUDINA OBESACAUDA, sp. nov.

(*obesa*, fat, + *cauda*, tail; in reference to the stout caudal appendage.)

PLATE IX, FIGS. 1-5.

Tentacles 15, each with 4 sharply pointed digits. Calcareous ring stout, the posterior prolongations of the radial pieces very prominent. Polian vessel single, long. Stone-canal single, small. Filaments of the genital glands very long and unbranched. Body stout, the tail not abruptly narrow. Calcareous particles, cups closed with a cross, similar to those of *C. coriacea,* but the knobs are not so prominent. The anal papillæ are crowded with modified cups and irregular perforated plates, and do not seem to have any such deposits as those figured by Théel (and called "characteristic") from the anal papillæ of *coriacea.* In the tail, however, the deposits are very much crowded, heavily knobbed, and nearly spherical, and the holes are almost obliterated. Color, pale brown. Length, 115 mm., of which the tail is about one-third; diameter of body at middle, 30 mm.; of tail near base, 20 mm.; near middle, 12 mm., and near tip, 4 mm.

There is a single specimen (Cat. No. 19823, U. S. N. M.) of this large and notable species, bearing only the label "Marco, Florida." It is very obviously different from *arenata,* the common Atlantic species, but it is closely related to *coriacea* of the western Pacific. It differs from that form, however, in the shape of the body and in the calcareous particles of the caudal portion. If the label is correct, it is curious that this new species should find its closest ally in a species of the western Pacific. There is a small Caudina from Galveston Bay, Texas, which seems to be of this same species, but as it has at some time been completely desiccated, it is past accurate determination.

CAUDINA CONTRACTACAUDA, sp. nov.

(*contracta,* made abruptly smaller, + *cauda,* tail; in reference to the form of the caudal appendage.)

PLATE IX, FIGS. 9-13.

There is a single remarkable specimen of Caudina from the Aleutian Islands, "Albatross" Station 3600, lat. 55° 06′ N., long. 163° 28′ W., taken in 16 meters of water (Cat. No. 19824, U. S. N. M.). It is 70 mm. long, of which a little more than one-third is "tail," though the terminal portion is broken off. The greatest diameter, 24 mm., is just before the body suddenly contracts to form the caudal portion, which is 10 mm. in diameter at the base and 5 near the tip. The color is very pale brown, the body wall thick and firm, partially due to its being strongly contracted. The tentacles and internal anatomy are not peculiar, but like those of any Caudina. The posterior prolongation of the radial pieces of the calcareous ring are only moderately long. The calcareous particles in the body wall are cups closed by a cross, as in *coriacea* and *obesacauda,* but very few of them are symmetrical and even these are apparently without knobs. In fact, the vast majority of the cups are very irregular and incomplete.

Although this Caudina resembles both *coriacea* and *obesacauda,* the differences in the calcareous deposits, combined with the different shape of the body and the geographical isolation of the species, are sufficient to warrant its recognition.

Eupyrgus scaber Lütken.

There is an excellent specimen of this interesting little species, from off the coast of Alaska, "Albatross" Station 2852, 105 m. It agrees well with typical specimens, and I think there can be no doubt of its specific identity. It is of particular interest because the species has not been recorded hitherto from west of Greenland, and its occurrence near Alaska would seem to indicate a circumpolar range.

CERAPLECTANA, gen. nov.

(*κεραός*, horny, + *πλεκτάναι*, feelers; in reference to the extraordinary tentacles.)

Tentacles 10, simple, unbranched, horny, and pointed, provided with normal ampullæ. Body nearly cylindrical, but tapering posteriorly into a well-developed caudal appendage. Radial pieces of calcareous ring with marked, but not deeply forked, posterior prolongations. Calcareous deposits in the form of irregular branched plates or straight rods, perforated near the middle, and usually with a single, sharp, outwardly directed spine. Phosphatic deposits present.

The type species of this genus is the following:

Ceraplectana trachyderma, sp. nov.

(*τραχύς*, rough, + *δέρμα*, skin; in reference to the prickly body surface.)

Plate XIII, Figs. 5-13.

Color gray, flecked with numerous patches of red brown. Tentacles 10, almost the shape and color and nearly the size of apple seeds, arranged one pair in each interradius. The ampullæ are reasonably long. The respiratory tree divides some distance from the cloaca, and the left branch is very short. Deposits differ somewhat in different specimens. In the smallest the ellipses are small, pale yellowish brown, and occur singly or in groups of three, while the calcareous particles are fairly crowded, irregularly branched rods, flat and wide, and perforated near the middle by several holes, among which there is usually a single outwardly directed sharp spine. In the large specimen the ellipses are reddish brown and are collected in patches, while the rods are nearly straight, without a spine, and crowded at right angles to the axis of the body. The third specimen has deposits intermediate between the other two. Length of body, 63 mm. x 20 in diameter; tail broken; in another specimen the body is 30 x 10 and the tail is an even 10 more.

Three specimens from "Albatross" Station 3603, lat. 55° 23′ N. and long. 170° 31′ W., 3,188 m. (Cat. No. 19860, U. S. N. M.)

This remarkable species is so easily recognized by its peculiar tentacles that it cannot be confused with any other.

HIMASTHLEPHORA, gen. nov.

(ἱμάσθλη, thong of a whip, + φορός, bearer; in reference to the remarkable dorsal appendages.)

Tentacles 15, each with 4 digits, of which the terminal pair are the larger; without ampullæ. Body nearly cylindrical, rather stout, terminating abruptly in a long, slender, caudal portion. Mid-dorsal interambulacrum with 4–6 whiplash-like papillæ. Rudimentary pedicel-like outgrowths near both the anterior and posterior ends of the body. Genital papillæ prominent, 2 mm. or more in length. Respiratory trees small and delicate. Longitudinal muscles simple, flattened, and unpaired. Calcareous ring of 10 pieces, rather stout and synapta-like, with no posterior prolongations. No calcareous or phosphatic deposits in the skin. Careful examination of two specimens failed to show a stone-canal.

The type species of this genus is the following:

HIMASTHLEPHORA GLAUCA, sp. nov.

(γλαυκός, gray; in reference to the color.)

PLATE XIII, FIGS. 1-4.

Color light gray; tentacles and papillæ brownish. Length, 28 mm., of which nearly a third is tail; body 8 mm. thick. Genital glands noticeable as tufts of numerous, thick, unbranched tubes, one on each side of mesentery, 3-4 mm. back of calcareous ring. The papillæ in mid-dorsal interambulacrum are 4-6 in number and 5-6 mm. long. There appear to be 5 clusters of pedicel-like projections at the posterior end of the body, at the base of the caudal appendage, and there are rudimentary pedicel-like processes scattered about the anterior end also. Calcareous particles in the skin are wanting, but were possibly dissolved by impure alcohol, as the specimens were collected in 1886.

There are 4 specimens of this most remarkable and interesting holothurian, which were dredged by the "Albatross," Station 2678, in 1,316 m. off the coast of Georgia, lat. 32° 40′ N., long. 76° 40′ 30″ W. (Cat. No. 14726, U. S. N. M.). The general appearance and the tentacles are exactly like the other Molpadids, and the absence of true pedicels confirms the relationship to those forms, especially since Gerould ('96) has shown the presence of rudimentary subcutaneous pedicels in *Caudina arenata*. The papillæ in Himasthlephora are shown by sections (figs. 3 and 4) to be provided with ampullæ, which are connected with the radial canals, but the rudimentary pedicels do not seem to have any such connection. The radial canals, moreover, apparently terminate at the base of the tail instead of at the tip, as in Caudina, although in neither of the two specimens sectioned was this positively determined. In the form and arrangement of the longitudinal muscles (see the section of one in fig. 4) there is a resemblance to the Synaptidæ; but as a very similar arrangement occurs in Eupyrgus (Plate XII, fig. 27), it is not unique among Molpadids. It is very probably a primitive character, retained by Himasthlephora, which on the whole is apparently nearer the pedate ancestor of the apodous holothurians than any of the genera hitherto known except perhaps Gephyrothuria, its relation to which is discussed on page 184.

PART III.

THE SYNAPTIDÆ.

Order PARACTINOPODA Ludwig.

External appendages of water-vascular system arise from circular canal and appear only as circumoral tentacles. While five of these are radial in position, no true radial canals are present in adults.

Family SYNAPTIDÆ Burmeister.

More or less cylindrical elongated holothurians with terminal mouth, without respiratory trees and with water-vascular system greatly reduced; circumoral tentacles, either simple, pinnate, or digitate, are present but lack ampullæ; there are no pedicels or papillæ; circular muscles of body-wall continuous, *i. e.,* not broken or interrupted at radii; characteristic sense-organs (positional organs) present, situated beside radial nerves, near nerve ring; minute ciliated funnels, apparently having an excretory function, usually present in body-cavity on or near mesenteries; calcareous deposits, in form of anchors and plates, wheels or sigmoid bodies usually present, but no tables or phosphatic deposits (see p. 142) occur.

MORPHOLOGY.

FORM AND SIZE.—The body is generally elongated and more or less cylindrical, but the exact shape and proportions differ in different species, and, owing to its remarkable contractility, its form differs greatly in the same individual under varying conditions. The largest species in the family is *Synapta maculata,* which reaches a length of more than 200 cm., though the diameter is not commonly more than 3 cm. The smallest species is *Leptosynapta minuta,* which is only 3 to 5 mm. long. Between these two extremes we find great diversity, but species more than 30 or less than 3 cm. when fully grown, are infrequent.

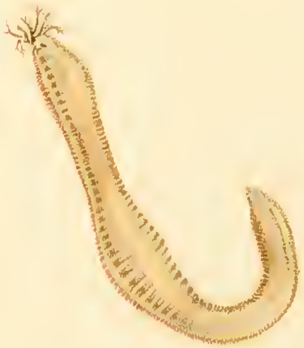
COLOR.—In color there is some variety, but really bright colors are rare; white, flesh-color, dull yellowish, and gray are the more usual shades, but dull shades of red are common. *Protankyra rodea* is said to be "carmine-red" and *Scoliodota japonica* "blood-red." Green is occasionally found in an olive, or some other dull shade, but the bright shades are rare. Some species are very dark-colored, and have been described as "crimson-black," "dark violet-black," and "brown." The color is seldom uniform, but spots and little papillæ—

Plate II.

Figure 1. *Anapta gracilis* Semper.
2. *Protankyra similis* (Semper).
3. *Chiridota rigida* Semper.
All natural size and from Semper, 1868.

3.

1.



2

East Indian Synaptidæ.

white, brown, or red—are often quite thickly scattered over the body. Fine lines of a darker shade often ornament the skins of gray and brown species, and occasionally longitudinal stripes are present. Large irregular blotches of darker or lighter shades often variegate the color. A few species are colored more darkly on one side than on the other, and this is probably due to their manner of life. Subterranean species are usually white or nearly colorless, while species which live about reefs are apt to be gray or brown, and those which live among living corals are generally the bright-colored forms. The color is due, at least in large part, to the presence or absence of pigment cells in the connective tissue of the body-walls. These cells are irregularly radiant in shape, and may be scattered or closely crowded. In *Synaptula hydriformis* the green color is due in some measure to unicellular algæ in the connective tissue. The chemical composition of the pigment varies considerably; in some species pure alcohol does not affect the color, while in others the pigment is dissolved by it; acids and corrosive sublimate dissolve or modify the pigment rapidly. White spots are very frequently due to the aggregations of miliary granules or other calcareous bodies in the skin. Complete absence of pigment tends to make the body-wall transparent, and the longitudinal muscles then stand out as five prominent opaque bands. Even in dark-colored species, the position of these muscles is often indicated by a darker (or lighter) longitudinal stripe.

Body surface.—The surface of the body in the Synaptidæ is almost always more or less rough, and is seldom smooth and slimy, though there are glands in the epidermis. The roughness may be due to the small, usually crowded, and regularly arranged projections of the body-wall itself, known as *verrucæ*, or to the calcareous bodies, single or in heaps. Verrucæ vary greatly in size and prominence, according to the size of the animal and the amount of contraction of the body-wall. In the larger species, they may be very prominent, 5 or 6 mm. high, and 6 or 8 in diameter; in such cases, they generally form regularly transverse and longitudinal rows, the latter usually 10 in number. These large verrucæ are by no means constant in size and form and seem to be dependent on the condition of the animal. They may be large, small, or wholly wanting in individuals of a single species (see Plate I), and, in *Euapta lappa* at least, in a single individual at different times. It is probable that their presence is due to unusual muscular contraction brought on by abnormal external conditions. Their presence or absence is therefore not a character which is of any taxonomic importance. True verrucæ are much smaller and usually much more numerous, sometimes as many as 500 to the square centimeter. They usually contain calcareous deposits and oftentimes pigment. The largest and most noticeable verrucæ occur in the genera Synapta and Euapta, but the smaller ones are found in Leptosynapta, Synaptula, and Tæniogyrus. They are generally wanting in other genera. In most Synaptids the calcareous particles are not of sufficient prominence to affect the appearance of the body surface, but in those species in which the anchors are more than 250 μ in length, or where the calcareous bodies are accumulated in special heaps (as the so-called "wheel-papillæ" of Chiridota), the surface may become rough and even very prickly, not only to touch but to sight. The degree of roughness depends to no little extent on the amount of contraction of the circular muscles of the body-wall, and is almost always more noticeable in preserved than in living specimens. In Trochoderma the body-wall is firm and stiff from the crowded calcareous deposits.

Tentacles.—The number of tentacles varies from 10 to 27, but it must be borne in mind that the number in the young is at first five, and that thereafter the number varies with the age of the animal, certainly until sexual maturity is reached, and in some cases possibly thereafter. In some species there is a distinct 7-tentacled stage, while in others the second quintet of tentacles appears simultaneously, and we have a 10-tentacled larva. After that it is probable the tentacles appear singly or in pairs; they certainly do in the 12-tentacled species, whose development is known, but we have no knowledge of the development of any species with more than 12 tentacles. Now these facts have an important bearing on what we are to consider the normal number of tentacles in a given species. Where a large number of mature individuals have been examined, the normal number of tentacles is not difficult to determine, but where only a few individuals, and some or all of those obviously immature, have been available, it is clear that we cannot decide positively on the number for that species. Unfortunately, comparatively few species are sufficiently well known to make our knowledge on this point satisfactory. Although 10 tentacles are characteristic of Rhabdomolgus, Trochoderma, and Trochodota, and of some species of Synaptula, Leptosynapta, Protankyra, Tæniogyrus, and Myriotrochus, few of these latter forms are sufficiently well known to put the matter beyond dispute. One species of Labidoplax (*buskii*) has constantly only 11 tentacles, and since many specimens have been examined, this is probably the normal number. Many Synaptids have the number of tentacles constantly 12, and individual specimens of these species not infrequently have 13. Several species have been described as having 13 tentacles, but all are known from only a few specimens, and it is quite possible that 13 is not the normal number. Many species have 15 tentacles, and individuals of these may have 13, 14, or 16 instead of the normal number. Several species have been described as having 16, 17, 18, or 19 tentacles, but all are East Indian forms, and not one can be said to be satisfactorily known. It is very probable that the normal number for these species will be found to be 20 or possibly 18. It is rather remarkable that not one authentic species is known with 20 tentacles, though one or two have been so described.

The genus Polyplectana has more than 20; the normal number is probably 25, but individuals with as many as 27 are known, and it is common to find specimens with less than the normal number. In regard to the arrangement of the tentacles, when 10 are present there are 2 in each interradius; when 12 are present, the right and left dorsal interradii have 3 each; when 13, the additional tentacle is either in the mid-dorsal or in one of the ventral interradii; when 15, there are 3 in each interradius. We have no information in regard to the arrangement of the tentacles in the species with more than 15 tentacles. The shape of the tentacles differs very markedly, but they are usually provided with finger-like outgrowths called *digits*. Rhabdomolgus is the only genus in which there are no distinct digits whatever. In all other Synaptids there are always at least 2 digits, one on each side, and the number may be as great as 30 on each side. In many cases the tentacles are truly *pinnate* (Plate VI, fig. 19), having a tapering shaft with the digits arranged in a simple row along each side. Those near the middle are the oldest and usually the longest, new digits being formed at both ends of the shaft as the animal grows. In some cases the tentacles are very short, and the few digits (2 or 4) arise at the tip end, from what is nearly a common source; such tentacles are called *digitate*. In the Chiridotinæ we have an arrangement of the digits along the margin of a flattened disc which occupies the upper and outer side of the tentacle. The longest digits are at the top, the youngest and smallest at the lower, outer end. Such tentacles are sometimes called *peltato-digitate*. When contracted, the two sides of the disc fold toward each other outwardly, and, thus folded, the whole disc can be withdrawn more or less completely into the base of the tentacle. The tentacles are sometimes connected with each other at their bases by a more or less evident membranous fold, and in some species the digits are united to each other in a similar manner. So far as known, the tentacles of adult Synaptids are always of equal size. The cases which have been recorded where such was not the case are clearly young individuals, or the observer has been deceived by the unequal contraction of the tentacles. The tentacles are always hollow, containing, as they do, the tentacular canals of the water-vascular system. The wall of the tentacles is made up of a thin cutis overlying a layer of epithelial cells, beneath which is a connective tissue layer—an arrangement essentially the same as in the body-wall. Any calcareous particles present in the tentacles lie in the connective tissue. The cavity of the tentacle is lined with a thin epithelium, and between this and the connective tissue occur the muscles. Longitudinal muscles are always present, so far as synaptid histology is known, but the presence of circular muscles is a disputed point. They are certainly absent in some species, but seem to be present in *Labidoplax digitata* and perhaps in some others. The digits of the tentacles have the same structure as the tentacle itself, but the central cavity which each one contains is, in some species at least, entirely cut off from the tentacular canal (Plate VI, figs. 19 and 20). At the tip of the tentacle the epithelium is much thickened, especially on the outer side, and the thickening probably serves as a special organ of touch. There are no tentacle ampullæ in any of the Synaptidæ. (See p. 147.)

Sense-organs.—The sense-organs of Synaptids are of four very distinct sorts—light-detecting, positional, gustatory, and tactile organs. The *light-detecting organs,* or eyes, are known in only a comparatively few species, and their function has been a matter of some dispute. They are best known in *Synaptula hydriformis,* where at least they are simple eyes (Plate VI, fig. 15). They are situated, a pair at the base of each tentacle, and consist of a distinct, rather horny mesodermal layer, containing scattered nuclei, overlying the swollen end of a large nerve, which arises on each side from the circumoral ring at the base of the tentacle nerve. The ends of these nerves are made up of nerve cells of considerable size with big nuclei, which are somewhat swollen, and are apparently vacuolated at their outer extremities. They are polygonal in outline when seen in cross-section, and the inner ends taper off into fibers which run out into the nerve. The mesodermal covering, which also has the appearance of being vacuolated, is clearly a continuation of the thin mesoderm layer which surrounds all the nerves. The eyes are about $60\,\mu$ in diameter, the mesodermal covering being rather more than one-tenth as thick. The pigment, which is contained in the mesodermal covering, is at first bright green, but gradually becomes deep reddish brown, so that the eyes look like small brown spots. In some instances it has been shown that the so-called "eye-spots" are simply clusters of "wandering cells" and are not supplied with special nerves, and are therefore of course not sense-organs at all. The *positional organs* are generally, though incorrectly, called "auditory vesicles," or "otocysts." They are known to occur in a number of species of Leptosynapta, Synaptula, Protankyra, Labidoplax, Chiridota, Myriotrochus, and Acanthotrochus, and no Synaptid is known to lack them. They are spherical sacs situated just outside the calcareous ring, one on each side of each radial nerve, with which they are connected by small nerves. They differ greatly in size, those of *Synaptula hydriformis* (Plate VI, fig. 16) measuring only 60 or $70\,\mu$ in diameter, while those of *Labidoplax digitata* are sometimes as much as $210\,\mu$. They are lined with cilia and filled with fluid, and contain one or more little spheres, which are kept in active movement by the action of the cilia. These spheres are heavier than the fluid in which they lie, and constantly tend to sink to the lowest part of the sac, and by contact with the cilia give rise to sensations of changed position. Whether these spheres are made up wholly or in part of inorganic salts is still undetermined, but they appear to be vesicles filled with a denser fluid than that in the sac. The *gustatory organs* (Plate V, fig. 22; Plate VII, figs.

21-22) occur in a number of species of several distinct genera, but many species are known which do not have them. They are small cup-shaped outgrowths on the inner face of the tentacles, near the base, just large enough to be seen with the naked eye, or even smaller. The number on each tentacle varies from 1 to 30 or even more in large animals. Each cup is lined with cilia and is connected by a small branch nerve with the tentacle nerve. There seems to be little doubt that these cups serve as organs of either taste or smell, although the evidence is not conclusive. *Tactile organs,* or "touch-papillæ" (Plate VI, fig. 17), occur in many and perhaps all Synaptids, not only in the tentacles, which are themselves such important organs of touch, but also scattered all over the surface of the body. These "sense-buds" or "touch-papillæ" are small groups of epithelial cells connected at their inner ends with special ganglia situated at the ends of small nerves, which arise as branches of either the radial or tentacle nerves.

Nervous system.—The complete nervous system is known in very few Synaptids, but those species in which it is known agree so well that there is little reason to expect anything strikingly different in other species. At the extreme anterior end of the body lies the *circumoral ring,* a band of nerve tissue surrounding the œsophagus and giving rise to the five *radial nerves* and the *tentacle nerves,* the number of which corresponds to that of the tentacles. The circumoral ring lies above or within the calcareous ring, close upon the outer wall of the circular sinus in which the œsophagus lies, and is a tenth of a millimeter, more or less, in thickness. The outer layers contain most of the ganglion cells, the interior being chiefly fibrous. In those Synaptids which have eyes the optic nerves arise directly from the circumoral ring, and in some species special nerves or nerve bands arise from the inner or lower side of the ring and run to the oral disc and œsophagus. The radial nerves run outward, over or through the radial pieces of the calcareous ring, and then, bending abruptly backward, run with little diminution in size to the extreme posterior end of the body. Each nerve consists of an inner and an outer band, the latter of which contains most of the ganglion cells on its outer side. The two bands lie close together in the connective tissue of the body-wall just outside of the circular muscles. Each radial nerve gives rise to the nerves supplying the positional organs, and to numerous small branches, which supply the muscles and "sense-buds" of the body-wall. In many Synaptids there is an open space or canal, between the radial nerve and the longitudinal muscle, known as the *hyponeural canal;* but it is not always present; it is wanting in *Synaptula hydriformis.* The tentacle nerves arise from the outer, lower side of the circumoral ring and run upward on the inner face of the tentacle, giving off branches to the digits and to such sensory cups or papillæ as may be present.

Body-wall.—The body-wall of the Synaptids is thin and generally translucent, if not actually transparent. In Myriotrochus and some species of Leptosynapta and Chiridota it is so transparent that the inner organs are readily seen through it. It consists of five parts (Plate VI, fig. 21), a cutis and a layer of epithelial cells, which together make up the epidermis; a layer of connective tissue in which lie the calcareous bodies, pigment, etc., a layer of circular muscles—in the radii the longitudinal muscles—and an inner epithelium, which lines the body cavity.

1. *Epidermis.*—The cutis is a thin, transparent, structureless layer, secreted by the epidermal cells, and exhibiting no special peculiarities. The epithelial cells beneath are of three distinct sorts; ordinary, more or less elongated, irregularly polygonal cells, which greatly predominate, but among which are scattered sensory and gland cells, the former in clusters of several dozen, forming the "sense-buds" to which reference has already been made. The sensory cells are much more elongated than the ordinary epithelial cells, and the inner end is drawn out into a fiber which connects directly with the small ganglion lying underneath the sense-bud. Sometimes such sensory cells occur scattered singly among the ordinary epithelial cells. The gland cells are of two kinds, but their number, size, distribution, and activity undoubtedly differ much in different Synaptids, according to the manner of life. The so-called *goblet glands* are the more numerous, and occur in nearly all parts of the epidermis, while the larger *club glands* are much less common and more widely scattered. Both kinds of glands are most numerous and best developed in the epidermis of the tentacles, especially on the outer side near the tip and on the outer side of the digits, the surface of which is quite viscid in most Synaptids. Whether the so-called "contractile rosettes" (see Becher :06) are epidermal structures does not seem to have been determined, but they probably lie deeper. Very possibly they are identical with the larval glandular organs of *Synaptula hydriformis* referred to on page 61.

2. The *connective tissue layer* makes up as a rule more than three-fifths of the body-wall, although the proportion varies with the total thickness. It consists of a mass of fibers, the outgrowing prolongations of spindle- or star-shaped cells, imbedded in a clear, transparent, nearly colorless ground-substance of gelatinous consistency. Besides these connective-tissue cells, so-called *wandering cells* are abundant, which are more or less oval in outline, but often possess pseudopodia as they are capable of amœboid movements. In the connective-tissue layer are found two of the most important structures of the body-wall, the *pigment cells* and the *calcareous bodies.* The *pigment cells* are sometimes more or less oval or spherical bodies, but are often irregular, much-branched particles of coloring matter, most numerous in the outer part of the body-wall just below the epidermis. They are often aggregated in particular

parts of the body and in some species chiefly about the anterior end or on the dorsal side. They often crowd about the calcareous ring and even occur in that structure. The color is generally some shade of red, brown, or black; but purple, green, and yellow pigments also occur, and perhaps other colors. It is possible that the pigment bodies sometimes crowd into the epidermis, but it is doubtful if this is a normal condition. The pigment is generally, if not always, insoluble in water, ether, or pure alcohol, but is rapidly discolored or profoundly changed by acids, alkalies, and corrosive sublimate.

The *calcareous deposits* of the body-wall are rarely entirely wanting. They are formed by special mesenchyme cells in the connective-tissue layer, and their manner of growth is well known. They are almost, if not entirely, pure carbonate of lime. It is most convenient to classify them under four heads: anchors and plates, wheels, curved rods, and miliary granules; all four kinds never occur in any one species, though three often do, and there are usually at least two kinds present.

The *anchors and plates* (Plates IV and V) are more or less symmetrical, and always lie in the body-wall, with the anchor over or outside the plate, and usually their long axes are at right angles to the long axis of the animal. The plate arises as a short rod, parallel to the long axis of the animal, which soon forks at each end. The forks grow and divide dichotomously, with more or less regularity, but the subsequent branches do not grow with equal rapidity. As a consequence, branches of the third and higher degrees meet and fuse, thus inclosing the open spaces which are the perforations in the completed plate. The edges of these holes may remain smooth, or they may become toothed, although the smallest holes are always smooth. In some species the branching, which gives rise to the plate, proceeds so irregularly that the plates become very asymmetrical, this being especially true when the perforations are small and numerous. In species with symmetrical plates the number of large, toothed holes is generally 6 or 7, rarely more, but the number of small, smoooth holes is not limited, though generally less than 10; they are found mostly at the smaller end of the plate. Usually the plates are not flat, but are more or less concave on the outer side, and the posterior end frequently bears an outwardly curved bow, which thus arches the concavity. This bow sometimes bears teeth at the center on the anterior edge. The bow is often imperfect and frequently wanting. Anchor-plates vary in size from 0.1 mm. up to 1 mm. in length, and the breadth is from one-half the length up to nearly equaling it. The plates are always shorter than the anchors which accompany them, though the proportion between the two pieces is very variable. The plates are frequently longest at the posterior end of the body. They are occasionally double and provided with two bows. Two quite different sorts of plates sometimes occur in the same species. The anchor consists of a more or less curved shaft, lying with the convex side against the plate, the posterior end (*stock*) frequently, if not always, connected with the bow or posterior portion of the plate by connective tissue, and the two arms, which are more or less outwardly flaring. The arms are frequently toothed on their outer sides, the teeth, however, pointing, not backward, but forward or outward. When the arms are smooth, there are often several small knobs on the vertex of the anchor, where the two arms and the shaft fuse. The stock is more or less expanded, and may be undivided and edged with numerous fine teeth, or it may be more or less branched, the branches bearing teeth. In exceptional cases the anchors bear arms at both ends. Not infrequently the anchors are asymmetrical, one arm being larger than the other, and occasionally a third arm occurs. The anchors of the posterior end of the body are oftentimes longer than those of the anterior end, and sometimes there are two entirely different kinds of anchors found in a single species. Anchors vary in size from 0.12 to 1.1 mm. in length, those of the latter size being quite easily seen with the unaided eye. They arise as straight rods lying perpendicularly to the long axis of the animal, and therefore at right angles to the rods giving rise to the plates. They are of considerable size before the plate rods appear, and already show the rudiments of the arms, which extend outward at first, and later bend backward. The teeth on the arms, and the branches and teeth on the stock are the last parts to appear. The number of anchors and plates varies greatly, not only with their size, but also with the habits and habitat of the animal. In some species there may be only a few—less than 25, perhaps—to a square centimeter of skin, while in other cases there are from 1,000 to 1,500 per sq. cm. They are often more numerous posteriorly than anteriorly.

The so-called *wheels* (Plates VII and VIII) occur in a number of genera, in several forms, either scattered singly in the skin or collected in little heaps or papillæ. These heaps are generally large enough to be visible to the naked eye, and then appear as small white spots. They are covered only by the very thin epidermis and are easily rubbed off. They occur chiefly on the interambulacra, often in definite longitudinal rows, but are sometimes scattered over the whole body. When the wheels are scattered and not in heaps, they are usually quite widely separated; but they may be crowded, and occasionally so much so as to form several layers and make the body-wall firm and hard. The wheels are sometimes flat or nearly so, but more commonly they are decidedly concave, somewhat saucer-shaped, so that the margin is higher than the center, though the latter may be higher than the surrounding spokes. Most commonly the wheels have 6 spokes, which are rather wide and flat, but in other cases the spokes are narrower and more numerous, from 8 up to 25 in number. The rim of the wheel is usually smooth on its outer margin, though sometimes it bears prominent spines, alternating with the spokes. The inner margin is generally toothed, either with numerous minute teeth or with from 15 to 30 larger teeth which point inward, but it may be perfectly smooth. The center or "hub" of the wheel is usually smooth, but is sometimes rough on the outer end. Its inner end is the point of attachment for a strand of connective tissue, the exact function of which is not known. In size the wheels vary from about 30 to upward of 350μ, the diversity being very noticeable oftentimes in a single individual. The various kinds of wheels arise first either as discs or saucer-like plates, with fluted edges, or as star-shaped bodies (Plate VIII, figs. 9-12). The spokes arise either from the projections on the edge of the plate or from the rays of the star. As they increase in length, they expand at the outer end, and the expanding branches meet and fuse to form the rim of the wheel.

The *curved rods* occur most commonly as supporting rods in the tentacles (Plates IV, V, and VII), but are sometimes found scattered in the body-wall itself. In the former case they are usually more or less branched, toothed, or perforated at each end, though in some cases they are smooth and solid. They show great diversity in size and shape, ranging from 20 to 200 μ. Their long axes are generally parallel to the long axis of the tentacle or to that of the digit in which they lie, but they are sometimes collected more or less irregularly near the base of the tentacles, especially on the inner side. The rods which lie scattered in the body-wall may be only very small elongated particles, with smooth, rounded ends (Plate IV, fig. 14), or they may be more or less curved, having the ends somewhat enlarged and often toothed (Plate VII, figs. 4, 7, and 12); or the form may be that of a hook or bracket or an elongated letter S (Plate VII, figs. 5, 6, 9, 10, and 11). The latter are called sigmoid deposits. In such deposits the curves of the opposite ends may lie in the same plane or in planes at right angles to each other. The rods and sigmoid deposits of the body-wall are irregularly scattered, though the latter generally lie at right angles to the longitudinal axis of the animal. The rods range from 20 to 100 μ in length, while the sigmoid deposits are larger, usually measuring between 100 and 200 μ. The sigmoid deposits arise as simple, smooth, curved rods, which gradually increase in size and curvature until the perfect form is assumed.

The so-called *miliary granules* (Plate IV, figs. 16 and 21) are very small particles of lime, sometimes smooth and rounded, sometimes cross- or star-shaped, and sometimes branched and irregular, which occur not only in the connective tissue of the body-wall, but often in the underlying muscles also, both circular and longitudinal. Generally they occur scattered more or less uniformly in the body-wall, but are sometimes confined to the radii. They are often collected in small heaps or patches, which appear to the naked eye as white spots on the skin. The irregularly branched forms are sometimes called *rosettes* (Plate IV, figs. 18 and 23). In size the miliary granules vary from 3 to 30 μ.

3. The *circular muscles* of the body-wall of all Synaptids run completely around the body-cavity, just without its lining epithelium. In most species the layer is of uniform thickness and continuity in all parts of the body, except that it becomes somewhat better developed near the cloacal opening, for which it forms a sphincter muscle. It may perhaps also thicken on or near the oral disc. In Acanthotrochus, however, the circular muscles occupy only the interradial portions of the body-wall, except at the ends of the animal, where they are continuous, as in other Synaptids.

4. The *longitudinal muscles* of the body-wall are confined to the radii, where they project more or less markedly into the body-cavity, the epithelial lining of which covers them. They are usually single folds or strips, attached anteriorly to the calcareous ring, and posteriorly thinning out and disappearing near the cloacal opening. They are generally most compressed anteriorly, and become flattened near the middle of the body and imperfectly cylindrical at the posterior end. In some cases the anterior part of the muscle may be divided into an outer and an inner portion, and in such cases the inner half is called a *retractor* muscle, and is regarded as homologous with the retractor muscles of Dendrochirotæ; but the constant presence of such muscles in any Synaptid is open to doubt; they are said to be characteristic of *Euapta lappa*, *Synapta maculata*, and *Chiridota rotifera*, but although I have examined these species, macroscopically and microscopically, both living (except *maculata*) and preserved in alcohol, I have never found the slightest evidence of a retractor muscle. Those of *Chiridota rotifera* are said to be very short and joined by connective tissue to the longitudinal muscle. In this statement lies a probable explanation of the whole difficulty; the anterior portion of the longitudinal muscles, being strongly compressed, may divide more or less incompletely in a plane parallel to the body-wall, and where the division is only partial such an arrangement as is reported for *Chiridota rotifera* would arise, while if the division were completed it would result in the arrangement said to occur in *C. discolor*. Now, as I have examined specimens of both *rotifera* and *discolor* and have failed to find any trace of a separate retractor muscle, I am convinced that the matter is one of individual diversity, or perhaps correlated with age. At any rate, the presence or absence of retractor muscles is a character upon which only the slightest value can be placed for purposes of classification.

5. The *innermost layer* of the body-wall is a simple, epithelial layer, which covers all of the surface bordering on or projecting into the body-cavity. It consists of polygonal cells similar to the ordinary epithelial cells of the outer

surface, but much more flattened. Whether they are provided with cilia or not is a disputed point. Hamann ('84) asserts that cilia are present, but other investigators have failed to find them. My own observations lead me to believe that cilia are not usually present on the cells of this inner epithelium.

Body-cavity.—The body-cavity of the Synaptids is always spacious, and extends from the oral disc to the posterior tip of the body without any marked separation into parts, although the portion around the œsophagus has had a different origin from the rest in the development of the animal. Longitudinally the cavity is divided on the dorsal side by the mesentery, which supports the intestine, and anteriorly it is traversed by strands or folds of tissue which support the œsophagus. All parts of the body-cavity are lined with the thin, flattened epithelium, already described as forming the innermost layer of the body-wall. The fluid contained in the body-cavity is largely water, but contains albuminous material and corpuscle-like cells. It is probably identical with the fluid in the water-vascular system, but may contain more water. So far as known, the body-cavity is always in communication with the water-vascular system through the madrepore bodies and stone-canal. In *Synaptula hydriformis* and probably in *Chiridota rotifera* the body-cavity is in communication with the outside through openings in the wall of the rectum and at times through rupture of the body-wall near the anus. The former openings seem to be permanent, but the latter are only formed when the young are born and apparently heal up thereafter. In the viviparous species just mentioned, the body-cavity fluid must contain nutritious material which serves as food for the young, as the latter grow to considerable size (10 mm. long or more) before birth.

Calcareous ring.—Surrounding the œsophagus in Synaptids, as in all other holothurians, is a circular ring, made up of more or less distinct calcareous plates. Of these, five lie at the anterior ends of the longitudinal muscle bands, which are attached to them, and are called the *radial* pieces, while the remainder are called *interradial*. These plates arise from calcareous bars (Plate VI, fig. 9) which branch more or less irregularly, the branches anastomosing and fusing until solid plates are formed. The plates are generally more or less quadrilateral, but may be higher than wide (*Synaptula hydriformis*, Plate VI, figs. 7 and 8) or approximately square (Plate V, fig. 14) or wider than high (*Leptosynapta roseola*, Plate V, fig. 16). Usually the posterior margin of each plate is slightly concave or even notched, but it is never forked or deeply divided. The anterior margin may be straight or convex, or distinctly pointed (Plate IV, fig. 2), and frequently the radial pieces are either pierced or notched for the passage of the radial nerves; in *Labidoplax digitata* only the three ventral radial pieces are so pierced. Occasionally the radial pieces of the ventral side are better developed than those of the dorsal, or the reverse condition may occur. The number of interradial pieces ranges from five upward, but the most frequent number is seven, the two dorsal interradii each having an extra piece. Where the number of interradial pieces is more than seven, there is usually an agreement between the number of tentacles and the total number of plates in the ring, but several species have been described in which there is no such agreement. It should be borne in mind that new pieces may form in the ring with the growth of the animal, and that such unusual numbers as 16 and 18 plates very possibly are an indication of immaturity. There will probably prove to be a reasonably definite correlation between the number of tentacles and the number of pieces in the calcareous ring, when all the facts are known.

CARTILAGINOUS RING.—In the genera Synapta, Polyplectana and Synaptula and sometimes in Opheodesoma, there is a noticeable ring of cartilage or some similar connective tissue immediately posterior to the calcareous ring (Plate VI, fig. 18). In bulk it may exceed the latter, with which it is in more or less close contact. This ring is often without projections or perforations, but in some cases it is provided with 15 openings, either anteriorly or posteriorly. The presence or absence of this ring has been used as a generic character, but as its development is apparently more or less variable, it is still a doubtful question as to how great a taxonomic value it has. Its function has never been determined, but it probably gives a more or less useful, though flexible, support to the calcareous ring.

WATER-VASCULAR SYSTEM.—Encircling the œsophagus at a greater or less distance behind the calcareous ring or the cartilaginous ring, when the latter is present, is a tube, which forms the central part of the water-vascular system and is known as the circular ring. It is from a fifth to a half of a millimeter in diameter, more or less, according to the size of the individual, and the wall is a thin layer of connective tissue and circular muscles, covered on the outside with the body-cavity epithelium and lined with a very similar layer of cells. From this circular ring arise the tentacle canals, which run, one to each tentacle, passing upward, on the inner side of the calcareous ring. Just before entering the tentacle, each canal is provided with a valve which permits fluid to pass into the tentacle, but prevents its outflow. The number of tentacle canals may be fewer than the number of tentacles, but such cases are due to immaturity or arrested development. In many, if not all, Synaptids, the anterior margin of the calcareous ring projects forward so far (Plate VI, fig. 18) that the outer half of the lower part of the cavity of each tentacle forms a blind sac or rudimentary ampulla, separated by the calcareous ring from the inner half, which is directly continuous with the tentacle canal. The sacs are always very short and closely appressed to the outer side of the calcareous ring. Dependent from the circular canal are the polian vessels (Plate

VI, fig. 6; Plate VII, fig. 29), the size and number of which are very diverse. They are more or less elongated, blind sacs, the diameter of which varies greatly with the amount of fluid contained within. In Synapta and sometimes in Euapta they may be branched; that is, a number of vessels arise from a common stalk-like outgrowth of the circular ring. Comparatively few Synaptids have only a single polian vessel, the great majority having more than two. Many have from 8 to 16, and a few species have 50 or even more. When more than one, the polian vessels are seldom of the same size, and when numerous there is the greatest variety in length. When only one is present, it is generally of very moderate size, usually less than a tenth of the body length. This single polian vessel lies on the left side of the body, usually in the left dorsal interradius; but when more are present, they arise from the ventral portion of the circular ring, and when very numerous they spring from all parts of that ring. The wall of the polian vessel has essentially the same histological structure as the circular ring; in the connective tissue of either there may occur small calcareous particles, but they are never conspicuous or numerous. Arising from the circular ring is still another outgrowth, the so-called "stone-canal," which may be single, or there may be a number. In the great majority of cases the "stone-canal" is a single, unbranched tube, arising in the mid-dorsal interradius and more or less completely inclosed in the mesentery. In Synapta the stone-canal is usually single, but branched, while sometimes in that genus, and commonly in Opheodesoma, a large number of stone-canals are present, arising from almost any part of the circular ring. While the inner end of the stone-canal is in immediate connection with the ring, the outer end is almost always unattached, and bears a more or less prominent and irregular enlargement which corresponds to the madrepore plate of other echinoderms, and is known as the madrepore body. Through the openings in the madrepore body the stone-canal, and hence the entire water-vascular system, is in direct communication with the body-cavity. In *Synaptula hydriformis,* moreover, the madrepore body lies in the mesentery and is attached to the dorsal wall in such a way that there is present at least one opening between the stone-canal and the water outside. This opening is on the dorsal side, just in front of the genital duct. In all Synaptids the wall of the stone-canal consists of only three layers, the outer epithelium, a connective-tissue layer, and an inner epithelium of high, more or less cylindrical cells, which are conspicuously ciliated. There are no muscle fibers anywhere in the tube wall, but the connective-tissue layer contains a large quantity of irregular particles of carbonate of lime, giving that firmness and brittleness to the tube which has led to its being called a *stone*-canal. The madrepore body is mainly a mass of such calciferous connective tissue, more or less extensively pierced by the openings between stone-canal and body-cavity, which are very short tubes, lined with a prominent ciliated epithelium. Owing to this direct connection between the lumen of the water-vascular system and the body-cavity, the fluids contained in the two are essentially identical.

Alimentary canal.—The mouth of Synaptids is a circular opening in the center of the oral disc, around which the tentacles form a single circle, and which constitutes the anterior end of the body. The mouth opens at once into a slender thin-walled œsophagus of variable length, which is encircled by the calcareous ring and water-vascular ring, and which is more or less connected with them and with the body-wall by strands of connective tissue. The œsophagus opens into a more or less well-marked stomach, the thicker and more muscular walls of which usually distinguish it from both œsophagus and intestine. The latter is usually thin-walled and of nearly uniform diameter; it may be short and without a loop (a condition practically unknown among other holothurians) or it may be elongated to such an extent that from the point of union with the stomach it bends forward and runs for a greater or less distance toward the mouth before it bends again and takes its course backward to the vent. The latter is the ordinary arrangement. It terminates in a slight enlargement homologous with the cloaca of the lung-bearing holothurians, but as no other organs enter it, in the Synaptids it is better called the rectum. The vent or anal opening is always terminal. A cross-section through the alimentary tract at any point reveals an outer epithelium, the ordinary lining of the body-cavity; inside of this a very thin layer of connective tissue, following which is a muscular layer consisting first of longitudinal and then of circular fibers; within this is a thick layer of connective tissue, and then the lining epithelium of the canal. The layer of muscles is thickest on the stomach, the walls of which are decidedly muscular. The inner epithelium is more or less glandular, especially in the stomach, and is frequently ciliated, at least in the intestine. Some writers have described a delicate cuticle there instead, but this is possibly a misinterpretation of the appearance of the cilia in preserved material. Wandering cells (often bright red in the living animal) occur more or less abundantly throughout the lining epithelium. The alimentary canal is supported through part or all of its course by a mesentery, usually consisting of three sections. The first supports the œsophagus and stomach and is attached to the body-wall in the mid-dorsal interradius; the second supports that part of the intestine which runs forward from the end of the stomach and is attached in the left dorsal interradius; the third supports the remainder of the intestine and is attached in the right ventral interradius. The second section may be greatly reduced and is practically wanting in those species which have an approximately straight alimentary canal. In other cases the first and second sections of the mesentery run backward considerably posterior to the point where the intestine bends forward, and, being united together over the left dorsal radius, they form a blind sac which Semper has called the "mesenterial canal." In *Myriotrochus minutus* the mesentery is greatly reduced, and there are special connections between the loops of the intestine and with the body-wall. The mesenteries are usually attached a little to one side of the mid-line of the interradius in which they lie. They consist of a very thin layer of connective tissue, with or without muscle fibers and covered on each side with the epithelium of the body-cavity.

Ciliated funnels.—In the body-cavity of all Synaptids, so far as known, except *Rhabdomolgus ruber* and *Labidoplax buskii,* there occur minute, more or less funnel- or cornucopia-shaped bodies conspicuously ciliated over a part of their surface (Plate V, figs. 11, 12, 20, 21; Plate VII, figs. 14, 23, 28). These ciliated funnels are very characteristic of the family, and are not known to occur in any other animals. They are very few in number in *Leptosynapta minuta* and it may be that they will yet be found in the species of Labidoplax and Rhabdomolgus, where they are said to be wanting. They most commonly occur upon the mesenteries close to where the latter join the body-wall, but they may occur on the body-wall itself and on the face of the mesentery also. They may occur in connection with all three sections of the mesentery or only with one or two. The funnels may be individually distinct and uniformly separated, they may occur in small groups, or a number may be united into a cluster having a common stem (Plate VII, fig. 14). They range from less than 80 μ to considerably over a millimeter in length. When connected on a common stalk, the whole group may be nearly a milimeter high, and the individual funnels range from 70 to 250 μ. In any one species the size as well as the arrangement of the funnels is fairly constant, though in some cases two very distinct sorts of funnel occur in the same individual. Thus in *Leptosynapta inhærens* the ordinary funnels are generally less than one-tenth of a millimeter in height, but scattered here and there among them are funnels of a somewhat different shape from four to twelve times as large (Plate V, fig. 20). The stalk of the funnels is always a slender strand of connective tissue covered with an epithelium, both direct continuations of the same tissues of the mesentery or body-wall. In groups having a common stalk, the latter is said to contain muscle fibers. The funnel itself is made up of connective tissue covered on the outer (convex) side with the flattened epithelium of the body-cavity and lined with an epithelium of high, cylindrical, crowded cells, each of which bears a cilium. The exact form of the funnel, the thickness of the various parts, and the size of the space inclosed vary greatly in different species, and to some extent in different individuals of the same species, and in different funnels of the same individual.

Blood system.—In connection with the digestive canal, there are present in the Synaptidæ two long longitudinal vessels, which form the principal portion of the blood system (Plate VI, fig. 6). One of these lies just at the line of union of the mesentery and alimentary canal, and is called the dorsal vessel, while the other is on the opposite side, and is called the ventral vessel. These vessels may be closely appressed to the stomach and intestine or they may be completely separated from them by a greater or less distance. In the former case they are connected with each other by lacunar spaces in the wall of the alimentary canal, but when separated from the latter they are connected with its wall by short cross-vessels which open into the lacunar spaces or into a secondary longitudinal vessel from which lacunæ arise. The ventral blood-vessel runs from the lower end of the œsophagus back as far as the middle of the third section of the alimentary canal, both ends fading out into lacunar spaces. Between the ventral blood-vessel of the first and second sections of the digestive tube (sometimes between second and third, sometimes even between first and third) there are usually present one or more connecting vessels of considerable prominence. The dorsal vessel runs backward about as far as the ventral vessel, but anteriorly it extends to the water-vascular ring, upon the inner surface of which there lies the circumœsophageal ring of the blood-system, in which it terminates. Direct connection between the ventral vessel and this ring has yet to be demonstrated in the Synaptidæ. From the blood-ring arise vessels running into each tentacle along the inner surface, close to the tentacle canals. The genital gland receives its blood-supply directly from the dorsal vessel. Radial blood-vessels are wanting in the Synaptids. The blood is usually colorless, but in some of the larger species it is yellowish. It contains much more albuminous material than the fluid of the water-vascular system; it also contains corpuscles, amœboid cells, and minute granules.

Reproductive system.—The reproductive organs of the Synaptidæ consist of a more or less branched pair of tube-like projections, one on each side of the dorsal mesentery, in which lies the common genital duct, into which they open. The duct is short and opens to the outside by a single pore, in the mid-dorsal interradius, just back of the circle of tentacles. In *Synaptula hydriformis,* however, the duct is not united with the outer epithelium of the body-wall and probably communicates with the exterior by several minute pores. The genital tubes themselves lie in the anterior part of the body-cavity; there is rarely only a single branch on each side, generally several or many branches. Usually the branches or tufts of branches of the two sides are of equal size in adult Synaptids, but in the young, so far as is known, that of the left side is the smaller, and this asymmetrical condition may persist in some adults. The tubes are often somewhat colored, usually yellowish, sometimes green, but more commonly they are white, although the shade varies with the condition of the contents of the tubes. In their finer structure the tubes are found to consist of an outer epithelium continuous with that of the mesentery, and an inner germinal epithelium. Between these there is always present more or less of a connective-tissue layer (though this may be reduced to scattered mesenchyme cells) and a more or less evident layer of longitudinal muscle fibers. In some cases a layer of circular muscle fibers is also said to occur. The finer structure of the genital duct is similar to that of the tubes, but the muscle layers are wanting, and anteriorly the wall of the duct may even be reduced to a single layer of cells. Hermaphroditism is common in the family, but many species are unisexual. In the latter the germinal epithelium gives rise only to eggs or spermatozoa, as the case may be, but in the former the eggs arise on one side of the germinal epithelium, the spermatozoa on the other, or they arise at different places on the inner side or at different times. It is possible that some of the cases reported in which individuals seemed to be of different sexes are simply cases of protandry; but this phenomenon is not certainly known to occur among the Synaptidæ, and in some cases there is no question that eggs and spermatozoa are present and maturing in the same part of the genital tubes and at the same time.

Embryology.

Our knowledge of the embryology of the Synaptidæ is confined to a very few species, particularly *Labidoplax digitata, Synaptula hydriformis, Chiridota rotifera,* and *Tæniogyrus contortus,* and the following account is based upon the observations recorded of them. The eggs range in size from rather more than 100 microns to upwards of 330 microns. They are spherical, contain considerable yolk, which gives them a yellowish or brownish tinge, and are more or less transparent. They are generally set free in the water, but in some cases develop within the body-cavity of the parent, or even in the genital tubes of the mother. Nothing is known positively of the formation of the polar bodies or the process of fertilization, though the latter must, in viviparous forms, take place internally. Segmentation is total and approximately equal (Plate VI, figs. 1 and 2) and results in the speedy formation of a blastula from which the gastrula arises by invagination. The subsequent developmental changes depend very largely upon whether the embryos are protected within the body of the mother or not. If development is so protected, it proceeds directly and with considerable rapidity; but if not, the young Synaptid passes through more or less prolonged larval stages. In any case the archenteron soon bends to one side, and uniting with the body-wall, brings its lumen into connection with the exterior, and this opening forms the water-pore and indicates the dorsal surface of the animal. The archenteron continues its growth forward, however, and, bending downward, unites with the ventral surface of the larva, and the mouth is subsequently formed at that point. In this growth of the archenteron the portion connected with the water-pore comes to lie at one side (the left) and soon is separated as a pouch by itself. This pouch grows backward and constricts, so that its posterior part soon becomes a distinct pouch, which grows out laterally to the right across the dorsal surface of the archenteron onto the right side. The right and left halves of the pouch then separate and become entirely distinct. At this stage, then, we have a larva with a mouth, gut, and anus (the blastopore), a hydrocœl connected with the exterior by a water-tube, and two cœlomic pouches, one on each side of the gut. Scattered throughout the segmentation cavity are more or less numerous mesenchyme cells, which have arisen from the endodermal cells of the archenteron. In those Synaptids which have free-living larval forms, the external appearance of the larva at this stage is very characteristic, and is very similar to the *auricularia* larva of other holothurians. The Synaptid auricularia is a dorsally-flattened, wide, squarish larva with a deep depression on the ventral side (oral vestibule), at the bottom of which opens the mouth. The uniform ciliated coat of the gastrula has given place to a complicated symmetrical series of ciliated bands. A larval nervous system, muscles, and wheel-shaped calcareous bodies are also present. After a time the auricularia becomes barrel-shaped, and the ciliated bands form five encircling rings around the body; this stage is sometimes called the *pupa,* sometimes *barrel-shaped larva.* At the upper or anterior end of the pupa is a very deep, constricted, funnel-shaped space, the vestibule, in the floor of which lies the mouth; the hydrocœl completely encloses the œsophagus, forming the water-vascular ring from which arise the polian vessel and the tentacles; of the latter, five are already indicated, and between each pair are five other outgrowths corresponding to the radial water-canals of pedate holothurians; these may be quite well-marked in the pupa, running back toward the rear of the body; the cœlomic pouches have become fused ventrally, but on the opposite side are still separated by the dorsal mesentery; the rudiments of the calcareous ring have appeared, and the positional organs are well formed. With the growth of the five tentacles the vestibule disappears and the larva assumes the *pentactula* form (Plate VI, fig. 3), characterized by the short, oval body, the absence of ciliated rings and the five prominent tentacles without digits. The muscular and nervous system are fairly distinct and are rapidly assuming the adult condition. The transformation from the pentactula to the adult form is chiefly marked by the appearance of the blood-system, ciliated funnels, and reproductive organs and the increase in the number of the tentacles, with accompanying development of digits. In *Tæniogyrus contortus* the sixth and seventh tentacles appear simultaneously in the lateral dorsal interradii (Plate VII, fig. 13), and subsequently the eighth, ninth, and tenth appear in the other three interradii, but in *Synaptula hydri-*

formis the second quintet of tentacles appear all at the same time. Probably the 10-tentacled larva (Plate VI, fig. 4) is characteristic of all Synaptids. In the viviparous species the auricularia seems to be wanting and the pupa stage is passed through quickly, nor are there any sharp lines between the different steps in the process of development; the pentactula and 10-tentacled larvæ are, however, plainly shown. In other respects there is little essential difference between the development of the oviparous and viviparous species. In the larvæ of *Synaptula hydriformis,* however, there are peculiar glandular organs in the ectoderm, which may have some use in absorbing food material from the body-cavity fluid of the parent. Perhaps these glandular organs are identical with the "contractile rosettes" of certain other Synaptids. (See Becher, :06.) In species with twelve tentacles, the eleventh and twelfth arise, one in each of the two lateral, dorsal interradii; nothing is known of the development of the additional tentacles in species with more than twelve.

In conclusion, the organogeny of the Synaptids may be stated as follows: *Ectoderm:* The epithelium of the entire body surface, including the sensory epithelium of the tentacles, the entire nervous system, the sense-organs, the anterior part of the œsophagus and possibly the posterior part of the rectum arise from the larval ectoderm. *Mesoderm:* The calcareous concretions, the calcareous ring, the pigment-cells and all cartilaginous and connective tissues arise from the mesenchyme cells of the larva, which in turn arise from the archenteron; there is no satisfactory evidence that any muscles are formed from these cells. *Endoderm:* The alimentary canal (except the ectodermal portions already mentioned), the water-vascular system, the entire musculature, the ciliated funnels, the blood-vessels and corpuscles, the reproductive organs, and all internal epithelial tissues arise from the larval endoderm, either directly from the archenteron or from the hydrocœl and cœlomic pouches to which it gives rise.

PHYSIOLOGY.

Comparatively little work has yet been done in studying the functions of various organs of Holothurians or indeed of any Echinoderms, and particularly is this true of Synaptids. Most of our knowledge of the physiology of these animals is the result of casual observation or chance discoveries made while some problem of morphology or embryology was under investigation. What little is known may be conveniently grouped under the following heads:

MOTION.—The movements of Synaptids are mainly concerned with the collection of food and the avoidance of enemies, and are dependent upon the fluids within the body-cavity and water-vascular system quite as much as upon the muscles; the calcareous particles in the body-wall also play an important part in the locomotion of many species. In the search for food, the animal is usually fully extended, and while the tentacles clearly assist, the principal means of locomotion is by the alternate contraction and extension of the body-wall, due to muscular movements. The contraction of the longitudinal muscles draws the posterior end of the body forward, and their relaxation, accompanied by the contraction of the circular muscles, forces the anterior end ahead; for since the body-cavity is filled with fluid, the decrease in its diameter, due to the contraction of the circular muscles, necessarily results in its increased length, and this causes a forward movement, since the body is prevented from slipping backward by the marked projection of the calcareous particles. This projection is brought about by the contraction of the circular muscles—a contraction that begins at the posterior end of the body and moves forward to the head. In species which are distinctly subterranean the calcareous particles of the rear of the body are frequently much larger and more numerous than those anteriorly, in accordance with their use. When moving through sand or mud, the tentacles play an important part in the progress by separating and loosening the particles and pressing them apart, thus permitting the anterior end to be forced forward by the contractions of the body muscles. The subterranean species often move about in burrows, gathering food as they go, the glands of the skin providing a secretion which serves to give the walls of the burrows a certain smoothness, as well as increasing their firmness. Synaptas can turn in their burrows, although they do not usually do so, and backward movements are possible, but not frequent. In collecting food, Synaptids do not lie in their burrows, with their tentacles extended on the surface of the sand, waiting for what may be brought them, but they gather it as they creep about, picking it up by the tips of the tentacles and passing it inward to the mouth. The movements of the tentacles and digits are effected partly by the contained fluid of the water-vascular canals, but mainly by the longitudinal muscles lying on the inner surface. Under pressure from behind, due to muscular contraction of polian vesels and perhaps of the water-ring itself, the fluid tends to straighten the tentacles, while the contraction of their longitudinal muscles tends to bend them inward. Movements to avoid enemies are occasionally like those already described, but may take the form of sudden, active, and very powerful muscular contraction. Similar movements may be produced artificially by changes in environment or by unnatural stimuli. The results of these movements depend of course upon the muscular systems involved. When the whole animal is affected, the body becomes reduced in bulk, both the longitudinal and lateral diameters being evidently decreased; the tentacles may be so strongly contracted as to be entirely invisible, crowded as they are into the now concave surface of the oral disc. Contraction of the circular muscles is always more marked than of the longitudinal, and may go so far as to break the body up into a number of fragments. Such disastrous movements, however, probably do not occur under normal conditions. Subterranean species draw back into their burrows when attacked, and may even retreat into them for some distance, Few, if any, Synaptids swim, except in the larval state, but young ones up to 2 cm. in length are sometimes found floating, if not swimming, in the water. They seem to move partly by the aid of the tentacles and partly by undulatory movements of the body. Many species crawl about with more or less activity, by means of the tentacles, and a few forms can climb the glass walls of aquaria, using the glandular sensory epithelium of the outside of the tentacle tips as adhesive organs. In rare cases the calcareous particles of the body-wall assist in climbing about in seaweeds. As for the rate of movement, it of course varies greatly with the individual and the external conditions, but a healthy Synaptid of moderate size can move from 20 to 30 mm. per minute; larger specimens may move more rapidly.

Digestion and absorption.—So far as is known, these processes show no special peculiarities, taking place as they do in a remarkably simple alimentary system. The food pushed into the mouth by the tentacles is carried by the short and narrow œsophagus into the stomach, where it becomes mixed with the digestive secretion of the gastric glands. Digestion begins here, but probably takes place also in the intestine, while absorption, which may take place to a certain extent in the stomach wall, is mainly accomplished by the wall of the intestine, the absorbed food material being received in the two main trunks of blood system through an extensive system of lacunæ in the intestinal wall. The rectum receives and ultimately rejects the excrement. It is possible that the "larval glandular organs" of *Synaptula hydriformis* (see page 61) and the "contractile rosettes" of *Leptosynapta minuta* (see Becher, :06) are absorptive organs, but it is by no means certain what their function is.

Circulation and nutrition.—There is no true circulation in the blood-system of the Synaptidæ, and the so-called blood plays no part in the carrying of oxygen to the tissues or in removing excreta from them. We are to look upon the movements of the fluid as normally away from the digestive system to the various parts of the body, and as carrying simply the absorbed food to its destination. The system thus is essential to normal and healthful nutrition, but cannot be considered as in any true sense a circulatory system. There is no heart or other vascular organ for propelling the fluid, but contractions of the muscles in the wall of the alimentary canal serve to force the fluid products of digestion into the lacunæ and thence into the larger vessels, and from them on and away, while contractions of the muscles in the body-wall and elsewhere may serve to open up the minute lacunar spaces that drink in the nutritious fluid. No proper investigations of the fluid or its movements in a Synaptid have yet been made, and whether the corpuscles play any important part is unknown.

Respiration.—The providing of oxygen for the tissues of the body is not delegated to any particular system, so far as we know, but the needed gas is taken from the water directly through the skin, probably of all parts of the body, but particularly of the tentacles. Probably some oxygen passes entirely through the skin into the body-cavity fluid, whence the alimentary canal and reproductive system may be supplied. Naturally the tentacles and anterior part of the body require more oxygen than other parts, and there is some reason for believing that the oral disc and tentacles are particularly active in respiration. There is no reason for attaching any respiratory function to the blood system, but we as yet know nothing of the actual movements of gases to, from, or in the tissues.

Excretion.—The getting rid of waste matter from the tissues takes place in Synaptids as in other echinoderms, chiefly by means of the wandering cells already referred to (p. 48), but assisted in a large measure by the peculiar ciliated funnels (p. 57) so characteristic of the family. Whether the water-vascular system, the blood system, or the alimentary canal play any part in excretion we do not know. Excreta passes into the body-cavity fluid from all those tissues which it touches, and much or all of this waste matter, certainly if it be in solid particles, is sooner or later swept into the ciliated funnels. It collects there and seems to be seized on by the "wandering cells," which carry it into the connective tissue of the body-wall. Here these cells may remain indefinitely, but probably most of them ultimately pass on through the skin to the water outside. Fluid and gaseous excreta probably pass directly through the skin into the water. As a matter of fact, we really have almost no evidence on the subject of excretion, except observations made on the action of the ciliated funnels, and while collecting solid particles from the body-cavity fluid is undoubtedly an important function of these organs, it is by no means proven that they are exclusively excretory. As for the wandering cells, most statements regarding them are hypothetical, but there is some evidence in support of the view that as the animal grows older, these cells, with their loads of excreta, collect more and more thickly in the skin and cause the darker or brighter colors which large Synaptids show as compared with their young. What the essential difference is between such cells and the normal pigment cells has yet to be shown, but there can be little doubt that there is a definite correlation between color and excretion. Whether the calcareous particles are to be regarded as the product of excretion is an open question.

Sensation.—The senses of a Synaptid are apparently very simple. Touch is the most widely distributed, almost any part of the body responding to a mechanical stimulus, but it is specially keen in the digits of the tentacles, which are exceedingly sensitive. So far as we can interpret the actions of a Synaptid, the sensations caused by a mechanical stimulus is the same as in all other animals, and the character of the object touched is appreciated to a limited degree. In some cases at least food is recognized apparently by the sense of touch only. Sight is seemingly limited merely to the distinguishing between light and shade, and is probably confined to those species which have special light-detecting organs, but it is entirely conceivable that in other species light may in some way act as a stimulus. Experiment has shown that some such sense as that of taste or smell is apparently possessed by those species which have the special gustatory organs or cups on the inner face of the tentacles, and that this sense is located in these cups. The evidence is not conclusive, however, and it is not known whether any such sense exists in other Synaptids or not. The sense of hearing is apparently entirely lacking, but the sense of position is good, and experiment has shown that the difference between going *up* and going *down* is perfectly evident to a moving Synapta. There is no doubt either that this sense is located in the so-called "otocysts" (positional organs) at the base of the tentacles. There is no evidence of anything like intelligence in the actions of Synaptas, and even their movements are apparently not dependent on an intact nervous system or even an uninjured circumoral nerve-ring; for the severing of the nerve-ring in half a dozen places does not, after the first shock is over, interfere with normal coördinated movements. The habit of contracting the body so strongly as to rupture the body-wall is frequent, and may possibly indicate a lack of any such feeling as that which we call pain, but it is out of the question to determine positively whether a Synaptid feels pain or not. Stupefying by means of magnesium sulphate, chloral, etc., is, as a rule, easily accomplished to such an extent as to render the animal unresponsive to any sort of stimulus. The difference between a sandy (or muddy) bottom and a glass (or porcelain) surface is rather slowly detected, but leads to definite alteration of conduct and movement. Changes in the composition of the water (percentage of salts, CO_2, etc.) are readily detected and also lead to altered movements, but it is doubtful how far these are due to nervous stimulation.

Regeneration.—The power of regeneration in Synaptids is quite remarkable in some ways, but as yet very little experimental work has been done to show how great it is. One or more tentacles, even the whole circle, will be reproduced if external conditions are at all favorable, but if the whole oral end is cut off, there seems to be no power of reproducing it. On the other hand, if the body is bisected, the anterior end appears to be able to reproduce the posterior portion, although the latter cannot form a new oral end for itself. This seems to be true, no matter where the bisection is made. Apparently it is not essential that any considerable portion of the alimentary canal or blood system should be left in the regenerating part. No experiments have been carried through to show how far sense-organs or nerves can be reproduced.

Reproduction.—Reproduction in the Synaptidæ is always sexual, but a large number of species, probably the great majority, are hermaphroditic. Fertilization ordinarily takes place in the water, outside the body of the egg-producing individual, but in the viviparous forms it seems to occur in the body-cavity or even in the genital ducts. So far as known, there is nothing like sexual union between two individuals, but the viviparous species are often, if not always, more or less gregarious, so that fertilization is thereby facilitated. In the great majority of cases, the fertilized eggs undergo their development in the water entirely independent of the parent, but in four species they are known to be retained in the body and undergo their development there. In one case (*Tæniogyrus contortus*) the development takes place within the genital tubes, which thus serve as a uterus, but in the other cases (*Synaptula hydriformis, Leptosynapta minuta, Chiridota rotifera*) the body-cavity serves as the brood-pouch. How the eggs get into the body-cavity is not certainly known, but it is supposed that they pass in from the ovaries directly by rupture of the covering epithelium. When and where fertilization takes place, in such a case, are undetermined points, but probably it occurs after the eggs have left the ovary and are free in the body-cavity. If such is the case, the spermatozoa must pass into the cœlum either directly from the hermaphroditic gonads or else indirectly through the wall of the rectum, openings in which are present in *Synaptula hydriformis*. In *Tæniogyrus contortus* the sexes are separate and the spermatozoa must enter the uterus from the outside water. The young remain in the body-cavity of *S. hydriformis* until 5 mm. or more (sometimes 20 mm.) in length, and are then born by a rupture of the body-wall near the rear of the body. In *T. contortus* the young remain in the uterus until 3 mm. long, and then pass out through the genital opening. Little is known as to the frequency with which young are produced or the number of eggs matured at each breeding period, but some of the tropical Synaptas seem to breed throughout the year, while the more northern species are known to mature their reproductive cells only in the spring or summer. The number of eggs produced at each sexual period seems to range from five to several hundred, but the exact limits are not known in even one species.

Ecology.

The Synaptidæ are all marine animals and have a bathymetrical range from above low-water mark to at least 4,200 meters. The very great majority, however, are littoral forms and there are few species occurring at depths of over 350 meters. They are found in all parts of the world, but seem to be most abundant in the region southeast of Asia, where more than half the reported species are said to occur. They appear to be least abundant in the region west of South America, where no species is known to occur. An unusual number of genera occur in the Arctic and Subarctic region, but the number of species there is not large. Several of the tropical species occur in mangrove swamps, where the sea-water is not as saline as on the reefs, and at least one of the Philippine species is known to live ordinarily in distinctly brackish water. As a rule, however, the Synaptids are quite susceptible to impurities in the water and are to be found only where it is clean and well aërated. Three quite distinct groups, in the matter of habitat, can be recognized, though they are not sharply distinguished from each other. First, there are those species which are really subterranean, living buried in the sand or mud and rarely coming out from their burrows. A second group is made up of those species which live under stones and in similar hiding places; and third are those species which live among corals or seaweeds, not concealed, except as their color and form harmonize with their surroundings. The habitat of any given species varies in different regions, so that subterranean species are often found under rocks, and similar situations are sometimes frequented by species which are ordinarily unconcealed. A certain amount of correlation between color and habitat is seen throughout the family, for the brightly colored species are those which live among corals, while the white, colorless, or inconspicuous species are usually subterranean or at least lie concealed under stones. In some cases this correlation is very striking; for example, *Synaptula hydriformis* in Jamaican waters is reddish brown in color, in perfect harmony with the seaweed it inhabits, while at the Bermudas it is more or less bright green, in harmony with the Ulvaceæ among which it lives.

Very little is really known as to the food of the Synaptidæ, but the alimentary canal is usually found well filled with particles of sand and other inorganic substances, which are taken in with the food. The tentacles of a living Synaptid are in almost constant motion, continually bending in toward the mouth, and then curving outward again, and it is often possible to see particles of solid matter being pushed into the mouth. In *Synaptula hydriformis* the food is largely, if not wholly, vegetable, diatoms forming a conspicuous part of it, and it is probable that the same is true of all those species which live in seaweeds. The food of *Leptosynapta inhærens* is organic matter, taken in with the sand through which it burrows, and apparently consists of both animal and vegetable remains; probably all of the subterranean species and those which live under stones feed on similar material. Whether the species which live among corals are carnivorous has yet to be shown; on *a priori* grounds, it is highly improbable.

Like all holothurians, Synaptids are very inactive animals. Unless irritated by some exceptional external stimulus, their movements are slow and uniform. There is no good ground for believing that they are more active during the night than in daylight. Those forms which live under stones appear to be the most restricted in their movements; for while both the subterranean and the free-living forms are more or less continually moving about in search of food, they seem to remain for long periods of time in a single spot. As a rule, Synaptids do not thrive in aquaria, but some of the subterranean forms will do very well if there is an abundance of pure sea-water. The free-living forms are very sensitive to changed conditions and soon die in ordinary aquaria. The length of life and the rate of growth are wholly unknown, though there is reason to believe that both are closely correlated with the abundance of the food supply. It is hard to say whether Synaptids have any enemies of importance or not; so far as we know, they are not sought after by any animals, but it is difficult to see why they would not serve, as well as worms, for food for fishes. Some starfishes and a few mollusks are known to eat holothurians and some Synaptids may be destroyed by such foes. Parasites are quite common; some half dozen sporozoans, a sponge, several trematode worms, a rotifer, a crustacean, and half a dozen mollusks are already known, which live upon or within some Synaptid, and there are doubtless others which have not yet been noted. Some of these probably obtain little, if any, nourishment from their host, but some of the internal forms are true parasites of the most degenerate kind. Whether any of them seriously enfeeble their host is, however, an open question.

Abnormal individuals (aside from some diversity in the number of tentacles) have only been reported in the case of *Synaptula hydriformis*, where the young are sometimes more or less grown together in pairs (Plate VI, fig. 22) or triplets, occasionally even in quartets and quintets. It is more than doubtful whether these monstrosities ever reach maturity, but one adult with only 3 radii and 11 tentacles has been recorded. Additional tentacles and abnormal calcareous particles are frequent and are known in many species. So far as the human race is concerned, the Synaptidæ are absolutely useless; none of them serves as food or even as the source of articles or substances which are of the least value to man, nor do they furnish food for any animal of commercial importance. The geological history of the Synaptidæ is very imperfectly known, but calcareous particles clearly referable to members of the family have been found in Eocene rocks, and there is reason to believe that the family dates back to the Cretaceous period at least.

Taxology.

The classification adopted in this report has already been discussed and fully outlined (pp. 14-17), but a few words may be added here in explanation of the principles which have been used in determining the validity of the genera and species herein accepted. In attempting to distinguish a "good species," it is essential that the possibilities of individual diversity should not be forgotten; for this reason it is unfortunate when it is necessary to describe a new species from a single specimen, but this necessity often arises. As a general rule, however, we may say that any individual Synaptid belongs to that species of its own genus which inhabits the region where it was taken, unless it shows a marked and tangible difference, constant and without any intergrading series, *either in the form or size of the calcareous particles, in the number or form of the tentacles, or in the special localization of the calcareous particles in spots, rows or papillæ.* In case more than one species of the genus occurs in the region where the individual under consideration was taken, the latter will of course be compared with each one and assigned to that one which it most nearly resembles, unless it shows some one or more of the above-mentioned differences. In case such a difference does appear, the individual is then compared with all other known species of the genus, regardless of locality, and in case the difference is still unique, it must then be given a new name. On the other hand, great care must be used to prevent confusing really distinct species from one side of the globe with nearly related ones from the other; on *a priori* grounds, it is to be assumed that a species from the Atlantic Ocean is distinct from its nearest allies in the western Pacific. Even slight differences, if they are constant, may be used to distinguish species from widely separated areas. Of course, however, it is understood that the character must be sufficient to distinguish individuals of the allied species from each other, regardless of whether their geographical habitat is known or not. Of characters used to distinguish species, the most reliable and satisfactory are undoubtedly the chief calcareous particles of the body-wall, their form, size, and distribution; making proper allowance for individual diversity and the possible solutive effects of preserving fluids, these deposits are remarkably constant in any species. The number and form of the tentacles are good characters, if the specimen is unquestionably mature, but differences in the form and abundance of the lesser calcareous deposits, in the number and length of the digits, in the presence or absence of a web or membrane between digits or between tentacles, and in the relative length of the tentacles must all be regarded with great suspicion, especially if only preserved material is available; of course, where plenty of living material is at hand, some of these characters may prove to be of great importance. Color and size are valuable characters in some species, but very little weight can be attached to them except where a large amount of living or fresh material has been examined. Several other external characters, such as roughness or thickness of the body-wall, prominence of verrucæ (see p. 43), and proportion of diameter to length, have been used in describing species, but little or no weight attaches to them, as a rule. Of internal characters, the form of the pieces of the calcareous ring is the best; but even in this there is some individual diversity. The number of polian vessels and stone-canals, the form of the ciliated funnels, the arrangement of the alimentary canal and its mesenteries, the form of the longitudinal muscles (including the presence of so-called "retractors"), and the appearance of the reproductive organs are all characters which are subject to much individual diversity, often according to age, time of year, size, and habitat, and little weight can be placed on them in distinguishing species. Of characters for distinguishing genera, aside from the calcareous particles, the number and the form of the tentacles are the best, and while others may occasionally be used, no great weight attaches to them. The genera used in this report are easily recognizable (except that Molpadia and Caudina are not always distinct from each other), and there need be no difficulty in distinguishing them. Unfortunately the same cannot be said for the species. Many of the latter are very closely related, but still apparently distinguishable, and must be retained for the present, while others are almost certainly based on abnormal or immature individuals. In other cases it is quite possible that two or more species are included under a single name. No doubt the present compiler has made errors in many cases, but it is hoped that in spite of these the classification here offered may prove satisfactory to students of the Synaptidæ, and may be the basis for much further investigation of the taxology of the group.

KEY TO THE SUBFAMILIES OF SYNAPTIDÆ.

A.—No wheels, sigmoid or bracket-shaped particles present in the skin, but usually anchors and perforated plates; deposits rarely wholly wanting: tentacles never peltato-digitate. SYNAPTINÆ

AA.—Wheels, sigmoid or bracket-shaped particles commonly present in the skin, but no anchors; deposits sometimes wholly wanting; tentacles commonly peltato-digitate.
  Wheels present or wanting; if present, never with more than six spokes. CHIRIDOTINÆ
  Wheels present, with eight or more spokes .... MYRIOTROCHINÆ

SYNAPTINÆ Östergren, 1898*b*.

Tentacles with the stalk cylindrical or terete, not becoming widened distally, either with digits along each side for most of its length (*pinnate*) or with only one or two digits on each side near the tip (*digitate*) or without digits at all (*simple*). Calcareous deposits, usually anchors and perforated plates, often accompanied by irregular, curved rods or minute particles (*miliary granules*), but any or all of these may be wanting. Hermaphroditic so far as known, except possibly Rhabdomolgus.

In the following keys and descriptions the terms which are used are commonly self-explanatory, but some explanation is needed of those used in reference to the calcareous particles. The term *miliary granules* does not include any particles occurring in the tentacles or in the longitudinal muscles, so that a species in which it is stated that the "miliary granules are wanting" may have supporting rods in the tentacles and small oval bodies in the longitudinal muscles. When the miliary granules have a number of short curved branches, they are called *rosettes*. The different parts of the *anchor* are the *arms* and the *shaft;* the point where the arms meet and join the shaft is the *vertex,* and this is the *anterior* end; at the opposite (*posterior*) end of the shaft is the *stock*. The *anchor-plate* lies below the anchor, and the end beneath the stock is of course the *posterior* end; it is across this end that the rod extends, which is called the *bow;* the *anterior* end is commonly the wider. In the key to the genus Protankyra the term "accessory calcareous particles" is used for any calcareous bodies in the skin (*not* in the tentacles) other than the anchors and their plates.

KEY TO THE GENERA OF SYNAPTINÆ.

A.—Calcareous particles present in form of anchors and anchor-plates.

B.—Arms of anchor smooth; vertex usually with minute knob-like projections (plate IV, figs. 17, 25).

C.—Cartilaginous ring posterior to calcareous ring usually wanting; stock of anchor branched irregularly (plate IV, fig. 25).

Calcareous ring without noticeable anterior projections; stone-canals not numerous; anchor-plates not abruptly contracted at posterior end, but with a large, smooth hole on each side (plate IV, fig. 24). EUAPTA

Calcareous ring with conspicuous anterior projections; stone-canals numerous; anchor-plates abruptly contracted posteriorly, and thus lacking a large, smooth hole on each side (plate V, fig. 24). OPHEODESOMA

CC.—Cartilaginous ring commonly present; stock of anchor not branched (plate IV, fig. 17).

D.—Tentacles numerous, normally 25 .... POLYPLECTANA

DD.—Tentacles normally 15 or fewer.

Size very large; anchor-plates subrectangular or irregular, with numerous smooth holes (plate IV, fig. 19) .... SYNAPTA

Size diverse; anchor-plates rounded in front, narrow behind, with few holes, the largest dentate and regularly arranged (plate VI, figs. 11, 12) .... SYNAPTULA

BB.—Arms of anchor usually serrate, sometimes smooth; vertex without knobs (plate IV, figs. 3, 8, 12, 15; plate V, figs. 1, 3, 5).

C.—Tentacles pinnate, with 5-21 (usually more than 7) digits or simply pinnately notched, without digits .... LEPTOSYNAPTA

CC.—Tentacles digitate with 3-5 digits.

Anchor-plates abruptly narrowed into a sort of handle (plate V, fig. 23) LABIDOPLAX

Anchor-plates irregular with numerous holes, not narrowed into a handle (plate IV, figs. 4, 5, 9, 13) .... PROTANKYRA

AA.—Calcareous particles never in form of anchors or perforated plates.

B.—Tentacles 12, with digits.

Tentacles pinnate, with 5-13 digits .... ANAPTA

Tentacles digitate, as in Protankyra, with only 4 digits........ DACTYLAPTA

BB.—Tentacles 10, without digits..................................... RHABDOMOLGUS

EUAPTA Östergren, 1898b.

Tentacles pinnate, 15, occasionally 16; individuals not fully mature often have 12, 13, or 14. Digits numerous, 10-35 on each side. Cartilaginous ring usually wanting. Polian vessels numerous. Stone-canals one or more. Sense-organs, in form of pigment-eyes at base of tentacles on oral disc, often present. Stock of anchors distinctly branched; arms smooth; vertex with some minute knobs. Anchor-plates with large central hole surrounded by six (rarely seven) other large holes, all more or less dentate, and with several holes of variable size and arrangement (one on each side, large), but with smooth margins, at posterior end, where a well-formed and arched bow crosses outer surface of plate.

The Synaptids of this genus are of large size and variable color, shades of brown, dull green, and gray predominating. They occur in shallow water, upon or near reefs in tropical seas. The number of valid species is doubtful, as it is impossible to determine from the material and data now available what is the status of the following forms, which seem to belong here or in one of the next four genera: *Fistularia fusca* and *punctulata* Quoy and Gaimard, 1833; *Oncinolabes mollis* Brandt, 1835; *Synapta intestinalis, raynaldi* and *zebrina* Held, 1857, and *Fistularia vittata* Forskål, 1775 (see under Synaptula, p. 80). The forms here recognized as valid species may not prove, on examination of more extensive material, to be distinct. The differences which are supposed to separate them are really very slight and doubtless variable, and further study of the living animals is necessary to fully determine their relationship.

KEY TO THE SPECIES OF EUAPTA

Base of digits united by a membrane; malformation of anchors more or less frequent; East Indian .... GODEFFROYI
Base of digits not united by a membrane; malformation of anchors very rare; West Indian. LAPPA

EUAPTA GODEFFROYI.

Synapta godeffroyi Semper, 1868, p. 231. Calcareous ring and particles, pl. XXXIX, fig. 13.
Euapta godeffroyi Östergren, 1898*b*.

LENGTH.—200-400 mm., with diameter 15-20 mm.

COLOR.—Yellowish gray or creamy-white, with radii indicated by greenish-brown or pale brown stripes, and the dorsal interradii marked with large, dusky greenish-brown blotches. Young speckled with silvery gray (Bedford, '99*a*).

DISTRIBUTION.—Reported from Mauritius (Haacke, Ludwig); Thursday Island, Torres Strait (Sluiter); Great Sangir Island, Celebes (Sluiter); Pelew Islands (Bedford); Caroline Islands (Bedford); Fiji Islands (Lampert); Rotuma (Bedford); Samoa (Semper); and Hawaii (Fisher). Apparently ranging throughout the Indo-Pacific region, between 50° E. and 155° W. longitude and 20° N. and 20° S. latitude, although it has not yet been found about either Ceylon or the Philippines.

Remarks.—Fisher (:07) gives a very good account of the appearance in life and the anatomy of this species. It occurs among pebbles and coral on sandy or gravelly bottoms, in the Hawaiian Islands, but is apparently not very common.

Euapta lappa.

Plate IV, Figs. 23-25.

Synapta lappa Müller, 1850, p. 134. Calcareous ring, with some anatomical details, in Müller, 1854, pl. x. fig. 4; calcareous particles, pl. vi. fig. 17.
Synapta polii Ludwig, 1874, p. 80.
Euapta lappa Östergren, 1898*b*.
Euapta polii Östergren, 1898*b*.

Length.—200–450 mm., with diameter 15–20 mm.

Color.—Silvery gray, finely mottled with black and white; interradii often distinctly darker, the specimen appearing imperfectly longitudinally striped; occasionally the ground color is brown and the longitudinal stripes almost black; the numerous white specks are due to the crowded miliary granules.

Distribution.—Reported from "West Indies" (Müller); Gomera, off Teneriffe (Théel); Barbados (Ludwig); Jamaica and Porto Rico (Clark); Bermuda (Clark, antea); probably ranging throughout the Caribbean Sea and southward along the coast of tropical America; not yet known from Florida, but extending eastward to the Canary Islands.

Remarks.—This species is quite common under fragments of coral rock on sandy bottoms near the reefs about Jamaica. It is sluggish in all its movements and apparently feeds on particles of organic matter pushed into the mouth by the tentacles, which seem to be in constant movement. It is not at all subterranean in habit, nor does it seem to occur among the living corals. How long individuals remain under one piece of rock is an open question, but they were never observed moving from one place to another, and it is quite possible that they remain throughout adult life in a single place. At the base of each tentacle is a pair of conspicuous black pigment-spots, though whether they function as light-detecting organs was not determined by the few observations made. Ludwig's description of his solitary specimen from Barbados, which he named *polii*, leaves no doubt in my mind that it is identical with Müller's *lappa*.

OPHEODESOMA Fisher, 1907.

Tentacles pinnate, 14-16. Digits numerous, 10-35 on each side. Polian vessels numerous. Stone-canals numerous. Anchors as in Euapta. Anchor-plates with large central hole surrounded by six (rarely seven) large holes, all more or less dentate; posterior end of plate abruptly narrowed so that there are only a few small, smooth holes there; a bow across plate is, however, present.

The general appearance of the synaptids of this genus is like that of an Euapta or Synapta, and the close relationship of the three genera is obvious. The number of valid species is doubtful, but can only be determined by the examination of much material. All the described species are Indo-Pacific in their distribution.

Key to the Species of Opheodesoma.

A.—Base of digits united by a membrane; color, reddish brown or lighter, either uniform or spotted and marbled with other colors.
  Surface of body smooth, not roughened by anchors; cartilaginous ring absent. GLABRA
  Surface of body very rough from anchors; cartilaginous ring well developed. SPECTABILIS

AA.—Base of digits not united by a membrane; miliary granules numerous and aggregated into heaps: color, grayish, mottled.
  Ground color obscured by numerous irregular spots and narrow dusky bands (sometimes white, without markings)................................... GRISEA
  Ground color clear greenish-gray or dusky yellowish-brown, with few large blotches (sometimes wanting) and broad dusky bands, some or all of which may be very indistinct .... SERPENTINA

Opheodesoma glabra.

Plate V, Fig. 24.

Synapta glabra Semper, 1868, p. 12; pl. II. Calcareous ring and particles, pl. IV, fig. 8.
Euapta glabra Östergren, 1898*b*.
Opheodesoma glabra Fisher, 1907.

Length.—300–900 mm., with diameter about 25 mm.

Color.—Uniformly reddish brown, the tentacles greenish brown; according to Sluiter ('94), a large specimen from Saleyer was whitish, but possibly it was bleached by the formalin in which it was preserved.

Distribution.—Reported from Bohol, Philippines (Semper); Cebu, Philippines (Théel); Amboina (Sluiter); Bima and Saleyer, D. E. I. (Sluiter); Thursday Island, Torres Strait (Sluiter); and Fiji Islands (Théel). Probably having the same range as *godeffroyi,* although not yet known from any station west of Bima.

Remarks.—Nothing is recorded of the habitat or habits of this species. It seems to be well characterized by the dark color, smooth, thick skin, scattered miliary granules, numerous stone-canals and polian vessels, and webbed digits, but the constancy of these characters is not beyond question.

OPHEODESOMA SPECTABILIS.

Opheodesoma spectabilis Fisher, 1907, p. 723; pl. LXVI. Calcareous particles and anatomical details, pl. LXXX, figs. 1, 1*a-d*; pl. LXXXI, fig. 2.

LENGTH.—300-650 mm.

COLOR.—"In life, reddish-orange spotted with brown, the brown forming transverse more or less interrupted bands; ventral surface posteriorly grayish, spotted with whitish and barred with dark gray. Tentacles, dark dull greenish" (Fisher).

DISTRIBUTION.—Hawaiian Islands (Fisher).

REMARKS.—In view of Fisher's excellent description of this species and his critical comparison of it with *glabra,* I am inclined to suspend judgment and await further material before deciding that the two species are identical. I have to thank Dr. Fisher for sending me an excellent specimen of this most interesting form, which he reports as very common in Pearl Harbor, near Honolulu.

OPHEODESOMA GRISEA.

Synapta grisea Semper, 1868, p. 11. Calcareous ring and particles, pl. IV, figs. 6 and 7.
Euapta grisea Östergren, 1898*b*.
Opheodesoma grisea Fisher, 1907.

LENGTH.—300-900 mm., with diameter 20-25 mm.

COLOR.—Mottled dusky greenish and bluish gray, with narrow dusky lines and irregular spots, the radii appearing as clearer stripes. Sluiter ('94) describes a white variety from Thursday Island, but it is possible the specimens had bleached in the preserving fluid.

DISTRIBUTION.—Reported from Bohol, Philippines (Semper); Bay at Batavia, Samoa, Timor, Bima, Pater Noster Islands, Sawan and Saleh, D. E. I. (Sluiter); Thursday Island, Torres Strait (Sluiter); Fitzroy Island, Queensland (Bell); and Bowen, Queensland (Théel). Probably with the same distribution as *godeffroyi,* though not yet reported so far east or west.

REMARKS.—Were it not for Sluiter's ('88) opinion to the contrary, I should have no hesitation in pronouncing this species identical with the next, but as he has had abundant opportunities for comparing them, I yield to his judgment. The difference in color is hardly of primary importance, while the difference, so often referred to in the calcareous rings, is very intangible. The figure of *grisea* given by Semper ('68) is sufficiently different from that given for *serpentina* by Müller ('54), but Sluiter ('88) particularly says that in *grisea* the anterior prolongations are as long as the rest of the ring is high, thus making the whole structure like Müller's figure. This species seems to be a common reef-frequenting form in the East Indies and along the northern and eastern coasts of Australia, but nothing is recorded of its habits.

OPHEODESOMA SERPENTINA.

Synapta serpentina Müller, 1850, p. 132. Calcareous ring and attachments in Müller, 1854, pl. IX, fig. 5, and calcareous particles, pl. VI, fig. 16.
Euapta serpentina Östergren, 1898*b*.
Opheodesoma serpentina Fisher, 1907.

LENGTH.—300–900 mm., with diameter 20–25 mm.

COLOR.—Clear greenish gray or dusky yellowish brown, with or without broad dusky bands and a few dusky blotches; the bands are three or four times as wide as the dusky lines in *grisea*.

DISTRIBUTION.—Reported from Zanzibar (Selenka, Lampert, Ludwig); Celebes (Müller); Bay of Batavia, Bima, Kur, Amboina, D. E. I. (Sluiter); Ternate (v. Marenzeller); and Pulo Edam, E. I. (Ludwig). Apparently having the same distribution as *godeffroyi*, though it has not yet been taken west of the East India Islands.

REMARKS.—Sluiter ('88) says this species is much more rare than *grisea* in the Bay of Batavia, but is easily distinguished by the difference in color, and adds that the calcareous ring is somewhat different. Later ('94) he says that the only way the specimen from Amboina could be distinguished from *grisea* was by the calcareous ring. Lampert ('96) mentions a small specimen with 17 tentacles, notes some interesting color variations, and calls attention to the resemblance to *grisea*. It is very probable that the two species are identical.

POLYPLECTANA, gen. nov.

(πολύς, many, + πλεκτάναι, feelers; in reference to the numerous tentacles.)

Tentacles pinnate, 25, sometimes 26 or 27; individuals are often found with 24 or fewer. Digits numerous, 15–40 on each side. Cartilaginous ring present. Polian vessels very numerous, 20 or more. Stone-canal single. Stock of anchors not branched, though finely toothed; arms smooth, but vertex with some minute knobs. Anchor-plates with large central hole, surrounded by six other large holes, all dentate except the most posterior, which may be smooth, and with two large and several small entire holes at narrower posterior end, where a well-formed and distinctly arched bow crosses outer surface of plate. Miliary granules present, but tentacles without supporting rods.

This genus is monotypic, for I am unable to find any valid character by which to distinguish *Synapta kallipeplos* Sluiter ('88) from the longer and better-known *Synapta kefersteinii* Selenka ('67). As for *Fistularia tenuis* Quoy and Gaimard ('33), I think it very unlikely that the specimen was a Synaptid at all; certainly it is impossible to determine the point positively. The following, then, must be considered the type and only known species.

POLYPLECTANA KEFERSTEINII.

PLATE IV, FIGS. 20-22.

Synapta kefersteinii Selenka, 1867, p. 360. Calcareous ring and particles, pl. XX, figs. 120-121.

Synapta kaltipeplos Sluiter, 1888, p. 217. Calcareous ring and particles, pl. II, figs. 41-43.

Chondrocloea kefersteinii Östergren, 1898*b*.

Chondrocloea kallipeplos Östergren, 1898*b*.

Synaptula kefersteinii Fisher, 1907.

LENGTH.—250–450 mm., with diameter 10–15 mm.

COLOR.—Purplish, reddish brown, or dark brown, darker above than beneath, and more or less speckled and spotted with lighter; the spots are probably due to the heaps of miliary granules. In life the color is brownish-green (Fisher).

DISTRIBUTION.—Reported from Kosseir, Red Sea (Lampert); Amboina, Moluccas (Ludwig, Sluiter); Batavia, Java (Sluiter); Ternate (v. Marenzeller); Rotuma (Bedford); Samoa (Semper); and Hawaii (Selenka, Fisher). Probably occurring, like the preceding genus, throughout the Indo-Pacific region.

REMARKS.—Nothing whatever is recorded concerning the habits of this species, except that Sluiter ('88) says of the specimen which he described as *kallipeplos* that it did not hide under stones, but crept about on the corals. I see no reason to doubt that this individual was a large example of *kefersteinii*, in which the tentacles were still incompletely developed. Sluiter's description of the calcareous ring would indicate a unique condition for a mature Synaptid with so many tentacles; but, after comparing his figure with Selenka's, I am inclined to think there is a possible mistake in his interpretation of the condition he found, or possibly in adults of *kefersteinii* the interradial pieces become completely merged together, each quintet becoming a single piece. Sluiter's specimen was much larger than any other that has been recorded and the color was somewhat different, but these differences cannot carry much weight. Semper ('68) says *kefersteinii* is common at Samoa, and it would seem to be common also at Amboina. The specimens from the latter island examined by Ludwig ('88) showed great diversity in the number of tentacles; of 11 specimens, 1 had only 15, 6 had 20, 1 had 22, 2 had 26, and 1 had 27. The 8 examined by Sluiter ('94) were remarkable for the imperfect condition of the calcareous particles, but he does not refer to the number of tentacles; presumably, therefore, they had 25 each, as did those from Rotuma, Kosseir, Samoa, and Hawaii.

SYNAPTA Eschscholtz, 1829.

Chondroclœa Östergren, 1898 (partim).

Tentacles pinnate, 15, occasionally 16; individuals not fully mature have 14 or fewer. Digits numerous, 15–30 on each side. Cartilaginous ring present. Polian vessels very numerous (up to 50) and sometimes branched. Stone-canal single and branched, or there may be two or even a small tuft of them. Stock of anchors finely toothed, but not branched; arms smooth, but vertex, with a few minute knobs, arranged in one or two groups. Anchor-plates subrectangular or irregular, much longer than wide, with seven or eight large, and numerous small, smooth holes; at posterior end, on outer side, a well-arched bow crosses plate. Miliary granules abundant, but tentacles without supporting rods.

This is also a monotypic genus (with the type species *maculata*) and may be easily recognized by the large size and the characteristic calcareous particles, while the branched polian vessels and stone-canals are also notable. Théel ('86*a*) considers, with good reason, that Lesson's ('30) *Holothuria oceanica* is synonymous with the single species of this genus. Whether *Oncinolabes forsteri* and *fuscescens* of Brandt ('35), *Holothuria radiosa* of Reynaud (in Lesson '30), *Holothuria tentaculata* of Forster (in de Blainville '21), *Fistularia dorcyana* of Quoy and Gaimard ('33), and *Synapta fasciata* of Kuhl and Van Hasselt ('69) also belong here it is impossible to say positively, but some, if not all, of them probably do.

SYNAPTA MACULATA.

PLATES I AND IV, FIGS. 17-19 AND 26.

Holothuria maculata Chamisso and Eysenhardt, 1821. p. 352, pl. xxv.
Synapta mammillosa Eschscholtz, 1829, Hpt. 2, p. 12; pl. x. fig. 1.
Holothuria oceanica Lesson, 1830, p. 99; pl. 35.
Synapta beselii Jäger, 1833, p. 15; Semper, 1868, pl. I. Calcareous particles in Théel, 1886*a*, pl. I. fig. 12.
Synapta oceanica Jäger, 1833.
Synapta mammillosa Jäger, 1833.
Synapta maculata Jäger, 1833.
Synapta astrotabi Held, 1857, p. 269.
Synapta agassizii Selenka, 1867, p. 361.
Synapta Beselli (also *Besellii*) Tenison-Woods, 1880, p. 129.
Chondroclœa beselii Östergren, 1898*b*.

LENGTH.—1–2 meters with diameter not over 50 mm.

COLOR.—Brown, greenish brown, dark olive-green, or bluish gray, often with large spots and blotches of darker and lighter shades, or less commonly with the dark markings arranged in five longitudinal stripes. The striped form is the *agassizii* of Selenka, which Lampert ('85) considers a valid species and Bedford ('99*a*) a good variety. Further investigation is necessary to determine whether it is entitled to any recognition. Kent ('93) describes and figures *S. beselii* as *bright pink,* and furthermore his figure shows but 10 tentacles. Whether the Australian Synaptid thus figured really exists must be determined by other observers, but if it does, it is obviously not *beselii.*

Distribution.—Reported from Kosseir, Red Sea (Lampert); Zanzibar and Mauritius (Lampert); Seychelles (Ludwig); Indian Ocean (Ludwig); Ceylon (Pearson); Nicobar (Semper); Philippines (Semper); Celebes (Jäger); numerous stations, D. E. I. (Sluiter); Lucipara Islands (Lampert); Ternate (v. Marenzeller); New Guinea (Bedford); Port Douglas, Queensland (Tenison-Woods); Caroline Islands (Semper); New Hebrides (Théel); Marshall Islands, (Chamisso and Eysenhardt); Samoan Islands (Semper); and Society Islands (Eschscholtz, Théel). Evidently commonly and widely distributed throughout the Indo-Pacific region.

Remarks.—There can be no question, I think, that *Synapta mammillosa* Eschscholtz and *Holothuria oceanica* Lesson are identical; and that they are both the same as Jäger's *beselii* hardly admits of question. There is more room for doubt as regards *maculata* Ch. & Eys., but I am entirely satisfied that the holothurian so designated is the same huge Synapta. On the first comparison of the colored figures given by Eschscholtz and by Chamisso and Eysenhardt, it seems incredible that they can both represent the same species, but when we read their descriptions and see how far the plates are from showing the natural colors as they give them, we realize that little weight can be placed on that point. Moreover, Eschscholtz's picture is seemingly taken from a strongly contracted specimen showing big verrucæ, while the specimen of *maculata* was evidently in normal condition. It may be mentioned in passing that Semper's colored figure also represents the animal as having prominent verrucæ, and therefore probably in an unusual state of contraction. While it is not out of the question that *maculata* should be *Opheodesoma grisea* (Semper), the latter species is not known from any of the South Sea Islands, and the evidence, such as it is, all points to *beselii* Jäger as being the species figured by Chamisso and Eysenhardt.

Although so well known to zoölogists, very little is recorded of the habits of this interesting giant Synaptid. Semper ('68) says they move about between the rocks and on the sand of the reefs, but are exceedingly sluggish. On account of their size and appearance they well deserve the name "sea-serpent," which is sometimes applied to them. Studer (see Lampert '89*b*), on the other hand, affirms that their movements among the blocks of coral are remarkably swift for a holothurian. Sluiter ('90) says that those he found in the Bay of Batavia were exactly like *Opheodesoma grisea* in appearance and could only be distinguished by an examination of the calcareous plates; he adds that while he at first overlooked "*beselii*" on this account, more careful investigation convinced him that it was really much more common there than *grisea.*

SYNAPTULA Oersted, 1849.

Heterosynapta Verrill, 1867.
Chondrocloea Ostergren. 1898 (partim).

Tentacles pinnate, 10–15. Digits at least five on each side. Cartilaginous ring present. Polian vessels three or more. Stone-canal single, unbranched. Sense-organs in form of pigment-eyes at the base of tentacles on oral disc, often (always?) present. Stock of anchors finely toothed, but not branched; arms smooth, but vertex with a few minute knobs. Anchor-plates with a large central hole surrounded by six other large holes, all more or less dentate, and with two large and several small smooth holes at the narrow, posterior end, where a well-formed and distinctly arched bow crosses outer surface of plate.

This genus contains an unusually large number of poorly described or imperfectly known species, so that it is exceedingly difficult to determine which are valid. Those which are well known occur upon or among seaweeds and corals, creeping about very slowly by means of their tentacles and the wormlike movements of their bodies, clinging tenaciously to a rough surface by their anchors, and feeding upon diatoms and other micro-organisms. All the known members of the genus are tropical. It is almost certain that some of the oriental species here given as valid are really identical with some of the others, but further and more careful study of plentiful material is necessary to determine their true relationships. Whether *Chiridota verrucosa* and *lumbricoides* (*Synapta lumbricus* Jäger ('33)) of Eschscholtz ('29) and *Fistularia reciprocans* (*Holothuria glutinosa* Lamarck ('16)) and *vittata* of Forskål (1775) really belong to this genus it is simply impossible to say from the available evidence. The Synaptid which Herouard ('93) identified as *reciprocans* is almost certainly *Synaptula nigra;* but, as Forskål's description is practically worthless, it is impossible to determine whether Herouard and he refer to the same animal. As for *vittata*, Müller ('54), Lampert ('85), Ludwig ('86*b*), Bedford ('99*a*), and Sluiter (:01) all profess to have found it, but none of them give any distinguishing characters or add anything to Forskål's (1775) original inadequate description. Their remarks are not altogether consistent, and it is hard even to determine the genus to which the species should be referred. The figures given by Held ('57) show clearly that his specimen was an Euapta. The name had better be entirely discarded and with it, of course, Leuckart's genus Tiedemannia, of which it is the type. Since Oersted ('49) made *Synapta vivipara* (=*H. hydriformis* Le Sueur) the type of a new genus Synaptula, it is clear that this name should have precedence over Östergren's (1898) name Chondrocloea, for Östergren places Oersted's *vivipara* in his later genus. It seems probable, however, that, as at present constituted, Synaptula includes at least two groups of species which further knowledge will necessitate recognizing as separate genera; one of these is best represented by *nigra* and the other by *vivipara*. Should these groups be separated in the future, the former would of course be called Chondroclœa, unless indeed Forskål's *vittata* is rediscovered and found to belong in that genus, which would then, apparently, have to be called Tiedemannia.[1]

Key to the Species of Synaptula.

A.—Tentacles 15, with numerous digits (20-30 pairs) united at their bases by a thin membrane; color uniform dark brown or violet........................NIGRA

AA.—Tentacles 12-13 (often 15 in *recta*, perhaps normally in adults), with 10-30 pairs of digits (pl. VI, fig. 19).

    B.—Tentacles normally 12, with 10-20 pairs of digits; viviparous; occidental. HYDRIFORMIS

    BB.—Tentacles usually 13 (often 15), with 10-30 pairs of digits; not viviparous so far as known; oriental.

        C.—Gonads unbranched; polian vessels few; tentacles very long and slender, with about 10 pairs of digits ....INDIVISA

        CC.—Gonads branched; polian vessels numerous; tentacles not excessively elongated.

            D.—Miliary granules very minute, simple oval bodies usually arranged in circles; color gray, with darker spots.................PSARA

            DD.—Miliary granules irregular rosettes.

                Color, very variable; digits very short..................RECTA

                Color, dark brown-violet, longitudinally striped with white; digits long and united by a delicate membrane............VIRGATA

AAA.—Tentacles 10

    Digits numerous (12-15 pairs), long; color, milk-white or with a rosy tint..LACTEA

    Digits few (5-6 pairs), short; color variable, but not white..........RETICULATA

Synaptula nigra.

Synapta nigra Semper, 1868, p. 12. Calcareous particles, pl. IV, fig. 9.
Synapta orsinii Ludwig, 1886*b*, p. 33.
Synapta reciproquans Herouard, 1893, p. 137.
Chondroclœa nigra Östergren, 1898*b*.
Chondroclœa orsinii Östergren, 1898*b*.

Length.—100–200 mm.; Semper's type was only 60 mm.

Color.—Dark brown, deep brownish red or violet, sometimes with a black longitudinal stripe on the outer surface of each tentacle.

Distribution.—Reported from Bohol, Philippines (Semper); Australia, and Red Sea (Lampert); Margalla Bay, Assab (Ludwig), and Fontaine de Möise, Red Sea (Herouard). Probably occurs along the entire southern coast of Asia, throughout the East Indian Archipelago, and southward to Australia.

Remarks.—This is one of the least-known members of the genus, no additional information regarding it having appeared since Semper's original description, save for the localities given by Lampert ('85), the description of a specimen from the Red Sea as a new species (*orsinii*) by Ludwig ('86), and

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[1] For an excellent discussion of this point see Fisher (:07), pp. 718–719.

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the remarks of Herouard ('93) concerning a specimen, also from the Red Sea, which he identifies with *reciprocans* Forskål. My reasons for believing that these latter specimens are really *nigra* are: (1) Ludwig's description agrees perfectly with Semper's, save for the color, the miliary granules, and the anchors and plates. (2) Herouard's account does not indicate a single difference between his specimen and *nigra*, save the numerous abnormal anchors. (3) The difference in color between Ludwig's specimen and the others is obviously not of great importance. (4) The anchors and plates of Ludwig's specimen are exactly like those of Herouard's. (5) The miliary granules in Herouard's specimen are exactly like those of Semper's. (6) The appearance of the miliary granules in Ludwig's specimen and their scarcity would indicate the possibility at least of partial dissolution. It is practically impossible, therefore, to draw even an arbitrary line of division between the specimens of the three writers, and I am satisfied that they all refer to the same animal. I do not believe, however, that it is possible to determine from the data at hand whether this is one of Forskål's *Fistularias* or not, but I am exceedingly doubtful.

SYNAPTULA HYDRIFORMIS.

PLATE VI.

Holothuria hydriformis Lesueur, 1824, p. 162.
Holothuria viridis Lesueur, 1824, p. 163.
Synaptula vivipara Oersted, 1849, p. VII.
Synapta viridis Pourtales, 1851, p. 14.
Synapta pourtalesii Selenka, 1867, p. 365.
Leptosynapta hydriformis Verrill, 1867.
Leptosynapta pourtalesii Verrill, 1867.
Heterosynapta viridis Verrill, 1867.
Synapta vivipara Ludwig, 1886*b*.
Synapta picta Théel, 1886*a*, p. 10.
Chondroclœa vivipara Östergren, 1898*b*.

LENGTH.—100–150 mm., with diameter from 4 to 9 mm.

COLOR.—Pale reddish brown to dark greenish brown or even green, more or less mottled and spotted with white; these white specks are really aggregations of the abundant miliary granules. The ground color of the animal corresponds very well with the environment, the reddish tints predominating in case the surroundings are mainly red and brown algæ, while the green tints prevail where the Synaptids live among green algæ.

DISTRIBUTION.—Reported from West Indies (Oersted); Bermuda (Théel, Clark); Biscayne Bay, Florida (Pourtales); Watling's Island, Bahamas (Clark, antea); Jamaica (Clark); St. Thomas (Lesueur); Guadeloupe (Lesueur); and Abrolhos Reef, Brazil (Ludwig); doubtless occurs in suitable situations throughout the Caribbean Sea, the Gulf of Mexico, and the warm portion of the western Atlantic Ocean, from 32° N. to 18° S. latitude.

Remarks.—This is undoubtedly the best-known member of the genus, as it is very common at Bermuda and in Kingston Harbor, Jamaica, and owing to its being viviparous, it has attracted an unusual amount of attention. In addition to the characters already mentioned, the presence on the oral disc of a pair of pigment-eyes at the base of each tentacle, and the opening of the stone-canal to the outside of the body are notable features of the anatomy. It is a somewhat gregarious Synaptid, numbers of individuals occurring together. They live in tufts and patches of seaweeds, where they creep about by means of their tentacles, the anchors assisting in clinging to the plants. In Bermuda they live chiefly in Ulvaceæ and are correspondingly green, while in Jamaica they occur in Acanthophora (one of the Florideæ) and are very decidedly reddish brown; so that Bermudan and Jamaican specimens appear very different at first sight. They are quite sensitive to changed conditions and do not live well in aquaria. The food consists almost wholly of diatoms. Breeding appears to go on throughout the entire year, for specimens taken in April, May, June, July, September, and December all contained embryos and young at various stages of development. The eggs develop in the body cavity of the parent, and the young ultimately escape through rupture of the body-wall near the anus; as many as 176 young have been taken from a single individual. For a full account of the development, anatomy, and habits of this interesting species, see Clark ('98*a*). There can be no doubt that Lesueur's ('24) *viridis* was a green specimen of *vivipara*, with incompletely developed tentacles, and his *hydriformis* a red individual of the same species. His description of the latter answers admirably to living examples from Jamaica, while his description of the former is sufficiently near (save for its abnormal tentacles) to specimens from Bermuda to leave no doubt in my mind that they are the same. Nor can there be any question that Pourtales' ('51) Synapta from Biscayne Bay, which he called *viridis*, is identical with Lesueur's and Oersted's West Indian species.

Synaptula indivisa.

Synapta indivisa Semper, 1868, p. 13. Calcareous particles, pl. iv. fig. 1.
Chondroclœa indivisa Östergren, 1898*b*.

Length.—40 mm.

Color.—"Translucent reddish gray" (Semper).

Distribution.—Reported from Zamboanga, Mindanao, Philippines (Semper); Rotti, D. E. I. (Sluiter); and Thursday Island, Torres Strait (Sluiter). Apparently confined to the East Indian region.

Remarks.—Nothing has been added to our knowledge of this species since Semper's original description, and no one but Sluiter ('94, :01) has seen a specimen. The undivided gonads, the extraordinarily long and slender tentacles, and the small number (3) of polian vessels are notable characters, but it is by no means improbable that this species will prove to be the young of some other member of the genus, in spite of the fact that in Semper's specimen the gonads were "completely developed." The tentacles were very slender, with 20 digits, and even in alcohol were two-fifths of the body length.

SYNAPTULA PSARA.

Synapta psara Sluiter, 1888, p. 219.
Chondroclœa psara Östergren, 1898*b*.

LENGTH.—400–500 mm.

COLOR.—Clear or dark gray, with irregular scattered darker patches, and more or less clearly sprinkled with white dots, due to the calcareous deposits.

DISTRIBUTION.—Reported from the Bay of Batavia, Java (Sluiter), and Saleyer, D. E. I. (Sluiter). Apparently entirely East Indian.

REMARKS.—This species appears to be well characterized by its color and the peculiar miliary granules. Sluiter ('88) says that it has in life the 10 rows of prominent verrucæ characteristic of the large Synaptas, and is in its general appearance very similar to *O. grisea* and *serpentina*. Like those species, it occurs about the reefs.

SYNAPTULA RECTA.

Synapta recta Semper, 1868, p. 14. Calcareous particles, pl. IV, figs. 2-3.
Synapta striata Sluiter, 1888, p. 216. Anchor and plate, pl. II, figs. 39-40.
Chondroclœa recta Östergren, 1898*b*.
Chondroclœa striata Östergren, 1898*b*.
Chondroclœa albopunctata Sluiter, 1901, p. 127.
Chondroclœa striata var. *incurvata* Vaney, 1905.

LENGTH.—100–240 mm.

COLOR.—Apparently very variable; clear grayish yellow, variegated with a network of dark brown or purple lines (Sluiter), or with alternate longitudinal bands of dark and light gray (Bedford), or dark violet finely reticulated with yellowish white (Semper), or striped lilac on a white ground (Pearson); more or less speckled with white, due to the calcareous deposits.

DISTRIBUTION.—Reported from Bohol, Philippines (Semper); Owen Island, Mergui Archipelago (Bell); Dutch East Indies (Koehler, Sluiter); China Strait, New Guinea (Bedford); near east end of Timor (Sluiter); Batavia, Java (Sluiter); Saleyer (Sluiter); Dutch East Indies (?) (Ludwig); Ceylon (Pearson), and Gulf of Aden (Vaney). Apparently an East Indian species, extending southward to New Guinea and westward to the coast of Africa.

REMARKS.—Although Semper lays much stress on the fact that in his type specimen the alimentary canal was straight (that is, without the customary loop), I quite agree with Östergren (:05) that this is purely an individual peculiarity without systematic importance. Accordingly, as Ludwig ('88) hints, we must consider *striata* as identical with *recta*, the difference between the anchors and plates of the two, to which Sluiter ('88) refers, being altogether too slight to carry any weight. Furthermore, I cannot consider *albopunctata* Sluiter (:01) as other than *recta* with unusually abundant miliary granules, although it *may* ultimately prove a valid species. Vaney's (:05) variety *incurvata* is hardly entitled to recognition. It is most interesting, as showing that 15 is probably the normal number of tentacles in the adult, as all of his specimens had 15, and were larger than those reported by Pearson (:03) from Ceylon. The slight peculiarity in the anchors described by Vaney is probably not constant, or it may have been overlooked by other observers. Nothing whatever is recorded as to the habits of *recta*. Semper reports it from water 11–15 m. deep and Sluiter (:01) from 27–54; Bell ('86), Koehler ('95), and Bedford ('99*a*) give no information whatever regarding anatomy, habits, or habitat.

SYNAPTULA VIRGATA.

Chondroclœa virgata Sluiter, 1901, p. 128; pl. I, fig. 5.
Chondroclœa aspera Sluiter, 1901, p. 128.

LENGTH.—200 mm.

COLOR.—Brown violet, with longitudinal white stripes due to the very numerous miliary granules.

DISTRIBUTION.—Reported only from Salawatti and Gebe, D. E. I. (Sluiter).

REMARKS.—Although it is by no means certain that this species is distinct from the preceding, it may be provisionally accepted; but there does not appear to be any reason for regarding *aspera* Sluiter as other than a young *virgata*, in which the miliary granules are entirely, and the anchors and plates partially, dissolved by some acid preserving fluid; the difference in length of anchors is not great enough to carry any weight, and the difference in number of digits (if difference there be) is doubtless due to difference in age.

SYNAPTULA LACTEA.

Synapta lactea Sluiter, 1888, p. 216.
Chondroclœa lactea Östergren, 1898*b*.

LENGTH.—Not given, but apparently the size is about the same as in the next species.

COLOR.—Milk white, varying to clear rose.

DISTRIBUTION.—Reported only from Batavia, Jedan, and Banda, D. E. I. (Sluiter).

REMARKS.—This appears to be a well-marked species, though it has not yet been met with by any one but Sluiter. He says that its manner of life is the same as that of *reticulata*, creeping about on living corals in shallow water.

SYNAPTULA RETICULATA.

Synapta reticulata Semper, 1868, p. 13. Calcareous ring and particles, pl. IV, figs. 4-5.
Chondroclœa reticulata Östergren, 1898*b*.

LENGTH.—100–160 mm.

COLOR.—Clear violet or brown, recticulated with dark brown; or (var. *maculata* Sluiter '88) with irregular blotches of dark violet or less often chestnut-brown, sometimes forming irregular broad bands; or (Lampert '89*b*) light gray with five narrow longitudinal, dark violet stripes; or (var. *nigropurpurea* Bedford '99*a*) dark, without markings, "crimson-black" when alive.

DISTRIBUTION.—Reported from Bohol (Semper); Mermaid Straits (Lampert); Isle of Pines, New Caledonia (Bedford), and numerous stations in the Dutch East Indies (Koehler, Sluiter).

REMARKS.—Numerous specimens of this species have been examined by Sluiter, and he regards it as well characterized. Both he and Lampert report individuals with 12 tentacles, and Sluiter's variety, *maculata,* has 11. There is certainly room for suspicion that young individuals (and perhaps adults) of two or more species are confused under the name *reticulata.* In its habits, this Synaptid is remarkable for making its home on living corals, upon which it creeps about very slowly. In its clinging closely to rough surfaces by means of the anchors and its power to climb up a vertical glass plate, *reticulata* resembles *hydriformis.*

LEPTOSYNAPTA Verrill, 1867.

Synapta Östergren, 1898.

Tentacles pinnate, 10–13. Digits usually four or more on each side (rarely three or only two or none). Cartilaginous ring wanting. Polian vessel usually single, rarely more than one. Stone-canal single, unbranched. Sense-organs never in form of pigment-eyes, but occur as minute cups, probably olfactory, on inner face of stalk of tentacles. Stock of anchors finely toothed, but not branched; arms usually with upwardly or outwardly projecting teeth on the outer edge; vertex smooth. Anchor-plates oval or somewhat elongated, with large central hole, surrounded by six other large holes, usually more or less dentate, and two large and several small smooth holes at the narrow posterior end, but without any arched bow crossing the outer surface; at the broad end there are often additional dentate holes; in *ooplax* the plates are often quite asymmetrical and all the holes more or less smooth.

Just why Östergren elected to apply Eschscholtz's name to this group of Synaptids it is difficult to understand. It is clear that Eschscholtz himself intended the large 15-tentacled, oriental forms to be placed here, while he refers Müller's *inhærens* to the genus Chiridota. (Of course this is a self-contradiction, as *inhærens* does not have digitate tentacles, the one distinguishing character which he gives for Chiridota.) It is necessary, therefore, even if it is disagreeable, to change Östergren's selection and use Verrill's ('67) name Leptosynapta for these forms of which *inhærens* is typical. The species *S. bachei* Ayres is an absolute *nomen nudum,* without a word of description or explanation. It is possibly a Chiridota.

The genus as now restricted includes nine species, of moderate or small size, all but one of which occur in the north temperate zone, though some of them range southward into the warmer seas of the tropics, while others occur in the cold waters of the far north. They live in sand or mud, usually burrowing like worms and feeding on the organic matter which they pick out of the dirt with their tentacles; but they are continually taking in grains of sand and other indigestible stuff with the food, so that the alimentary canal is usually filled with such material. They are sluggish in their movements and apparently come out of their burrows only on rare occasions, though they are sometimes found (particularly *roseola*) under rocks and in similar situations.

Key to the Species of Leptosynapta.

A.—Tentacles 12; length usually over 50 mm.

B.—Radial pieces of calcareous ring perforated for passage of the nerves (pl. v, fig. 14).

C.—Anchors and plates of variable size, but of only one kind.

D.—Anchors usually under 250 μ, never over 300 μ; plates more or less oval, with smooth margins and not more than 7 or 8 dentate holes.

E.—Anchor-plates more or less symmetrical, with distinctly dentate holes, more than 125 μ long in posterior part of body and much more than half as long as anchors there.

Anchor-arms usually with 4 or more teeth; calcareous particles in longitudinal muscles, oval or dumb-bell-shaped; radial pieces of calcareous ring decidedly concave on the posterior edge; polian vessel usually single .... INHÆRENS

Anchor-arms with only 2 or 3 small teeth; calcareous particles in longitudinal muscles C- or doughnut-shaped; radial pieces of calcareous ring scarcely concave posteriorly; polian vessels 3-7. DOLABRIFERA

EE.—Anchor-plates more or less unsymmetrical, with the holes smooth or with few teeth, less than 125 μ long in posterior part of body and only a little more than half as long as anchors there...... OOPLAX

DD.—Anchors usually over 250 μ and often over 500 μ; plates elongated, with more or less dentate margin and often more than 8 dentate holes.

Anchors not often over 500 μ; plates with 7 to 30 holes.. GALLIENNII

Anchors 500 to 800 μ; plates usually with 25 to 40 holes. MACRANKYRA

CC.—Anchors and plates of two quite distinct kinds (pl. v; figs. 1-4); polian vessels 2-5 .... ACANTHIA

BB.—Radial pieces of calcareous ring not perforated, but simply notched, for the passage of the nerves (pl. v, fig. 16)................................... ROSEOLA

AA.—Tentacles 10; length 3-50 mm.

Tentacles with digits; length 30-50 mm. ....DECARIA

Tentacles without digits; length 3-5 mm. ....MINUTA

LEPTOSYNAPTA INHÆRENS.

PLATE V, FIGS. 14, 15, 18, AND 20.

Holothuria inhærens O. F. Müller, 1776, p. 232; 1788, p. 35, pl. XXXI.
Chiridota pinnata Grube, 1840, p. 41.
Synapta inhærens Rathke, 1843.
Synapta duvernæa Quatrefages, 1842, p. 19, pls. II-V.
Holothuria flava Rathke, 1843, p. 138.
Synapta henslowana Gray, 1848, p. 12.
Synapta tenuis Ayres, 1851, p. 11.
Synapta girardii Pourtales, 1851, p. 14.
Synapta pellucida Ayres, 1852*b*, p. 214.
Synapta duvernea Held, 1857, anchor and plate, pl. II, fig. 1.
Synapta ayresii Selenka, 1867, p. 362.
Synapta gracilis Selenka, 1867, p. 363.
Synapta albicans Selenka, 1867, p. 363.
Synapta bifaria Semper, 1868, p. 14.
Leptosynapta tenuis Verrill, 1867, p. 325.
Leptosynapta inhærens Verrill, 1867, p. 325.
Leptosynapta girardii Verrill, 1874*a*, pp. 361 and 716.
Synapta inhærens Östergren, 1898*b*.
Synapta inhærens Clark, 1899*b*, pls. 10 and 11.
? *Synapta albicans* Clark, 1901*b*.
Synapta inhærens Clark, 1901*a*.

LENGTH.—100–300 mm., with diameter of 5–10 mm.

COLOR.—White to buffy yellow, with more or less red pigment modifying this ground color; most American specimens have little or no pigment and are thus nearly pure white, while most European specimens are decidedly red. According to Östergren (:05), they are always red, but the majority of those I have from Naples are as white as those from the coast of Massachusetts. Occasionally American specimens are colored exactly like Müller's (1788) figure. Pacific Coast specimens, so far as known, are nearly white.

DISTRIBUTION.—Reported from a great number of stations along the coasts of both Europe and North America; also from the Red Sea and the mouth of the Congo. These last two stations are almost certainly mistakes, and Östergren (:03) considers the report of its occurrence north of the Arctic Circle as equally unreliable. It undoubtedly occurs on the coasts of Norway, Denmark, Great Britain, France, and Italy, as there are abundant reliable records. On the American Atlantic coast it ranges from Maine to South Carolina, and also occurs at the Bermuda Islands, while on the Pacific coast it has been found at Puget Sound, Washington, and Mendocino, Pacific Grove, and Point Loma, Cal. Its occurrence on the Alaskan coast is still open to doubt. It seems very probable that it is a circumpolar species, ranging southward on the European and American coasts to subtropical waters. It has not, however, been reported from any part of the Asiatic coast, and it has yet to be taken in Bering Sea and the North Pacific.

Remarks.—This species is apparently the central one of the genus from which the others appear to have been derived, and it is, as one would therefore suppose, the most variable of all. Besides the characters already given, it may be added that the number of digits varies (probably with age) from 3–10 on each side, but is usually 5–7, and the terminal one is the longest, with the adjoining ones nearly as long; the sense-cups vary from 2–14 on each tentacle, but there are usually about 8; there is no distinct stomach nor is the intestine conspicuously looped; the ciliated funnels are numerous and of two distinct sizes; reproductive organs long and branched. (For an excellent detailed account of the specific characters, see Östergren :05*a*; for notes on habits, and physiology, see Clark, '99*b*.) Whether the common white Synapta of the New England coast is really distinct from the European species is regarded by Östergren (:05) as an open question, but it is exceedingly difficult to find any differences of importance; those mentioned by Östergren are certainly trivial. A careful comparison between individuals from Norway (for which beautiful specimens my thanks are due Dr. Östergren), Naples, California, and Woods Hole has failed to bring out a single constant difference, although I am not sure that the Pacific Coast form may not prove distinct, when living specimens are studied. The anchors and plates are noticeably smaller in these specimens than in those from Norway, but the Woods Hole and Naples specimens are intermediate and no real line of division can be drawn. Too much emphasis must not be placed on either dimensions or proportions of the calcareous particles, not only because they vary so much, even in specimens from a single locality, but because in measuring such minute objects the "personal equation" is a factor not to be ignored. Östergren suggests that the American form may be regarded as a distinct variety or subspecies, if not a fully accredited species; but I fail to see what would be gained by such a course, and, moreover, I can find no other ground than locality by which to distinguish it. For the present, therefore, I must believe that *inhærens* is (or has been) a circumpolar species and extends its range southward on both coasts of America as well as in Europe.

LEPTOSYNAPTA DOLABRIFERA.

Synapta dolabrifera Stimpson, 1856, p. 386.

Length.—50–90 mm., with a diameter of about 4 mm.

Color.—Dirty yellowish.

Distribution.—Port Jackson, New South Wales.

Remarks.—Besides the characters given above in the key, there are several others which aid in the recognition of this species. Stimpson's description is accurate, but not very complete, and as nothing further has ever been published, the following notes will be of value: Of the six specimens examined, four had

12 and two had 13 tentacles; each tentacle has 6–10 digits on each side and carries 5–15 sense-cups on its inner face. The stone-canal is single, but there are 3–7 polian vessels. The calcareous ring is narrow and the pieces of which it is composed are scarcely concave on their posterior edges. The anchors are about 230 μ in length and the plates are about 170 by 115 μ; those in the posterior part of the body do not seem to differ in size from those anteriorly. The anchor-arms have only 2 or 3 small teeth and the stock, although convex on its outer edges, is not bent in or curved at the ends as in *inhærens;* it is also less finely toothed, usually having only 12–20 rather coarse teeth. The particles in the longitudinal muscles are very similar to those in *roseola,* but the rods in the tentacles are longer and more slender than in that species, slightly curved and a little enlarged and notched. There can be no question that this species is more closely related to *inhærens* than to any other member of the genus, which, in view of its geographical isolation, is rather remarkable. It differs from *ooplax,* its nearest geographical neighbor, far more than it does from *inhærens.* As yet it is known only from Port Jackson, but it doubtless occurs elsewhere on the Australian coast. It will be interesting to learn its exact geographical range. Stimpson says it occurs "under stones, near low-water mark."

LEPTOSYNAPTA OOPLAX.

Synapta ooplax von Marenzeller, 1881, p. 122. Calcareous parts, pl. IV, fig. 1.

LENGTH.—70–150 mm., with diameter of about 5 mm.

COLOR.—Clear reddish, rosy, or even white.

DISTRIBUTION.—Reported from Japan (v. Marenzeller); Lifu, Loyalty Islands (Bedford); Dutch East Indies, 103 m. (Sluiter); Funafuti (Bedford); Kokotoni, E. Africa (Lampert); Zanzibar (Ludwig). Apparently a widely distributed Indo-Pacific species; the *inhærens* reported from the Red Sea is very likely *ooplax.*

REMARKS.—This Synapta is closely related to *inhærens* and is clearly the Asiatic representative of that species. In addition to the characters already given, however, there are several other points in which it differs. The plates are wider at the posterior end and contain more numerous and irregularly arranged holes, while the seven large holes of the free end have few teeth along the margin or may even be entirely smooth. Bedford ('99*a*) describes the specimens from the Loyalty Islands as a new variety (*lævis*), but as the characters he assigns (smooth, or nearly smooth, margins to all the holes in the plate, biscuit-shaped granules confined to ambulacra and 1–4 polian vessels) are too variable to be of much weight, there is little advantage in giving the form a name. The specimens from Funafuti, in the National Museum, correspond well to Bedford's description of *lævis,* but strangely enough he does not refer *his* specimens from Funafuti to that form. Japanese specimens have 9–11 digits on each tentacle, while those from Zanzibar have from 9 to 13. The latter are interesting further as the host of the remarkable parasitic bivalve, *Entovalva mirabilis.* Lampert's ('96) statement that the difference in proportions between the anchors and plates posteriorly and anteriorly is not due to a difference in the anchors, as v. Marenzeller ('81) says, but to a remarkable difference in the plates, is borne out by my measurements. The following table gives the figures involved, measurements in microns:

Observer.	Anteriorly.		Posteriorly.	
	Length of Anchor.	Plate.	Anchor.	Plate.
v. Marenzeller -	119	109	200	109
Lampert ------	124–140	110–115	120–140	60–90
Clark ---------	157	114	157	86

Leptosynapta galliennii.

Synapta galliennii Herapath, 1865, p. 5.
Synapta sarniensis Herapath, 1865, p. 5.
Synapta saruiensis Herapath, 1865, pl. 1.
Synapta sarniensis Lankester, 1868, p. 53.
Synapta bergensis Östergren, 1905*a*, p. cxxxii. Calcareous particles, fig. 1*a*.

Length.—100–300 mm., but usually about 150.

Color.—Reddish, similar to that of *inhærens.*

Distribution.—Reported only from Guernsey (Herapath, Lankester), Outer Hebrides (McIntosh) and Norway, Sweden, and the Faroes (Östergen). Probably occurs along the entire coast of northern Europe with its outlying islands.

Remarks.—This Synapta is certainly closely related to *inhærens* and is intermediate between that species and the following. Whether there is an unbroken series between the true *inhærens* and the Mediterranean *macrankyra* is still uncertain, but for the present we may conveniently recognize the three species. Östergren (:05*a*) considers the Norwegian form, which he calls *bergensis,* as quite distinct from Herapath's species, but the differences which he mentions (15–17 digits instead of 13, terminal digits no longer than the others, skin thicker and redder, slightly larger anchors, margin of plate not so continuously dentate, more holes in most of the plates) are so trivial, so very variable, and so commonly correlated with the age of the individual, that, when we consider he had only a single specimen of *galliennii* for comparison and that a very large one (250 mm.), we are not justified in regarding the two forms as specifically distinct; and this decision is confirmed by the fact that in the other points which Östergren emphasizes as distinguishing *bergensis* from *inhærens* (a muscular stomach and a decidedly looped intestine) it agrees entirely with *galliennii.* The latter has been quite unanimously regarded as a synonym of *inhærens,* but Östergren makes its right to be recognized quite clear, and the reader is referred to his admirable paper (:05*a*) for a full, clear, and interesting account of this Synapta.

LEPTOSYNAPTA MACRANKYRA.

Synapta hispida Semon, 1887, p. 272 (non Heller, 1868, p. 71).
Synapta macrankyra Ludwig, 1898*a*, p. 2.

LENGTH.—250–350 mm.

COLOR.—Reddish, deeper than that of *inhærens* (?).

DISTRIBUTION.—Mediterranean Sea, near Naples (Semon, Ludwig).

REMARKS.—Very little is known of this species, and it may still be regarded as an open question whether it is really distinct from the preceding. It is entirely conceivable that under specially favorable conditions, in some individuals of *inhærens,* the anchors and plates might increase in size to that which we find in *galliennii* and even in *macrankyra,* and in that case the increased number of perforations in the plate would be a natural accompaniment. The rarity of *macrankyra* would thus be easily accounted for. But at present we entirely lack the necessary evidence to determine such a point.

LEPTOSYNAPTA ACANTHIA.

PLATE V, FIGS. 1-13 AND 22.

Synapta acanthia Clark, 1899*a*, p. 126, pl. IV.

LENGTH.—250–350 mm., with a diameter of about 12 mm.

COLOR.—Very pale reddish to nearly pure white.

DISTRIBUTION.—Bermuda Islands (Clark).

REMARKS.—Nothing further has been recorded of this species since the original description, except a few field notes (Clark, :01*c*). It is apparently an isolated offshoot from *inhærens.* Östergren's (:05*a*) point in regard to the probable error in the original description of the alimentary canal is well taken. Careful examination of better material shows that the mesentery passes over from the mid-dorsal into the right ventral interradius as in *inhærens*; although a distinct stomach is present, it lies some distance back of the calcareous ring and not near it, as in *galliennii*; *acanthia* further resembles *inhærens* in the absence of any loop in the intestine. Besides the characters already mentioned, this species is notable for the large number (25–30) of sensory cups on each tentacle, and the numerous C-shaped miliary granules distributed over the entire body.

LEPTOSYNAPTA ROSEOLA.

PLATE V, FIGS. 16, 17, 19, 21.

Leptosynapta roseola Verrill, 1874*a*, p. 422.
Synapta roseola Théel, 1886*a*, p. 25.
Synapta roseola Clark, 1899*b*, p. 24; pls. 10 and 11.

LENGTH.—Rarely exceeding 100 mm.

COLOR.—Rosy red, sometimes yellowish, sometimes almost brick red.

DISTRIBUTION.—Southern coasts of Massachusetts, Rhode Island, and Connecticut (Verrill); Bermuda Islands (Clark).

REMARKS.—Although often found on the Massachusetts coast with *inhærens*, this species seems to be a more southern form and is particularly abundant in Bermuda, where *inhærens* seems to be rare. Unlike *inhærens*, it is commonly found under stones, and seems to burrow little in the sand. Besides the unique calcareous ring, the small size, slender body, soft thin skin, and few digits (5–9) serve to distinguish *roseola*, while there are also peculiarities in the ciliated funnels, the miliary granules, and the supporting rods of the tentacles.

LEPTOSYNAPTA DECARIA.

Synapta decaria Östergren, 1905*a*, p. CXLVI. Calcareous particles, fig. I B.

LENGTH.—30–50 mm., but diameter only 3.

COLOR.—Whitish.

DISTRIBUTION.—West coast of Scandinavia (Östergren).

REMARKS.—In spite of the presence of 2 or 3 polian vessels, it is not impossible that this is only the young of *inhærens*. There is a striking similarity in the calcareous particles and in the tentacles, the difference in number of digits being simply a matter of age. On the other hand, a comparison of Östergren's description with the remarks on p. 24, referring to fragments of synaptas from Alaska, suggests the possibility that *they* are *decaria*, and that it is a circumpolar species. In view of the very small amount of material available,. however, the matter cannot be fully determined at present.

LEPTOSYNAPTA MINUTA.

Synapta minuta Becher, 1906, pp. 505-509, with text-figures.

LENGTH.—3–5 mm.

COLOR.—Practically wanting.

DISTRIBUTION.—Reported only from the North Sea (Becher).

REMARKS.—This curious little synaptid is notable for several reasons, chief among which is its being viviparous. The anchors and plates show some peculiarities and "buttons" are said to be also present.

LABIDOPLAX Östergren, 1898b.

Tentacles digitate, 11 or 12, with 3 or 4 digits. Cartilaginous ring wanting. Polian vessel usually single. Stone-canal single. Stock of anchor toothed but not branched; arms usually toothed; vertex smooth. Anchor-plates with posterior end abruptly narrowed (forming a sort of handle), the bow crossing its outer surface rudimentary or wanting.

This small group of synaptids stands midway between the preceding and the following genus and doubtless indicates the line of connection between the two. They are confined to the Old World, but range from the Arctic Ocean to the tropics. As will be seen from the following artificial key, the genus falls naturally into two sections, and it is by no means certain that the second of these would not be associated more naturally with Protankyra.

Key to the Species of Labidoplax.

A.—Anchor-plates with 7 large, more or less dentate holes in the free end, arranged as in Euapta or Synapta (plate v, fig. 23).
  Tentacles 11, with 3 digits.................................... BUSKII
  Tentacles 12, with 4 digits.................................... MEDIA
AA.—Anchor-plates with numerous, irregular, smooth holes (plate v, fig. 25); tentacles 12, with 4 digits.
  B.—Anchor-plates, even anteriorly, usually much longer than wide. *i. e.*, width less than .60 of length; width of anchor-arms from tip to tip less than .70 of length of anchor and usually under .55; sense-cups commonly present on inner face of tentacles.
    Anchors posteriorly 300-500 μ long: anchor-plates with numerous small holes near margin, especially at posterior end, not showing any special arrangement.................... DIGITATA
    Anchors posteriorly 150-300 μ; anchor-plates with few small marginal holes and about 8-10 large holes arranged in 3 or 4 transverse rows......DUBIA
  BB.—Anchor-plates, at least anteriorly, very wide, *i. e.*, width usually more than .70 of length; width of anchor-arms usually .70, sometimes over .80, of length of anchor; no sense-cups on tentacles.................... THOMSONII

Labidoplax buskii.

Plate V, Fig. 23.

Synapta buskii McIntosh, 1866, p. 612. Anchor and plate, fig. 6.
Synapta tenera Norman, 1864 (no description).
Labidoplax tenera Östergren, 1898*b*.
Labidoplax buskii Östergren. 1903.
Labidoplax buskii Östergren, 1905*a*. p. CLVI.

Length.—15–30 mm., with diameter about one-tenth as much.

Color.—Pale, transparent grayish, without pigment.

Distribution.—Reported from Outer Hebrides (McIntosh); British Isles (Norman); west coast of Sweden (Théel); and coast of Scandinavia, from Cat tegat to Porsanger Fjord, at depths of from 18–405 m. (Östergren). Apparently confined to the northern coasts of Europe.

Remarks.—This curious little synaptid is easily recognized by the unusual number and form of the tentacles, both of which peculiarities are remarkably constant. It has been often confused, nevertheless, with *Leptosynapta inhærens*, according to Östergren (:03), but usually occurs at greater depths and is commonly found on a clay bottom. For a full and admirable description, see Östergren (:05*a*).

LABIDOPLAX MEDIA.

Labidoplax media Östergren, 1905*a*, p. CLVIII. Calcareous particles, fig. II B.

Length.—30–50 mm.

Color.—Not given, but the skin is said to be "thin, transparent."

Distribution.—Bergen, Norway (Östergren).

Remarks.—The tentacles easily distinguish this species from the preceding and the anchor-plates from all other known synaptids. Nothing more is known of its anatomy or habits than is given by Östergren.

LABIDOPLAX DIGITATA.

Synapta digitata Montagne, 1815, p. 22; pl. IV, fig. 6.
Synapta digitata Woodward and Barrett, 1858. Calcareous particles, pl. XIV, figs. 1-17.
Holothuria inhærens Delle Chiaje, 1823, p. 124.
Chiridota chiaii Grube, 1840, p. 41.
Labidoplax digitata Östergren, 1898*b*.

Length.—250–350 mm., with the diameter when fully extended one-thirtieth to one-fortieth as much.

Color.—Yellowish or reddish white, more or less heavily pigmented with brick-red, especially on the dorsal side, which is often sharply in contrast with the lower surface.

Distribution.—Reported from numerous stations on the coasts of Great Britain, France, Spain, Italy, and Austria to depths of 618 m. (Herouard). Lampert ('89) refers a fragment from near the mouth of the Congo to this species, but admits the possibility of error. Probably confined to the coasts of western and southern Europe and perhaps northern Africa.

Remarks.—According to Semon ('87), this species is probably not strictly subterranean, but lives on the bottom, where its rather peculiar coloration is apparently protective. He says further that small individuals do not occur at Naples, although the auriculariæ are common enough. For further notes on habits and physiology, see his paper, and for a very detailed account of the development his later report ('88). Ludwig ('98*a*) says the anchors of this species are from 170 to 310 μ in length, while those which I have measured in the posterior part of specimens from Trieste are from 350 to 500 μ. Ludwig further calls attention to the remarkable "giant" anchors, 700–950 μ long, first figured by Woodward and Barrett ('58), with perfectly smooth arms, which occur in the dorsal interradii of this species. I was unable to find any in the specimens from Trieste, so that I am in doubt as to their value as a specific character.

LABIDOPLAX DUBIA.

PLATE V, FIGS. 25 AND 28.

Synapta dubia Semper, 1868, p. 10. Calcareous particles, pl. IV, fig. 11.
Synapta incerta Ludwig, 1874, p. 79. Calcareous particles, pl. VI, fig. 3.
Synapta incerta var. *variabilis* Théel, 1886*a*, p. 14. Anchor-plates, pl. I, fig. 5.
Labidoplax dubia Östergren, 1898*b*.
Labidoplax incerta Östergren, 1898*b*.
Labidoplax incerta Sluiter, 1901.

LENGTH.—60–100 mm. Most of the reported specimens are fragments.

COLOR.—White, dirty-whitish, or reddish, or with a violet tinge; tentacles yellowish.

DISTRIBUTION.—Reported from Bohol and Zebu, Philippines (Semper); Banka, D. E. I. (Ludwig); Japan (Théel); and Dutch East Indies (Sluiter). Apparently a rare tropical and subtropical East Indian species.

REMARKS.—Owing to the small amount and poor condition of the material examined, there is room for difference of opinion as to the validity of Ludwig's ('74) *incerta*, but the differences between his specimen and Semper's ('68) are so slight (miliary granules) or are based on factors so variable in this genus (serration of anchor arms) that I can see no sufficient reason for separating the two, especially as Théel ('86*a*) thinks them probably identical. The specimens from Japan in the National Museum show conclusively that this is a valid species and convince me that *dubia* and *incerta* are identical. I think it possible that Semper ('68) mistook the first beginning of anchor-plates for miliary granules, but even if not, the differences between his figures and Ludwig's ('74) are not important. In the Japanese specimens the miliary granules are very scarce and are usually straight rods, but sometimes resemble Ludwig's figure. The anchor-arms are commonly smooth, but often have one, two, or three teeth, which are sometimes minute and sometimes conspicuous. The plates are commonly quite symmetrical, with three small holes near the tip, the middle one largest, and three, of about the same size, at the posterior end; between these two series are either two large, elongated holes side by side, or one long one and the other divided transversely into two, or both are divided transversely, making a group of four holes. The anchors measured 200–265 μ long, with the arms 80–115 μ across, while the plates are 180–235 μ long and 75–110 μ wide. There are 12 tentacles in each specimen, each with four digits; the presence or absence of a fifth rudimentary terminal digit in this species and its near allies, and in Protankyra, seems to me to be a character depending on the state of contraction and the opinion of the observer. Semper ('68) distinctly says there are no sense-cups on the tentacles, but he only had a single imperfect specimen. In the Japanese specimens there are five or six sense-cups on each tentacle in all of the specimens. They are small and might perhaps be overlooked.

LABIDOPLAX THOMSONII.

Synapta thomsonii Herapath, 1865, p. 6.
Synapta digitata from Antrim, Herapath, 1865, pl. I, fig. 5.
Synapta hispida Heller, 1868, p. 71.
Synapta digitata (partim) v. Marenzeller, 1893, p. 17. Anchor and plate, pl. II, fig. 6.
Synapta thomsonii Ludwig, 1898*a*.
Synapta thomsonii Östergren, 1898*b*.
"*Synapta johnstonii* Herapath," Lo Bianco, 1899, p. 476.

LENGTH.—250–350 mm., with diameter, when fully extended, of about one-fortieth as much.

COLOR.—Like *digitata*.

DISTRIBUTION.—Reported from Carrickfergus, North Ireland (Herapath); Concarneau, Brittany (Barrois); Naples (Ludwig); Adriatic Sea (v. Marenzeller). Apparently the range coincides with that of *digitata*.

REMARKS.—Although vouched for by such observers as Herapath and Ludwig, the status of this species is not beyond question. Marenzeller considered his specimens merely as a form of *digitata*. Five specimens which I received from Naples in 1898 as *digitata* all lack the sensory cups and the giant anchors, while the anchor-plates are similar to those described by Ludwig for *thomsonii*. It seems remarkable, however, that all of these specimens should belong to this species, when they were probably selected at random. Certainly further study of *digitata* and this, its nearest ally, is greatly needed.

PROTANKYRA Östergren, 1898*b*.

Tentacles digitate, 10–12, rarely 13 or 14. Digits two (rarely one only) on each side. Cartilaginous ring wanting. Polian vessels 2–10, or rarely only one. Stone-canal usually single, but rarely there are several. Stock of anchors more or less branched or only finely toothed; arms usually serrate; vertex without knobs. Anchor-plates without a handle, with numerous irregular perforations and with a more or less imperfectly developed bow across outer surface of posterior end; plates and perforations also, with either smooth or dentate margins.

The Synaptids of this, the largest genus of the family, are of medium or small size and dull color. With few exceptions, they occur only in tropical or subtropical waters and are specially characteristic of the Indo-Pacific region, where more than three-fourths of them occur. In most cases only one or two individuals of a species are known, so that specific limits are very hard to determine, but those herein accepted seem to have characteristic calcareous deposits. While most of the species occur in shallow water (under 100 m.), seven of them are from depths of over 1,000 m., and all known synaptids from such great depths belong in this genus. Little is known of their habits, and even the appearance in life is unrecorded for the great majority. The following key is based of necessity upon the size and form of the calcareous particles. When it is realized, however, that we do not at present know how greatly these may vary, not only in the individuals of a species, but in different parts of one individual, skepticism as to the validity of some of these species is bound to arise, and this is increased by the knowledge that in several cases only fragments of the animal, whether anterior or posterior is uncertain, are known. The two New Zealand species described by Hutton ('72), *uncinata* and *inequalis,* are absolutely indeterminable (see Dendy, '97) and are therefore omitted.

KEY TO THE SPECIES OF PROTANKYRA.

A.—Tentacles 12; entirely marine.

B.—Anchors and plates all of one kind, though they may vary somewhat in size.

C.—Anchors not conspicuously asymmetrical.

D.—Anchor-plates more or less elongated and irregular in outline, with comparatively few (20-50) holes; these have smooth margins, and one or more of those near center of plate are conspicuously larger than the others, and are polygonal or elliptical in shape (plate V, fig. 26; plate IV, figs. 4 and 5).

E.—Stock of anchor not branched (plate IV, fig. 3); accessory calcareous bodies not in the form of elongated slender, straight, or bent rods.

F.—Plates more or less asymmetrical (plate v, fig. 26).

Accessory calcareous bodies in the form of small oval, notched or irregular short rods, perhaps sometimes wanting. CHALLENGERI

Accessory calcareous bodies in the form of large, irregular perforated plates .... BICORNIS

FF.—Plates nearly symmetrical, with a single pair of large elliptical holes at center and a number of smaller ones at each end (plate IV, figs. 4 and 5) .... DUODACTYLA

EE.—Stock of anchor branched (as in fig. 25, plate IV); accessory calcareous bodies long, slender rods, either straight or bent, often notched at the tip.................................. SLUITERI

DD.—Anchor-plates more or less oval or elliptical, usually with numerous (40-150) holes, but sometimes with only 20-50; these are more or less circular, are often dentate, and near center of plate are usually somewhat larger than near margin (plate IV, figs. 9 and 13).

E.—Anchors 400 μ or less in length.

F.—Anchors over 200 μ in length; stock a conspicuous undivided bar at right angles to shaft (plate v, fig. 29).

Accessory calcareous bodies small, oval or somewhat constricted particles .... VERRILLI

Accessory calcareous bodies, dichotomously divided and branched rods, which often become so complicated as to form perforated plates (plate v, fig. 30) ..... BIDENTATA

FF.—Anchors mostly under 200 μ; stock widened and irregularly divided (plate v, fig. 31); accessory calcareous bodies much as in *bidentata* .... AUTOPISTA

EE.—Anchors 500 μ or more in length; accessory calcareous bodies curved rods, or simple, short, oval, or somewhat constricted granules, or wholly wanting.

F.—Stock of anchor more or less branched, dichotomously or irregularly divided, often denticulate, but not finely serrulate (plate IV, fig. 12).

G.—Anchors very large, usually over 700 μ; accessory calcareous bodies present.

H.—Anchor-plates about as long as anchors, much longer than wide; at least the larger holes at center with dentate margins (plate IV, fig. 13).

Anchor-arms dentate, nearly half as long as anchor .... BRYCHIA

Anchor-arms without teeth, about one-third the length of anchor.................. SUSPECTA

HH.—Anchor-plates much shorter than anchors, three-fourths as wide as long or more.

I.—Accessory calcareous bodies, simple oval or ellipsoidal particles.

Holes at center of plate not much larger than others; stock of anchor not divided into a number of slender anastomosing branches. ACULEATA

Holes at center of plate much the largest; stock of anchor with slender anastomosing branches .... CONFERTA

II.—Accessory calcareous bodies, curved rods with ends often enlarged, and notched............ ERRATA

GG.—Anchors from 500-700 μ in length; no accessory calcareous bodies.

H.—Plates more or less concave, with about 100 holes (plate IV, fig. 9).

Anchor-arms distinctly serrate....... ABYSSICOLA

Anchor-arms without teeth............ PACIFICA

HH.—Plates flat, with less than 50 holes........ TRISTIS

FF.—Stock of anchor usually finely serrulate, often slightly notched or forked, but not at all branched or divided (plate v, fig. 32).

G.—Anchors about 600 μ in length.

Anchor-arms and holes of anchor-plates with many teeth. INSOLENS

Anchor-arms with 5 or 6 teeth and holes in plates with 1-3 teeth or none...................... BENEDENI

GG.—Anchors over 1 mm. long.

Plate abruptly contracted posteriorly and provided with very numerous, small, entire holes (plate v, fig. 33). RODEA

Plate not abruptly contracted: provided with holes of very unequal size .... DENTICULATA

CC.—Anchors conspicuously asymmetrical (plate IV, fig. 15; plate v, fig. 36).

D.—Accessory calcareous bodies in the form of perforated plates.

Accessory perforated plates normally with 4 dentate holes (plate v, fig. 35) .... ASYMMETRICA

Accessory perforated plates normally with 10 dentate holes (plate v, fig. 34) .... LUDWIGII

DD.—Accessory calcareous bodies in the form of small cruciform or branched rods (plate IV, fig. 16). Anchors grotesquely asymmetrical (fig. 15). PETERSI

BB.—Anchors and plates of two distinct sorts, differing especially in size; large anchors with serrate arms.

Large anchor-plates with comparatively few (less than 100) holes: these are rather large, polygonal, and smooth; small anchors with smooth arms: accessory calcareous bodies, small cruciform or branched rods. PSEUDO-DIGITATA

Large anchor-plates with numerous (150 or more) holes; these are small, circular, and dentate; small anchors with serrate arms; accessory calcareous bodies, minute oval granules.......................... BANKENSIS

AA.—Tentacles 10; brackish water.. SIMILIS

PROTANKYRA CHALLENGERI.

PLATE V, FIG. 26.

Synapta challengeri Théel, 1886*a*, p. 14. Calcareous particles, pl. I, fig. 4.
Protankyra challengeri Östergren, 1898*b*.
Protankyra challengeri var. *Sibogæ* Sluiter, 1901, p. 131; pl. III, fig. 5.
Protankyra timida Koehler and Vaney, 1905, p. 108. Calcareous particles, pl. XV, figs. 33-35.
Protankyra albatrossi Fisher, 1907, p. 728. Calcareous particles, pl. LXXXI, figs. 1, 1*a*, and pl. LXXXII, figs. 4, 4*a–c*.

LENGTH.—80–100 mm.

COLOR.—Reddish, yellowish or whitish, sometimes with a lilac tinge.

DISTRIBUTION.—Reported from near the Fiji Islands, 252 m. (Théel); from near Aru, Arafura Sea, 1,788 m. (Sluiter); near Andaman Islands, 1,010 and 1,170 m. (Koehler and Vaney); Hawaiian Islands, 257–1,586 m. (Fisher).

REMARKS.—The anchor-plates ally this species to the preceding genus, with which it is a sort of connecting link. Sluiter's specimens were so nearly like Théel's that the slight differences in color, anchor-plates, and abundance of miliary granules are not enough to warrant our regarding the form as a distinct variety; neither is the difference in the depths at which they were taken sufficient to affect their identify; nor can the slight differences mentioned by Koehler and Vaney (:05) as distinguishing *timida,* and by Fisher (:07) as distinguishing *albatrossi,* warrant our regarding those as distinct species. The anchors are from 240–350 μ in length and their plates from 180–270 μ. There are two polian vessels and the usual single stone-canal, and in Fisher's (:07) specimens there were sense-cups on the tentacles.

PROTANKYRA BICORNIS.

Protankyra bicornis Sluiter, 1901, p. 131. Calcareous particles, pl. x. fig. 15.

LENGTH.—115 mm., with diameter about 5.

COLOR.—Unrecorded.

DISTRIBUTION.—Reported from near Timor, 828 m. (Sluiter).

REMARKS.—This is a very notable species, unique not only in the remarkable perforated plates, but in the presence of only a single digit on each side of the tentacle, and of four or five stone-canals, while there is only one polian vessel. The anchors are comparatively infrequent, about 330 μ long, and their plates are only 245 μ long and about half as broad. The accessory plates are much more numerous and are sometimes 350 μ in diameter; their perforations are circular and entire. On the whole, *bicornis* is one of the most interesting holothurians discovered by the "Siboga."

PROTANKYRA DUODACTYLA.

PLATE IV, FIGS. 1-7.

Protankyra duodactyla Clark (antea, page 26).

LENGTH.—60 mm., with diameter about 8.

COLORS.—Clear deep gray.

DISTRIBUTION.—Reported from off the coast of Washington in 1,000 m., and from near Unalaska, Aleutian Islands, in 1,777 m. (Clark).

REMARKS.—This species is related to the preceding in the presence of only a single pair of digits on each tentacle, but there are no accessory calcareous bodies; there are, however, irregular branched and perforated rods in the tentacles. The anchors are 300–360 μ and the plates about 320 μ in length, but few of the latter are complete and only rarely is the bow present. There are two polian vessels and a single stone-canal.

PROTANKYRA SLUITERI.

PLATE V, FIG. 27.

Protankyra sibogæ Sluiter, 1901, p. 132. Calcareous particles, pl. x. fig. 16.
Protankyra sluiteri Fisher, 1907, p. 729.

LENGTH.—More than 110 mm.

COLOR.—Unrecorded, but the skin is "thin" and "transparent."

Distribution.—Reported from north of Sumbawa, East Indies, 794 m. (Sluiter).

Remarks.—This is another of the "Siboga's" interesting discoveries, unique in the form of the accessory calcareous bodies, in the presence of teeth on the shaft of the anchor, and also, if Sluiter's figure is correctly drawn, in the direction of the teeth towards, instead of away from, the tips of the arms. As the only specimen was a fragment, nothing is known of the internal anatomy. Fisher's change of name for this species seems to be necessary.

Protankyra verrilli.

Plate V, Fig. 29.

Synapta verrilli Théel, 1886*a*, p. 12. Calcareous particles, pl. i, fig. 1.
Protankyra verrilli Östergren, 1898*b*.

Length.—About 23 mm.

Color.—Yellowish white (in alcohol).

Distribution.—Reported from near Cape York, Australia, 14 m. (Théel).

Remarks.—The simple calcareous particles is the principal character to distinguish this species from the next; but the small size, pale color, and tendency of the anchors to be asymmetrical are other differences. There were four polian vessels and a single stone-canal in the type.

Protankyra bidentata.

Plate V, Fig. 30.

Synapta bidentata Woodward and Barrett, 1858, p. 365. Calcareous particles, pl. xiv, figs. 23-25.
Synapta molesta Semper, 1868, p. 9. Calcareous particles, pl. iv, fig. 13.
Synapta distincta v. Marenzeller, 1881, p. 123. Calcareous particles, pl. iv, fig. 2.
Protankyra bidentata Östergren, 1898*b*.
Protankyra molesta Östergren, 1898*b*.
Protankyra distincta Östergren, 1898*b*.

Length.—30–100 mm.; diameter nearly one-fourth as much, according to Woodward and Barrett, but their specimen must have been greatly contracted.

Color.—Reddish gray, reddish violet, or clear reddish; according to Woodward and Barrett, their preserved specimen was "devoid of color."

Distribution.—Reported from China (Woodward and Barrett); Bohol, Philippines (Semper); Japan (v. Marenzeller. Théel); and Amoy (Ludwig).

Remarks.—Lampert ('85) is probably correct in identifying *molesta* Semper with *bidentata* Woodward and Barrett, but why he should have deliberately ignored the latter name, which has ten years' precedence and is accompanied by a good description and excellent figures, it is hard to see. The differences between *bidentata* and *distincta* are so slight and the calcareous particles of the latter so variable (see Théel, '86), that it is hard to believe they are not identical, especially since their geographical distribution is the same. The type specimen of *distincta* is a fragment, and all of Théel's specimens were also incomplete. Semper says there are four polian vessels and one stone canal.

PROTANKYRA AUTOPISTA.

PLATE V, FIG. 31.

Synapta autopista v. Marenzeller, 1881, p. 123. Calcareous particles, pl. IV, fig. 3.
Protankyra autopista Östergren, 1898*b*.

LENGTH.—More than 20 mm.; diameter of only known fragment, 6 mm.

COLOR.—Reddish brown.

DISTRIBUTION.—Reported from Miya Bay, Japan (v. Marenzeller).

REMARKS.—The very small size of the anchors and the peculiar shape of the stock easily distinguish this species, and yet it may be that the type and only known specimen is simply the anterior part of the body of a peculiar individual of the preceding species.

PROTANKYRA BRYCHIA.

PLATE IV, FIGS. 12-14.

Synapta brychia Verrill, 1885*b*, p. 539.
Protankyra brychia Östergren, 1898*b*.

LENGTH.—160 mm.; diameter about one-sixteenth as much.

COLOR.—Purplish brown or gray (in alcohol).

DISTRIBUTION.—Off Cape Hatteras, 1,688 m. (Verrill).

REMARKS.—The very large anchors and plates, a millimeter or more in length, are arranged in approximately three longitudinal rows in each interradius. Verrill says the anchor-arms are smooth; but that is not the case in the fully-developed anchors, which have about six teeth on each arm. There are no accessory calcareous bodies in the skin. There are at least two polian vessels and one stone-canal. The tentacles are unknown.

PROTANKYRA SUSPECTA.

Protankyra suspecta Sluiter, 1901, p. 132. Calcareous particles, pl. X, fig. 14.

LENGTH.—More than 70 mm.; only a fragment known.

COLOR.—Not recorded.

DISTRIBUTION.—Buton Straits, D. E. I., 148 m. (Sluiter).

REMARKS.—This is another of the discoveries made by the "Siboga," and also, unfortunately, another of the species known from only a slight, headless fragment. Although related to the preceding species, the differences are obvious.

PROTANKYRA ACULEATA.

Synapta aculeata Théel, 1886*a*, p. 13. Calcareous particles, pl. I, fig. 3.
Protankyra aculeata Östergren, 1898*b*.

LENGTH.—More than 65 mm.; only fragments known.

COLOR.—Light brownish or dirty white.

DISTRIBUTION.—Coast of Japan, 621 meters (Théel).

REMARKS.—This interesting species has the anchors 1.1 mm. long and the plates only about two-thirds as much. The anchors vary greatly in shape and sometimes even have flukes at both ends. In the type specimen the miliary granules occurred in a double row in each radius and were of a simple oval form.

PROTANKYRA CONFERTA.

Protankyra conferta Koehler and Vaney, 1905, p. 105. Calcareous particles, pl. XV, figs. 26-29.

LENGTH.—More than 72 mm.; only fragments known.

COLOR.—Brownish.

DISTRIBUTION.—Recorded from near Ceylon, 1,450 m., and off Masulipatam, Madras, 1,220 m. (Koehler and Vaney).

REMARKS.—This is one of the deep-sea species taken by the "Investigator," and regarding which we know all too little. The anchors are strikingly like those of *brychia* except in the length of the arms.

PROTANKYRA ERRATA.

Protankyra errata Koehler and Vaney, 1905, p. 106. Calcareous particles, pl. XV, figs. 14-16.
Protankyra inflexa Koehler and Vaney, 1905, p. 109. Calcareous particles, pl. XV, figs. 30-32.
"*Ankyroderma marenzelleri* Théel" Walsh, 1891.

LENGTH.—32–110 mm. and more; diameter about one-sixteenth as much.

COLOR.—Not recorded.

DISTRIBUTION.—Reported from near Andaman Islands, 234–270 m., and from Gulf of Bengal, 738–864 m. (Koehler and Vaney).

REMARKS.—The characters distinguishing *inflexa* from *errata* are too slight to justify us in keeping them separate, and it is probable that both are forms of *aculeata*, which is apparently a very variable species. Koehler and Vaney are authority for saying this species is Walsh's *Ankyroderma marenzelleri*.

PROTANKYRA ABYSSICOLA.

PLATE IV, FIGS. 8-11.

Synapta abyssicola Théel, 1886*a*, p. 14. Calcareous particles, pl. I, fig. 11.
Protankyra abyssicola Östergren, 1898*b*.

LENGTH.—65 mm.; diameter about 5.

COLOR.—Dark yellowish (in alcohol), with considerable reddish pigment at base of tentacles on inner side.

DISTRIBUTION.—Reported from tropical mid-Atlantic, 4,230 m. (Théel); off coast of New Jersey, 2,468 m. (Théel); off coast of Senegal, 3,200 m. (R. Perrier); Gulf of Mexico, 2,259 m. (Clark, antea). Probably distributed throughout the deeper parts of the Atlantic Ocean.

REMARKS.—One of the interesting discoveries of the "Challenger" was this abyssal Synaptid, which has since been taken several times. It is little modified by the great depth at which it lives and shows no special peculiarities of structure. There are seven polian vessels. Although miliary granules are wanting in the skin, the longitudinal muscles contain the usual oval particles, and there are nearly straight supporting rods in the tentacles.

PROTANKYRA PACIFICA.

Synapta abyssicola var. *pacifica* Ludwig, 1894, p. 174. Calcareous particles, pl. XVIII, figs. 13-19.

LENGTH.—85 mm.; diameter about 5.

COLOR.—Yellowish white or greenish gray.

DISTRIBUTION.—Reported only from outside the Gulf of Panama, in 3,000–3,189 m. (Ludwig).

REMARKS.—As the characters mentioned by Ludwig, which distinguished the Pacific from the Atlantic specimens, appear to be constant, there is no reason why this should not be regarded as a distinct species. The anchors and plates are really quite distinct in the two species, when compared side by side. The internal anatomy is not peculiar, but there were ten polian vessels in the specimen examined by Ludwig.

PROTANKYRA TRISTIS.

Protankyra tristis Koehler and Vaney, 1905, p. 107. Calcareous particles, pl. XV, figs. 17-18.

LENGTH.—More than 25 mm.

COLOR.—Grayish white.

DISTRIBUTION.—Off northern Madras, India, 2,358 m. (Koehler and Vaney).

REMARKS.—Although this species seems nearly related to *aculeata*, the small size of the anchors appears to distinguish it. Unfortunately, however, it is known only from an anterior fragment.

PROTANKYRA INSOLENS.

PLATE V, FIG. 32.

Synapta insolens Théel, 1886*a*, p. 13. Calcareous particles, pl. I, fig. 3.
Protankyra insolens Östergren, 1898*b*.

LENGTH.—40–110 mm.

COLOR.—Yellowish white.

DISTRIBUTION.—Reported from Torres Strait, 51 m. (Théel), and from near the Aru Islands, 57 m. (Sluiter).

REMARKS.—This "Challenger" species was found again by the "Siboga," and may be easily recognized by the anchors, which are 600–650 μ long and nearly 500 μ broad, with 12–18 teeth on each arm; the broadly oval plates with numerous dentate holes are also characteristic. There are five polian vessels and a single stone-canal.

PROTANKYRA BENEDENI.

Synapta benedeni Ludwig, 1881*a*, p. 55. Calcareous particles, pl. III, figs. 19-20.
Protankyra benedeni Östergren, 1898*b*.

LENGTH.—22–35 mm.; diameter about one-fourth as much; obviously the specimens were greatly contracted.

COLOR.—Whitish.

DISTRIBUTION.—Reported only from coast of Brazil (Ludwig).

REMARKS.—Ludwig says that the whole appearance of this Synaptid is like that of *Labidoplax digitata*, but the anchors and plates are so obviously different there is no doubt of the distinctness of the two species. The miliary granules are minute rods, rounded at the ends and constricted at the middle. There are six polian vessels and one stone-canal.

PROTANKYRA RODEA.

PLATE V, FIG. 33.

Synapta rodea Sluiter, 1890, p. 108. Calcareous particles, pl. I, figs. 10-14.
Protankyra rodea Östergren, 1898*b*.

LENGTH.—Up to 250 mm.

COLOR.—Carmine red.

DISTRIBUTION.—Reported from Bay of Batavia; Lombok; Timor; and near Madura, D. E. I., 330 m. (Sluiter).

REMARKS.—The huge anchors and plates, the minute miliary granules, and the conspicuous color make this species a notable one. There are two polian vessels. In his original description Sluiter says the calcareous ring consists of 17 pieces; it would be interesting to know whether further observations confirm this peculiar number. This species lives in mud near the coral reefs.

PROTANKYRA DENTICULATA.

Protankyra denticulata Koehler and Vaney, 1905, p. 105. Calcareous particles, pl. XV, figs. 36-39.

LENGTH.—Over 70 mm.; diameter, 12 mm.; known only from a fragment.

COLOR.—Brownish.

DISTRIBUTION.—Off Madras, India, 738 m. (Koehler and Vaney).

REMARKS.—Although allied to *rodea*, the shape of the plates easily distinguishes this species.

PROTANKYRA ASYMMETRICA.

PLATE V, FIGS. 35 AND 36.

Synapta asymmetrica Ludwig, 1874, p. 78. Calcareous particles, pl. VI, fig. 2.
Protankyra asymmetrica Östergren, 1898*b*.

LENGTH.—40 mm.

COLOR.—"Colorless."

DISTRIBUTION.—Reported from Banka, Sunda Islands (Ludwig, Théel); Saleyer and near Madura, 82 m., D. E. I. (Sluiter).

REMARKS.—The remarkable accessory calcareous plates with their four symmetrical holes and the peculiar anchors would seem to be sufficiently diagnostic, but Sluiter (:01, p. 129; Pl. X, fig. 13) describes and figures still other remarkable accessory calcareous bodies, in the form of curious double-headed rods. It is virtually certain that neither Ludwig nor Théel would have overlooked such calcareous bodies, so we are safe in assuming that they were not present in the specimens from Banka. The question naturally arises whether their presence in Sluiter's specimens would not indicate an important specific difference, but we must await further material before we attempt to decide the point. Ludwig's specimen had four polian vessels and one stone-canal. The anchors are 500 μ and their plates about 400 μ in length, and the accessory plates are about 50 μ in diameter.

PROTANKYRA LUDWIGII.

PLATE V, FIG. 34.

Synapta ludwigii Sluiter, 1890, p. 108. Calcareous particles, pl. I, figs. 4-9.
Protankyra ludwigii Östergren, 1898*b*.

LENGTH.—40 mm.

COLOR.—Ranges from carmine-red to "colorless," with a reddish tinge on the tentacles.

DISTRIBUTION.—Reported from Bay of Batavia; near Timor, 73 m.; and near Flores, 247 m. (Sluiter).

REMARKS.—While evidently allied to the preceding species, the very different accessory calcareous plates are an excellent mark of distinction. The anchors are about 500 μ in length and their plates only a little shorter; the accessory plates are about 80 μ in diameter. There are only two polian vessels and one stone-canal.

PROTANKYRA PETERSI.

PLATE IV, FIGS. 15 AND 16.

Synapta petersi Semper, 1868, p. 230. Calcareous particles, pl. XXXIX. fig. 12.
Protankyra petersi Östergren, 1898*b*.

LENGTH.—130 mm.

COLOR.—Clear reddish.

DISTRIBUTION.—Reported only from Amboina (Semper).

REMARKS.—The type specimen of this interesting species still remains unique. The curious grotesque anchors are accompanied by normal plates perforated with numerous smooth holes. Nothing is known of the habits, habitat, or anatomy.

PROTANKYRA PSEUDO-DIGITATA.

Synapta pseudo-digitata Semper, 1868, p. 9. Calcareous particles, pl. IV. fig. 12.
Synapta innominata Ludwig, 1874, p. 79. Calcareous particles, pl. VI. fig. 4.
Protankyra pseudo-digitata Östergren, 1898*b*.
Protankyra innominata Östergren, 1898*b*.

LENGTH.—60 mm.

COLOR.—Not recorded.

DISTRIBUTION.—Reported from Bohol, Philippines, 27 m. (Semper); Philippines (Ludwig); and Macasser (Sluiter).

REMARKS.—Ludwig himself expressed the opinion that his species was possibly identical with Semper's, and Lampert ('85) emphasizes the point. There is little doubt that such is the case. Ludwig had only a fragment 10 mm. long for his description and Semper had lost his only specimen when he wrote his description. He says it was similar to *Labidoplax digitata* in appearance, and Sluiter (:01) tells us there are 12 tentacles, each with four digits.

PROTANKYRA BANKENSIS.

Synapta bankensis Ludwig, 1874, p. 78. Calcareous particles, pl. VI. fig. 1.
Protankyra bankensis Ostergren, 1898*b*.

LENGTH.—More than 75 mm.; only fragments known.

COLOR.—Whitish with a reddish tinge.

DISTRIBUTION.—Reported only from Banka, Sunda Islands (Ludwig, Théel).

REMARKS.—This species is certainly nearly related to the preceding and it is an open question whether they are not identical. The differences in the calcareous particles are not beyond the range of individual diversity.

PROTANKYRA SIMILIS.

PLATE II, FIG. 2.

Synapta similis Semper, 1868, p. 10; pl. III, fig. 2. Calcareous particles, pl. IV, fig. 14.
Protankyra similis Östergren, 1898*b*.

LENGTH.—60–100 mm.

COLOR.—Semper gives the color as "transparent reddish," but the colored figure is pale fawn color with purplish tints.

DISTRIBUTION.—Reported only from Bohol, Philippines (Semper).

REMARKS.—The anchors and plates of this species are very much like the large ones of *P. pseudo-digitata*, and the accessory calcareous bodies also resemble those of that species. There is a single stone-canal and one or two polian vessels. Semper says this is one of the commonest and most interesting of the Philippine synaptids, living in the mud of brackish, mangrove swamps. It is well known to the natives and is called "dapan-dapan" in Visayan. It should perhaps be made the type of a distinct genus.

ANAPTA Semper, 1868.

Tentacles pinnate, 12. Digits 2–6 on each side and a long terminal one. Cartilaginous ring wanting. Polian vessels several (5–7). Stone-canal single. Anchors, perforated plates, wheels, and sigmoid bodies entirely wanting, the only calcareous particles in the skin being small oval or ellipsoidal bodies, and even these may be wanting.

This small group is closely related to Leptosynapta, but is of course easily distinguished therefrom py the entire absence of anchors. Östergren ('98*b*) considers that Sluiter's ('88) species *subtilis* is based on an abnormal individual, and he accordingly omits it; but since Sluiter especially states that the animal was examined when fresh, and consequently its peculiar characters cannot be due to decalcification, there is no reason to doubt its authenticity. Were it a regenerating synaptid, the calcareous ring would be normal and there would be some indications of calcareous bodies. Ludwig ('92*b*) proposes to include in Anapta, *Toxodora ferruginea* Verrill and *Scoliodota japonica* (v. Marenzeller), but the affinities of these two species seem to be so clearly with the Chiridotinæ that it would be very misleading to place them here.

KEY TO THE SPECIES OF ANAPTA.

A.—Calcareous particles present in the skin, longitudinal muscles or tentacles.
  Size large (up to 190 mm.); calcareous bodies scattered everywhere in the skin. GRACILIS
  Size small (under 100 mm.); calcareous bodies confined mainly to radii or longitudinal muscles and tentacles; those of latter often slightly branched at the end....FALLAX
AA.—Calcareous particles wanting.. SUBTILIS

ANAPTA GRACILIS.

PLATES II, FIG. 1; VII, FIGS. 19-23.

Anapta gracilis Semper, 1868, p. 17; pl. III, fig. 1. Calcareous particles, pl. IV, figs. 10-15.

LENGTH.—Up to 190 mm.

COLOR.—Pale purplish brown (rosy in the figure given), with numerous white papillæ.

DISTRIBUTION.—Reported only from Manila, Philippines (Semper).

REMARKS.—It seems strange that such a large and well-characterized species as this has not been met with since its original discovery, nearly 40 years ago. The calcareous ring, ciliated funnels, reproductive organs, and sensory-cups on the tentacles are all very much like those of a Leptosynapta.

ANAPTA FALLAX.

Anapta fallax Lampert, 1889*b*, p. 848.

LENGTH.—Up to 80 mm.

COLOR.—In life, flesh color, reddish anteriorly, the tentacles clear rose-red; in alcohol, yellowish brown or yellowish white.

DISTRIBUTION.—Reported from off Cape Blanco, Argentina, 114 m. (Lampert); Stanley Harbor, Falkland Islands, and southern coast of Tierra del Fuego (Ludwig); Punta Arenas, Susanna Cove and Calbuco, Chile (Ludwig); near Wellington Island, Chile (Clark, antea). The range apparently includes all the coasts of South America and neighboring islands south of 40° S., where the water is less than 125 m. deep.

REMARKS.—This is decidedly the best known of the three species, but it is somewhat difficult to see from the descriptions published any important difference between it and the preceding species. Ludwig's ('98*c*) statement, "wohl aber finden sich bei einzelnen, aber nicht bei allen, Exemplaren, in den Längsmuskeln, sehr zahlreiche, kurze, fast ovale Kalkstäbchen und in den Fühlern, * * *, kleine, klammerförmige * * * Kalkkörperchen," leaves one in doubt as to whether some of his specimens entirely lacked all calcareous particles or not, and if so, whether it might not have been due to acid alcohol. However, the geographical isolation of this species is so marked, it cannot be confused with any other, and it may well be considered distinct until its identity with *gracilis* is shown by a more careful study of the two species. According to Ludwig ('98*b*), *fallax* lives "am strande, im Sande."

ANAPTA SUBTILIS.

Anapta subtilis Sluiter, 1888, p. 211.

LENGTH.—Not given: "nur etwa dreimal so lang als breit."

COLOR.—Brownish, with numerous, clear yellowish white papillæ.

Distribution—Reported only from the Bay of Batavia (Sluiter).

Remarks.—Sluiter distinctly says that the absence of calcareous particles could not be due to impure alcohol, for he examined the animal when "ganz frisch." Östergren ('98*b*) expresses the opinion that this is only a regenerating individual of some synaptid, but that would not account for the entire lack of calcareous particles. Although the type specimen is still unique, it must be allowed to stand as a valid species until we have more light on the subject.

DACTYLAPTA, gen. nov.

(δάκτυλα, fingers, + ἅπτω, to fasten or bind; in reference to the tentacles and to correspond to Synapta, etc.)

Tentacles digitate, 12. Digits only four, two on each side, as in Protankyra. Calcareous particles, only short, curved rods, scattered in the skin.

This genus is instituted for the following unique species.

Dactylapta dubiosa.

Anapta (?) *dubiosa* Koehler and Vaney, 1905, p. 109. Calcareous particles and calcareous ring, pl. xv. figs, 11-12.

Length.—30 mm. and more; only an anterior fragment known.

Color.—Brown.

Distribution.—Reported only from Gulf of Bengal, 738 m. (Koehler and Vaney).

Remarks.—Although there is at least a possibility that this specimen, upon which a new species and genus is based, is only a diseased or abnormal Protankyra, we must for the present admit its validity. The form of the tentacles and of the calcareous deposits shows that the species bears the same relation to Protankyra that Anapta does to Leptosynapta, and it must therefore be placed in a distinct genus, so that this relationship may be emphasized.

RHABDOMOLGUS Keferstein, 1862.

Tentacles without digits, simply "am Rande leicht gelappt," 10. Cartilaginous ring wanting. Calcareous ring remarkably weak. Polian vessel one. Stone-canal one, but non-calcareous. Ciliated funnels wanting. Calcareous particles wholly wanting. Sexes separate (?).

The remarkable holothurian upon which Keferstein based this genus is in many ways much like a young synapta, and since no other zoölogist met with it, each succeeding writer has been more and more inclined to reject the genus and species altogether. Ludwig ('98*b*) places it in a foot-note and doubts its validity, and Östergren ('98*b*) ignores it entirely. It was therefore a matter of considerable surprise when Ludwig (:05) announced the rediscovery of Rhabdomolgus, and his complete report is awaited with keen interest.

RHABDOMOLGUS RUBER.

Rhabdomolgus ruber Keferstein, 1862, p. 34; pl. XI, fig. 30.

LENGTH.—5 mm. with diameter of .6 mm. (preserved material).

COLOR.—Bright red or carmine.

DISTRIBUTION.—Reported from St. Vaast (Keferstein) and "Sudspitze von Helgoland" (Ludwig).

REMARKS.—Keferstein secured only a single specimen, and that was floating near the surface, so that the question was raised as to whether the animal is pelagic. Ludwig (:05), however, has conclusively shown that under normal conditions it is a bottom form. It breeds in August; the sexes seem to be separate and the eggs are large.

CHIRIDOTINÆ Östergren, 1898*b*.

Tentacles with stalk short, becoming widened distally where it bears 3–10 digits on each side; the digit-bearing portion forms a sort of disc which can in many cases (perhaps always?) be drawn downward in contraction, more or less into the basal portion of the stalk; such tentacles may be called peltato-digitate. Cartilaginous ring wanting. Stone-canal single. Eye-spots wanting. Gustatory organs seldom present. Calcareous deposits either six-spoked wheels or conspicuous sigmoid or C-shaped bodies, or both, often accompanied by curved or straight rods or oval miliary granules; rarely minute curved rods only are present, or deposits are wholly wanting. Sexes apparently separate in many species, perhaps in all.

In the following keys and descriptions there are few terms which require any explanation, for nearly all are of the kind which carry their own meaning. The term "sigmoid" bodies is used for curved rods which bear a more or less close resemblance to that form of the Greek letter sigma, which is used at the termination of a word; that is to say, each end is curved, but in opposite directions, and very often in planes at right angles to each other. When rods are found in which the ends curve inward towards each other and in the same plane, they are called C-shaped or "bracket"-shaped particles. Both sigmoid and C-shaped rods may occur in the same individual.

KEY TO THE GENERA OF CHIRIDOTINÆ.

A.—No sigmoid bodies; wheels present, collected in little papillæ (plate VII, fig. 24).
  Tentacles 12 (10-14); ciliated funnels mostly single and scattered (plate VII, figs. 23, 28) .... CHIRIDOTA
  Tentacles 18 (16-20); ciliated funnels mostly single and scattered (plate VII, figs. 14) .... POLYCHEIRA
AA.—Sigmoid or bracket-shaped bodies or minute curved rods present (plate VII, figs. 3, 6, 9, 10, 11, 27).
  B.—Wheels present, in papillæ.................... TÆNIOGYRUS
  BB.—Wheels present, but scattered.................... TROCHODOTA
  BBB.—Wheels wanting.
    Sigmoid bodies present.................... SCOLIODOTA
    Sigmoid bodies wanting; minute curved rods present.................... TOXODORA
AAA.—Deposits wholly wanting.................... ACHIRIDOTA

CHIRIDOTA Eschscholtz, 1829.

Dactyloia Brandt, 1835.
Liosoma Brandt, 1835.
Trochinus Ayres, 1852.
Liodcrma Bronn, 1860.

Tentacles 12, exceptionally 13 or even 14. Digits 3–10 on each side, the terminal pair the longest. (Although Semper, Lampert, and others speak of a terminal unpaired digit, it is very doubtful whether such normally occurs. The number of digits on a tentacle may be odd, but examination will show that this is due to an extra digit on one side at the base of the series.) Polian vessels numerous, 3–20. No gustatory organs are known to occur. Ciliated funnels usually single, sometimes collected into little groups, but not forming true stalked clusters. Calcareous deposits in the form of 6-spoked wheels (Plate VII, figs. 8, 15, 26) collected in little papillæ containing 10–80 of divers sizes (Plate VII, fig. 24); no sigmoid deposits, but small curved rods with enlarged ends are often present (Plate VII, figs. 16, 27), and minute oval miliary granules, or somewhat larger rod-shaped particles, frequently occur in connection with the longitudinal muscles.

The species of this genus are of small or moderate size and of variable color. They are widely distributed in both warm and cold seas, but no one species, except perhaps *lævis*, has a very extensive range, so far as our present knowledge shows. They occur chiefly in shallow water, often along shore, but are frequently met with at depths of 500–1,000 m. and sometimes down to 3,000–3,200 m. Specific differences are very difficult to determine satisfactorily, for the number and length of digits on the tentacles is closely correlated with age and size, while the number and arrangement of wheel-papillæ appear to show a similar correlation. Thus full-grown specimens of *rotifera* have the wheel-papillæ very numerous all over the body and the ventral surface is not distinguishable from the dorsal; but in young specimens, 20–40 mm. long, the wheel-papillæ of the ventral side are few and confined to a single series in each interradius, and such specimens therefore closely resemble *rigida* (Plate II, fig. 3). The presence or absence of miliary granules along the radii seems to be another variable feature, for Ludwig ('98*b*) has shown that in some specimens of *pisanii* these granules are abundant, in others infrequent, and in still others entirely wanting. In the light of these facts, it is not strange that the number of species in the genus and their geographical distribution are still uncertain. The species described by Müller ('50) as *pygmæa* is apparently a young *lævis* or possibly *rotifera* (Selenka ('67) says it is West Indian), while the form called *rubeola* by Quoy and Gaimard ('33) is absolutely unidentifiable at present, and it may not be one of the Chiridotinæ at all. The same is true of *Synapta coriacea* Agassiz ('52), which has been considered a synonym of *Chiridota lævis*. The holothurian called *Aspidochir mertensi* by Brandt ('35) is thought by Ludwig ('81*b*) to be a Chiridota.

KEY TO THE SPECIES OF CHIRIDOTA.

- *A.*—Wheel-papillæ numerous, more or less uniformly scattered all over the body, with no evident arrangement in longitudinal series; digits 8-14. (In young specimens, papillæ may be very few on ventral side.)
  - *B.*—Numerous curved rods (plate VII, fig. 27), with more or less branched ends scattered all over interambulacra.. ROTIFERA
  - *BB.*—No such rods in interambulacra.
    - Miliary granules of longitudinal muscles, minute oval particles; polian vessels 5-10 .... FERNANDENSIS
    - Miliary granules of radii longer than diameter of wheels; polian vessels 15-20. STUHLMANNI
- *AA.*—Wheel-papillæ numerous or few, confined to interambulacra, and there forming more or less irregular longitudinal series, less abundant on ventral side and often wholly wanting there.
  - *B.*—Digits of tentacles about 20; wheel-papillæ in 5 irregular series; numerous minute crescent-shaped bodies in skin.................................... VIOLACEA
  - *BB.*—Digits of tentacles generally fewer than 16 (very rarely 18).
    - *C.*—Wheel-papillæ very few and only in right and left dorsal interambulacra; stellate, perforated plates (plate VII, fig. 25) in skin..........MARENZELLERI
    - *CC.*—No stellate plates in skin.
      - *D.*—Numerous "buttons" ("schnallenförmiger Hautkalkkörper") in skin; wheel-papillæ in 5 simple longitudinal series................ EXIMIA
      - *DD.*—No "buttons" in skin.
        - *E.*—Curved rods, with enlarged ends (plate VII, figs. 16 and 27), which may be smooth or spinous, or even branched, scattered in skin, at least along ambulacra.
          - *F.*—Size large, up to 200 mm.; color more or less purple; wheel-papillæ confined almost wholly to mid-dorsal interambulacrum.
            - Curved rods very small (40-60 μ), confined to ambulacra, and distinctly curved ....REGALIS
            - Curved rods larger (80-120 μ), uniformly scattered, and commonly almost straight .... UNISERIALIS
          - *FF.*—Size small, under 100 mm.; color not purple; wheel-papillæ and rods more or less generally present in all the interambulacra.
            - Color red or reddish; wheel-papillæ numerous dorsally; occurs about coral reefs ....RIGIDA
            - Color whitish; wheel-papillæ in an irregular single row in each interambulacrum; occurs in mangrove swamps. INTERMEDIA
        - *EE.*—No such curved rods in skin.
          - *F.*—Size small, usually under 100 mm. (rarely twice that); color in life yellowish, pink, red or purple, becoming whitish, grayish, yellowish, dusky or purplish red in alcohol; wheel-papillæ, of course, white.
            - Wheel-papillæ very large, 1-1.5 mm. in diameter; polian vessels few, only 4-5; austral....................PISANII
            - Wheel-papillæ smaller and polian vessels numerous, 10-20 or more; boreal .... LÆVIS
          - *FF.*—Size large, up to 300 mm.; color prevailingly grayish, with more or less red pigment in skin......................DISCOLOR

CHIRIDOTA ROTIFERA.

Synapta rotifera Pourtales, 1851, p. 15.
Chirodota rotifera Stimpson, 1860. Ludwig, 1881*a*, p. 41; pl. III, figs. 1-15.
Chiridota rotifera Ludwig, 1892*b*.

LENGTH.—Up to 100 mm.; usually about 50.

COLOR.—Reddish or purplish, with light tentacles and numerous white wheel-papillæ.

DISTRIBUTION.—Reported from Biscayne Bay, Florida (Pourtales); Brazil (Ludwig, Verrill, Rathbun); Jamaica (Clark); Key West, Florida (Clark, antea); and Bermuda (Clark). Apparently a typical West Indian species, with the same distribution as *Synaptula hydriformis*.

REMARKS.—This is one of the best known and most distinctly characterized species of the genus, and is of particular interest because it is viviparous—a fact first noted by Ludwig ('81*a*); the eggs undergo their development in the body cavity of the mother, as in *Synaptula hydriformis*. It occurs commonly under stones and fragments of coral on sandy beaches or among living corals, in shallow water, and is somewhat gregarious, a number often being found under the same stone.

CHIRIDOTA FERNANDENSIS.

Chiridota fernandensis Ludwig, 1898*c*, p. 446.

LENGTH.—Up to 100 mm.

COLOR.—In life, brownish yellow; in alcohol, whitish yellow; very numerous small wheel-papillæ, white.

DISTRIBUTION.—Reported only from the Island of Juan Fernandez (Ludwig).

REMARKS.—This species was collected by Dr. Ludwig Plate in March, 1898. He seems to have found it quite common, as some 20 specimens were taken. Nothing is recorded of its habits or habitat.

CHIRIDOTA STUHLMANNI.

Chirodota stuhlmanni Lampert, 1896, p. 67.
Chiridota stuhlmanni Östergren, 1898*b*.

LENGTH.—80 mm.

COLOR.—Yellowish, with white wheel-papillæ, each of which has a rust-red dot.

DISTRIBUTION.—Reported only from Tumbatu, East Africa (Lampert).

REMARKS.—This seems to be a very well characterized species, of which, however, only a single specimen is as yet known. The remarkably large (210–266μ), straight rods confined to the ambulacra, and the very numerous polian vessels are striking features.

CHIRIDOTA VIOLACEA.

Chirodota violacea Müller, 1849, p. 379; 1850, p. 137.
Chiridota violacea Ludwig, 1892*b*.

LENGTH.—300 mm. or more, with a diameter of only 6–8 mm.

COLOR.—Not given, presumably violet or purple.

DISTRIBUTION.—Reported from Ibo, near Mozambique (Müller); Amirante Islands (Bell). Semper ('69) gives "Zanzibar," but Ludwig ('99) says that is probably a mistake, as Semper's note apparently refers to Müller's original specimen in the Berlin Museum.

REMARKS.—Although commonly attributed to Peters, the original description of this species is obviously by Müller, and, so far as known, Peters never published one word about it; there is no reason, therefore, why the name should be written *violacea* Peters, even if that collector did select the name. Bell ('84) is the only zoölogist who has been fortunate enough to meet with this species since its original discovery, but unfortunately he does not consider that fact sufficient justification for giving any information whatever in regard to the specimen (or specimens?) collected by the "Alert." The large size of this species and the number of digits make it an unusually interesting form.

CHIRIDOTA MARENZELLERI.

PLATE VII, FIGS. 24, 25.

Chiridota marenzelleri R. Perrier, 1904*b*, p. 370, with text figures.

LENGTH.—33–36 mm., with a diameter of 10–11.

COLOR.—Reddish above, deepest along the mid-dorsal region, with a network of fine dark lines like cracks; yellowish white beneath.

DISTRIBUTION.—Reported only from Magellan Strait (R. Perrier).

REMARKS.—So well characterized is this species by its unique coloration, its still more unique stellate calcareous particles, its few wheel-papillæ (6 in one and 9 in the other dorso-lateral interambulacrum), and its tentacles (having only three pairs of digits, the terminal the largest), that one is almost inclined to assign it generic rank; but, after all, the only character which would clearly mark such a genus is the form of the stellate bodies, and we are scarcely prepared to accord that feature alone such distinction.

CHIRIDOTA EXIMIA.

Chirodota eximia Haacke, in Möbius, 1880, p. 47.
Chiridota eximia Ludwig, 1892*b*.

LENGTH.—Not given.

COLOR.—Not given.

DISTRIBUTION.—Reported only from Fouquet's Reef, Mauritius (Möbius).

Remarks.—Although this species is apparently well characterized, it is difficult to understand just what form the "schnallenförmige" particles have, and in view of the results of Ludwig's ('83) reëxamination of the material on which Haacke based his numerous (14) new species, we may be pardoned if we are very skeptical regarding this Chiridota, which Ludwig was unable to examine.

Chiridota regalis.

Chiridota regalis Clark (antea, p. 28).

Length.—Up to 200 mm., with a diameter of about 6 mm.

Color.—More or less deep, royal purple, deepest anteriorly; more grayish posteriorly.

Distribution.—Coast of Japan, 198–300 m. (Clark).

Remarks.—Although quite nearly related to *uniserialis* and also to *discolor*, which it approaches in size and general appearance, this seems to be a well-marked species.

Chiridota uniserialis.

Chiridota uniserialis Fisher, 1907, p. 733; pl. lxxxi, fig. 4, and pl. lxxxi, figs. 5, 5*a-c*.

Length.—150 mm., with diameter of 7–9 mm.

Color.—Dark purple or pale lilac.

Distribution.—North of Molokai, Hawaiian Islands, 590–745 m. (Fisher).

Remarks.—This species appears to be very close to the preceding, but the difference in the size, form, and distribution of the C-shaped rods is quite striking. Fisher notes well-developed retractor muscles in *uniserialis*, but I found none in *regalis*. The wheel-papillæ in *regalis* are often very numerous (70–80 or more), of very variable size, and most numerous *anteriorly*, where they may occur in the lateral interambulacra, while in *uniserialis* they are 9–50 in number, of conspicuous size, confined strictly to the mid-dorsal interambulacrum, and often most numerous *posteriorly*.

Chiridota rigida.

Plates II, Fig. 3; VII, Figs. 26-29.

Chirodota rigida Semper, 1868, p. 18; pl. iii, fig. 3. Calcareous particles, pl. v, figs. 3 and 13.
Chirodota liberata Sluiter, 1888, p. 212. Calcareous particles, pl. ii. fig. 44.
Chirodota amboinensis Ludwig, 1888, p. 819.
Chiridota rigida Ludwig, 1892*b*.
Chiridota liberata Ludwig, 1892*b*.
Chiridota amboinensis Ludwig, 1892*b*.
Chiridota hawaiiensis Fisher, 1907, p. 731; pl. lxxxi, fig. 5, and pl. lxxxii. figs. 3, 3*a-é*.

Length.—25–75 mm.

COLOR.—Red of some shade, ranging from reddish brown and reddish purple to rose-red; tentacles whitish; wheel-papillæ white.

DISTRIBUTION.—Reported from Bohol, Philippines (Semper); Bay of Batavia, Kur-reef, Lucipara and Binongka, D. E. I. (Sluiter); Pulo Edam and Amboina (Ludwig); Rotuma and China Straits, New Guinea (Bedford); and Hawaiian Islands (Fisher). Apparently well distributed throughout the entire East Indian region.

REMARKS.—Since Sluiter's description of *liberata* is obviously erroneous (he speaks of three ventral interradii), it is evident that his specimens were very similar to *rigida*, and as they were quite small, there can be little doubt that they were young ones of that species. Ludwig's *amboinensis* is apparently well within the limits of variation which such a species as *rigida* commonly shows and cannot be distinguished therefrom, and the same appears to be true of Fisher's *hawaiiensis*. This species occurs around coral reefs, either among the dead (less commonly, the living) corals or in holes in the blocks of coral rock.

CHIRIDOTA INTERMEDIA.

Chiridota intermedia Bedford, 1899*b*, p. 846. Calcareous particles, pl. LIII. fig. 6.

LENGTH.—20–30 mm.

COLOR.—Whitish, transparent posteriorly.

DISTRIBUTION.—Reported only from the Mangrove swamp, Funafuti (Bedford).

REMARKS.—Although this species is strikingly like a young *rigida*, the unusual habitat and the pale color make it seem probable that it is really quite distinct. Bedford says that the C-shaped calcareous particles rarely become S-shaped, "a condition which is normal in *C. contorta*," etc. No ordinary change of form would in itself make the calcareous particles of *rigida* (Plate VII, fig. 27) and *intermedia* like the sigmoid bodies of *Tæniogyrus* (Plate VII, figs. 9–11); these latter are an entirely distinct sort of calcareous deposit.

CHIRIDOTA PISANII.

Chirodota pisanii Ludwig, 1886*b*, p. 29. Calcareous particles, pl. II. fig. 14.
Chirodota purpurea Théel, 1886*a*, pp. 15 and 35. Calcareous particles, pl. II. fig. 1.
Chirodota purpurea Lampert, 1889*b*, p. 851.
Chirodota pisanii Lampert, 1889*b*, p. 851.
Chiridota pisanii Ludwig, 1892*b*.

LENGTH.—30–130 mm.

COLOR.—Red of some shade, varying from dark purple-red to rosy-white; the color becomes either intensified or bleached in alcohol; the longitudinal muscles sometimes show through as white stripes.

Distribution.—Reported from Calbuco, Porto Lagunas (Chonos Archipelago); Punta Arenas and Susanna Cove (Magellan Strait), Chile (Ludwig); Port Bridge, Tierra del Fuego (Ludwig); Orange Bay and Punta Arenas, Chile (R. Perrier); and Falkland Islands (Théel). Apparently ranges on both coasts of South America and among the neighboring islands to about 42° S. lat.

Remarks.—This species is of particular interest because, although quite different from its southern allies, it is strikingly similar to the widely distributed northern species, *lævis*. Curiously enough, Ludwig does not in any of his several papers ('86*b*, '98*b*, and '98*c*) make any reference to this similarity, and yet it is quite noticeable. . Indeed, it is hard to draw any sharp line between the two species, although *pisanii* is apparently redder, with fewer and larger wheel-papillæ and polian vessels, and oftentimes has minute oval calcareous grains in the longitudinal muscles. The southern species occurs in sand or mud along shore or out to a depth of about 100 m.

Chiridota lævis.

Holothuria lævis Fabricius, 1780, p. 353.
Holothuria pellucida Vahl in O. F. Müller, 1806, p. 17.
Chiridota lævis Grube, 1851, p. 41.
Trochinus pallidus Ayres, 1852*c*, p. 243.
Chirodota tigillum Selenka, 1867, p. 366.
Chirodota typica Selenka, 1867, p. 366.
Chirodota lævis Duncan and Sladen, 1881, p. 12; pl. I, figs. 14-19.
Chirodota læve Lockington, 1885, p. 180.
Chirodota abyssicola von Marenzeller, 1893, p. 19; pl. I, fig. 5.

Length.—Up to 200 mm., but usually 50–100.

Color.—Usually pinkish, sometimes bright pink, sometimes pinkish brown, sometimes nearly transparent and colorless, rarely grayish or yellowish.

Distribution.—Reported from numerous stations on the east coast of America from 42° N. lat. northward; from Greenland, from Spitzbergen, and from the northern coasts of Europe above 66° N. lat. Concerning its occurrence in the Pacific Ocean, see antea, p. 28. The bathymetrical range in the North Atlantic is commonly from low water to about 100 m., but von Marenzeller's *abyssicola* was taken in 2,870 m., north of the Azores, and specimens from the Pacific were taken in over 3,000 m.

Remarks.—The large series of specimens of a Chiridota, apparently this species, discussed on p. 28, shows that *lævis* has either not yet been clearly and accurately defined, or else has a remarkable geographical and bathymetrical range. It is entirely distinct from the following species, but in the present state of our knowledge it is surprisingly hard to draw a sharp line between them. No constant character by which to distinguish the deep-water forms has yet been pointed out, so that the interesting "species" *abyssicola* must be regarded as identical with *lævis*. Sandy, more rarely muddy, bottoms are the favorite resorts of *lævis*, but it also occurs sometimes among stones and seaweeds.

CHIRIDOTA DISCOLOR.

Chiridota discolor Eschscholtz, 1829, p. 12; pl. x, fig. 2.
Liosoma sitchænse Brandt, 1835, p. 58.

LENGTH.—Up to 300 mm., with a diameter of 10–15.

COLOR.—Whitish, yellowish, grayish, reddish, or brownish, the shade depending on the abundance or scarcity of red pigment scattered in the skin and the degree of contraction of the body.

DISTRIBUTION.—Reported from Sitka, Alaska (Eschscholtz), and Okhotsk Sea (Grube). For other localities, see antea, p. 27. Apparently common on the northwest coast of America and the northeast coast of Asia.

REMARKS.—There is no doubt that this is a valid species, but its specific and geographical limits have yet to be ascertained. It lives under stones, in loose sand along shore, but also appears to range outward into water 1,000 m. or even more in depth.

POLYCHEIRA, gen. nov.

(*πολύχειρος*, many handed; in reference to the numerous palmate tentacles.)

Tentacles 18, exceptionally 17 or 19. Digits 9–16 on each side, the terminal pair the longest. Polian vessels numerous, 6–19. Gustatory organs do not occur. Ciliated funnels collected into stalked clusters. Calcareous deposits similar to those in Chiridota.

This is a monotypic genus including only the wide-ranging and somewhat variable species to which the following names have been given:

POLYCHEIRA RUFESCENS.

PLATE VII, FIGS. 14-18.

Chirodota rufescens Brandt, 1835, p. 59.
Chirodota panansis Semper, 1868, p. 19. Calcareous particles, pl. v, figs. 1 and 21.
Chirodota vitiensis Semper, 1868, p. 19. Calcareous particles, pl. v, figs. 8 and 20.
Chirodota variabilis Semper, 1868, p. 20. Calcareous particles, pl. v, figs. 6, 7, 9–11, 19.
Chirodota dubia Semper, 1868, p. 21. Calcareous particles, pl. v, fig. 4.
Chirodota incongrua Semper, 1868, p. 22. Calcareous particles, pl. v, fig. 5.
Chirodota refuscens Théel, 1886*a*, p. 36.
Chiridota dubia, incongrua, panænsis, rufescens, vitiensis Ludwig, 1892*b*.

LENGTH.—60–100 mm.

COLOR.—Variable, ranging from very dark violet through clear reddish to almost colorless.

Distribution.—Reported from Bonin Islands (Brandt); Bay of Manila, Panaon bei Surigao, and north Luzon (Semper); Singapore (Théel); Hongkong (Lampert, Ludwig); Sunda Straits, *not* Bay of Batavia (Sluiter); Timor (Ludwig); Amboina (Ludwig, Sluiter); Japan (Ludwig); Ternate (von Marenzeller); Ceylon (Bell, Walter); Fiji Islands (Semper); Cape York, Australia (Semper); Loyalty Islands and Blanche Bay, New Britain (Bedford); Tumbatu (Lampert); Roepang (Lampert); and numerous places in the D. E. I. (Sluiter). Apparently distributed throughout the Indo-Pacific region, except perhaps in the northwestern part.

Remarks.—The collection and examination of such a large amount of material as is indicated by the above list of localities where this species occurs leaves little room for doubt that all of the Indo-Pacific Chiridotas with 16–19 tentacles must be referred to this one species. Semper ('68) himself was skeptical about *dubia* and *incongrua,* while the numerous specimens reported in the past twenty years show clearly that *panænsis* and *vitiensis* are not constantly distinguishable. The last-named species is usually ascribed to Gräffe, because Semper ('68) attributes it to him; but Dr. Gräffe never published a word about it, and Semper himself is really responsible for its description. Semper says that *panænsis* occurs among large stones near low-water mark, but nothing else is recorded of either habitat or habits.

TÆNIOGYRUS Semper, 1868.

Sigmodota Studer, 1876.

Tentacles peltato-digitate, 10 or 12. Digits 5–7 on each side, the terminal pair longest. Polian vessel single, or there may be several. No gustatory organs. Ciliated funnels not in stalked clusters. Calcareous particles consist of wheels collected in papillæ and large sigmoid bodies about 200 μ long scattered in the skin; no miliary granules in either skin or longitudinal muscles.

This seems to be a well-characterized genus intermediate between Chiridota and Trochodota. The two species it contains are apparently quite distinct from each other. They are confined to the southern hemisphere, but a specimen of Tæniogyrus is recorded from the Hawaiian Islands by Fisher (:07) which is probably an undescribed species nearly allied to *contortus*.

Key to the Species of Tæniogyrus.

Tentacles 10; polian vessel single; sigmoid bodies in papillæ, at least dorsally. . . AUSTRALIANUS
Tentacles 12; polian vessels 6 or 7; sigmoid bodies not in papillæ. . . . . CONTORTUS

TÆNIOGYRUS AUSTRALIANUS.

Chirodota australiana Stimpson, 1856, p. 386.
Tæniogyrus australianus Semper, 1868, p. 23.
Sigmodota australiana Östergren, 1898*b*.

LENGTH.—30–50 mm.

COLOR.—Yellowish

DISTRIBUTION.—Port Jackson, New South Wales (Stimpson).

REMARKS.—This very interesting species, rediscovered in the collection of the National Museum, is well worthy of the generic distinction, which Semper accords it. Like *Leptosynapta dolabrifera*, it is known only from Port Jackson, where Stimpson ('56) says it occurs under stones near low-water mark. The wheel-papillæ are conspicuous, but occur only in the dorsal interambulacra and are most abundant anteriorly. The sigmoid bodies are also in papillæ which are very abundant all over the body, but are largest and most noticeable dorsally. Each papilla contains six or eight sigmoid bodies. The calcareous ring is very narrow, much as Dendy ('97) figures it for *Trochodota dunedinensis*. The genital glands are distinctly branched. Each of the five specimens at hand has only ten tentacles.

TÆNIOGYRUS CONTORTUS.

PLATE VII, FIGS. 8-13.

Chirodota contorta Ludwig, 1874, p. 80. Calcareous particles, pl. VI. fig. 6.
Sigmodota purpurea Studer, 1876, p. 454 (non Lesson).
Chirodota purpurea Bell, 1881, p. 101.
Chirodota studerii Théel, 1886*a*, p. 33.
Chiridota contorta Ludwig, 1892*b*; 1898*b*, p. 73; pl. III. figs. 37-42.
Sigmodota contorta Östergren, 1898*b*.

LENGTH.—20–45 mm.

COLOR.—Very variable, ranging in life from orange through various shades of red and purple to brownish violet; tentacles lighter, white to orange-red; alcoholic material varies from yellowish white or gray to brownish red or violet.

DISTRIBUTION.—Reported from Port Gallant, Punta Arenas, the Elizabeth Islands, and stations in Strait of Magellan (Théel, Bell, Ludwig); Canal de Washington (R. Perrier); eastern coast of Patagonia (Lampert, Ludwig); Navarin Island, south of Tierra del Fuego (Ludwig); between Patagonia and Falkland Islands (Théel); South Georgia (Lampert); Marion Island (Théel); Kerguelen Island (Studer, Théel); near Madura Island, D. E. I., 82 m. (Sluiter). Apparently ranging from Kerguelen to the Strait of Magellan, across the southern Indian and Atlantic Oceans.

REMARKS.—This interesting species has had a peculiar history, which is admirably told by Ludwig ('98*b*), who also gives a very readable account of the morphology and development. It is found in sand and mud near low-water mark, or more commonly at depths of 10–220 m. It is especially remarkable for its breeding habits. The eggs undergo their development in the genital tubes of the mother, and consequently the species is not only viviparous but is unique among holothurians in the possession of uteri. One cannot avoid the feeling that a careful comparison of good material from Kerguelen and its vicinity with material from the Strait of Magellan and the Falkland Islands will show that there are two distinct species in these widely separated districts. The specimens reported from the East Indies by Sluiter (:01) probably represent a third species, while that from Hawaii (Fisher, :07) is very likely a fourth; but of course it is not impossible that *contortus* does occur throughout the southern hemisphere, and even extends its range northward into the East Indies and among the Pacific islands.

TROCHODOTA Ludwig, 18 2.

Tentacles 10. Digits 2–6 on each side. Polian vessel single. Stone-canal single. Calcareous ring of 10 slender pieces, the radial not pierced for passage of nerves. Gustatory organs sometimes (always?) present on tentacles. Calcareous deposits consist of sigmoid bodies (Plates VII, figs. 2 and 6) (90–160 μ in length) either scattered irregularly through the skin or arranged in circles or in little groups; with these are associated wheels, like those of Chiridota, but scattered through the skin and never collected in wheel-papillæ.

This is a very natural and well-defined group, first set off by Ludwig ('92*b*) under the name Trochodota. Its geographical distribution is remarkable, for while one of the species occurs only at New Zealand, a second is found only about the southern end of the American continent and the third is confined to the Bay of Naples. The last is, however, such a small species and so difficult to find that its range may really be very much greater than is supposed.

KEY TO THE SPECIES OF TROCHODOTA.

A.—Wheels about 150-180 μ in diameter; sigmoid bodies normally with one end rolled inward, the other curved outward in a different plane, and neither end enlarged (plate VII, fig. 6).

Wheels scattered all over the body; genital tube unbranched.......... PURPUREA

Wheels confined to 3 dorsal interradii; genital tubes somewhat branched. DUNEDINENSIS

AA.—Wheels about 80 μ in diameter; sigmoid bodies not as above, often thickened at one end (plate VII, fig. 3).. VENUSTA

TROCHODOTA PURPUREA.

Holothuria (Fistularia) purpurea Lesson, 1830, p. 155; pl. 53, fig. 1.
Chirodota purpurea Jäger, 1833.
Chiridota purpurea Brandt, 1835.
Sigmodota purpurea Studer, 1876, p. 454 (partim).
Chirodota australiana Théel, 1886*a*, p. 16.

> *Chirodota studeri* Lampert, 1889*b*, p. 849. Calcareous particles, pl. XXIV, fig. 12.
> *Trochodota studeri* Ludwig, 1892*b*.
> *Sigmodota studeri* Östergren, 1898*b*.
> *Trochodota purpurea* Ludwig, 1898*b*, p. 83. Calcareous particles, pl. III, figs. 43-45.

LENGTH.—Up to 40 mm.

COLOR.—Variable; yellowish, reddish, or brownish, more or less dusky or with red spots; Lesson gives the color in life as carmine-red to purple-red.

DISTRIBUTION.—Reported from Falkland Islands (Lesson, Ludwig); Strait of Magellan (Lampert, Ludwig, R. Perrier); Lennox Island and Picton Island, south of Tierra del Fuego (Ludwig). Apparently occurs only around the Falkland Islands and the extreme southern parts of the American continent.

REMARKS.—This species has been the source of much confusion, but Ludwig ('98*b*) seems to have straightened out the synonymy with great accuracy. It occurs commonly among the so-called "roots" of Laminaria and other algæ, but may perhaps also live in sand or mud, at depths of less than 20 m. The sigmoid bodies are scattered all over the body and lie at right angles to the longitudinal axis.

TROCHODOTA DUNEDINENSIS.

> *Chirodota dunedinensis* Parker, 1881, p. 418.
> *Chiridota dunedinensis* Ludwig, 1892*b*.
> *Chirodota dunedinensis* Dendy, 1897, p. 26. Calcareous particles, pl. III, figs. 1-8.
> *Trochodota dunedinensis* Ludwig, 1898*b*.
> *Sigmodota dunedinensis* Östergren, 1898*b*.

LENGTH.—Up to 50 mm.

COLOR.—Pale yellowish; in life, with minute red spots.

DISTRIBUTION.—Reported only from Otago Harbor, New Zealand (Parker, Dendy, Ludwig).

REMARKS.—Parker speaks of dark spots on the inner side of the tentacles, which are not affected by alcohol, but neither Dendy nor Ludwig refer to them, and we can only surmise as to whether they are gustatory organs, such as Semon ('87) says occur in *venusta*. The habitat of this species appears to be like that of the preceding, among seaweeds, in shallow water. It appears to be rare, for the specimens examined by both Dendy and Ludwig were from the original lot collected by Parker, and so far as I can learn, no others have been collected. There can no longer be any question as to the complete distinctness of this species from *Tæniogyrus australianus*. Dendy and Ludwig have each intimated that the two species were probably identical, and I have for several years considered them so, but the material of *australianus* in the National Museum has shown the error of such a belief.

TROCHODOTA VENUSTA.

PLATE VII, FIGS. 1-4.

Chirodota venusta Semon, 1887, p. 276; pl. 9, figs. 1-2; pl. 10, figs. 8, 11, 15.
Trochodota venusta Ludwig, 1892*b*.
Sigmodota venusta Östergren, 1898*b*.

LENGTH.—Up to 27 mm.

COLOR.—Nearly transparent, with a reddish tinge, due to very minute pigment-cells in the skin.

DISTRIBUTION.—Reported only from the Bay of Naples (Semon).

REMARKS.—This curious little species occurs among the roots of eel-grass and is apparently quite rare. Nothing is known of it beyond Semon's original account. He speaks of sensory-organs on the tentacles, but gives no details in regard to them.

SCOLIODOTA, gen. nov.

(σκολιὸς, crooked, + δοτός, granted, given; in reference to the crooked sigmoid bodies and to agree in termination with Chiridota.)

Tentacles 10. Digits 10 or more. Wheels wanting; calcareous particles sigmoid bodies only, commonly arranged in groups.

This is a monotypic genus, apparently quite closely related to Tæniogyrus, confined to the East Indian region, but ranging from Japan to Australia.

SCOLIODOTA JAPONICA.

PLATE VII, FIG. 5.

Chirodota japonica von Marenzeller, 1881, p. 123.
Chirodota japonica Théel, 1886*a*, p. 17. Sigmoid bodies, pl. II, fig. 3.
Anapta japonica Ludwig, 1892*b*.
Sigmodota japonica Östergren, 1898*b*.

LENGTH.—More than 40 mm. (v. Marenzeller) and up to 170 mm. (Théel).

COLOR.—In life, blood-red (v. Marenzeller); in alcohol, whitish gray or pale brownish violet, with numerous small dark red or violet papillæ (Théel).

DISTRIBUTION.—Reported only from Eno-sima, Japan (v. Marenzeller) and Port Jackson, Australia (Théel).

REMARKS.—Théel says that his specimens were highly incomplete, and it is not impossible that they represent a species quite distinct from the Japanese one, although, so far as I can see from the specimens in the National Museum, they agree perfectly with v. Marenzeller's description. It is not at all likely that wheels are normally present in this species, but much more extensive material is necessary before the matter can be considered settled beyond question.

TOXODORA Verrill, 1882.

Tentacles 12. Digits numerous, 10–16. Wheels wanting; calcareous particles consist exclusively of "minute, slender plates in the shape of a bow or parenthesis with the ends incurved."

This is another monotypic genus. Its relationship with Chiridota is perfectly obvious, but wheels appear to be consistently wanting. The calcareous particles are very small, only about 60 μ in length, and closely resemble the C-shaped rods of *Chiridota rotifera*.

TOXODORA FERRUGINEA.

Toxodora ferruginea Verrill, 1882, p. 220.
Chirodota ferruginea Théel, 1886*a*.
Anapta ferruginea Ludwig, 1892*b*.
Sigmodota ferruginea Östergren, 1898*b*.

LENGTH.—30 mm. or more, with a diameter of 5–10 mm.

COLOR.—Reddish brown, from the minute pigment-cells with which the skin is thickly filled.

DISTRIBUTION.—Reported only from several stations south of Nantucket and Marthas Vineyard, in 140–280 m. (Verrill).

REMARKS.—Thanks to the kindness of Professor Verrill and Miss Rathbun, I have had the opportunity of examining specimens of this interesting species. I find that the calcareous deposits are very much like the C-shaped particles of some species of Chiridota. But there is no indication that wheels are, or ever have been, present, and the species therefore cannot be placed in that genus.

ACHIRIDOTA, gen. nov.

(ἀ privative + *chiridota*; i. e., not chiridota.)

Tentacles peltato-digitate, 12. Digits small and rather numerous (6–8 pairs). Deposits entirely wanting. Polian vessel single, large. Calcareous ring well-developed.

This genus seems to be required for the following unique species, which bears the same relation to Chiridota that Anapta does to Leptosynapta and that Dactylapta does to Protankyra.

ACHIRIDOTA INERMIS.

Anapta inermis Fisher, 1907, p. 730; pl. LXXIII, fig. 2, and pl. LXXXII, fig. 1.

LENGTH.—About 100 mm.; greatest diameter, 14–20 mm.

COLOR.—Bleached grayish, profusely covered with small reddish-brown or yellowish-brown spots, most abundant anteriorly.

DISTRIBUTION.—Hawaiian Islands, 466–772 m. (Fisher).

REMARKS.—This singular species, of which Fisher had eleven specimens from seven stations, is very much like Chiridota in general appearance, but the single polian vessel and the entire absence of deposits separate it distinctly from that genus.

MYRIOTROCHINÆ Östergren, 1898*p*.

Tentacles digitate, much as in Chiridota, but weaker, with 2–8 digits on each side.[1] Cartilaginous ring, light-detecting and gustatory organs, and true ciliated funnels wanting. Polian vessel and stone-canal single. Calcareous deposits in the form of wheels, always with more than six spokes and never collected in wheel-papillæ. Other calcareous deposits very rare. Sexes separate. Size small. Distribution, arctic and subarctic, rarely north temperate.

This well-characterized little group has been made known to science almost exclusively through the efforts of the Scandinavian zoölogists—Danielssen, Koren, M. Sars, Théel, and Östergren—and to the last two in particular are we greatly indebted for careful and accurate work. All of the Myriotrochinæ are so small that they would be easily overlooked by careless workers, and as they occur in mud and sand, often at considerable depths, it is not strange that, with the exception of the largest and commonest species, very few specimens have been found. The group has for many years been supposed to consist of three monotypic genera, but the admirable work of Östergren has shown us that one of these genera contains at least four species. None of the terms used in the keys or descriptions require any explanation.

Key to the Genera of Myriotrochinæ.

A.—Wheels of only one kind, with 10-25 spokes.
  Rim of the wheels with numerous large teeth projecting horizontally inward (plate VIII, figs. 17, 18, 19, 22) .... Myriotrochus
  Rim of the wheel with scattered, somewhat pointed knobs, not projecting horizontally inward (plate VIII, fig. 13) .... Trochoderma
AA.—Wheels of two kinds, with 8-11 spokes (plate VIII, figs. 4 and 5) ...... Acanthotrochus

MYRIOTROCHUS Steenstrup, 1851.

Oligotrochus M. Sars, 1866.

Tentacles 10 or 12. Calcareous deposits consist of wheels with 10–25 spokes, and with numerous large, flat, sharp teeth projecting horizontally inward from the rim; these wheels vary greatly in size and in abundance, but all have the same general appearance. No other calcareous deposits in the skin and rarely in the tentacles.

Our knowledge of this genus has been revolutionized by Östergren's recent papers (:03, :05*a*, and :05*b*). Although two of the species have 10 tentacles and two have 12, it does not seem to be possible to divide the genus into two natural groups, either by that or any other character.

Key to the Species of Myriotrochus.

A.—Tentacles 12. Size moderate, 30 mm. or more.
  Wheels numerous all over the dorsal surface, infrequent or wanting ventrally, 140-330 μ in diameter, with 12-25 (average about 17) spokes and 16-35 (average about 26) teeth (plate VIII, fig. 22) .... rinkii

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[1] Figures 16 and 21, plate VIII, give very erroneous representations of the tentacles of Myriotrochus.

Wheels few, usually less than 30, confined to anterior and posterior parts of dorsal surface, 55-95 μ in diameter, with 11-16 spokes and 17-26 teeth (plate VIII, fig. 17). VITREUS

AA.—Tentacles 10. Size very small, less than 20 mm.

Calcareous rods present in tentacles; wheels of two sizes, with few intermediates, 55-80 μ and 100-150 μ, with 13-16 spokes and 18-26 teeth. . . . . MINUTUS

No calcareous rods in tentacles: wheels 130-225 μ, with 12-15 spokes and 24-30 teeth. THÉELI

MYRIOTROCHUS RINKII.

PLATE VIII, FIGS. 21-22.

Myriotrochus rinkii Steenstrup, 1851, p. 55; pl. III, figs. 7-10.
Chiridota brevis Huxley, 1852, p. CCXI.
Myriotrochus rinkii Théel, 1877, p. 2; pl. I.

LENGTH.—40–65 mm., the diameter one-fourth or one-fifth as much.

COLOR.—In life, "half-transparent" and "red" like "*Synapta inhærens*" (Östergren); alcoholic material is whitish, yellowish, or greenish.

DISTRIBUTION.—Reported from numerous stations between Bering Sea on the west to about 71° E. long., north to at least 82° N. lat., and south (on the east coast of North America) to at least 45° N. lat., but on the Scandinavian coast not south of 70° N. lat.; also reported by Théel ('86*a*) from the northern coast of Asia, so that there is good reason to believe the species is really circumpolar. The bathymetric range is from 2 to 666 meters.

REMARKS.—Although this species has such an extensive range, it exhibits comparatively little variation. Östergren (:03), in his interesting account of this species, points out that in the most northerly specimens the number of spokes is 70–80 per cent of the teeth, while in southern examples it is only 54–60 per cent. (See antea, p. 30.) In high arctic regions this species is sometimes found in water only 2 or 3 m. deep; usually, however, from 5–100 m., and in the southern part of its range it occurs chiefly at depths of from 60 to more than 300 m. Nothing is recorded of its habits except Östergren's statement that it shows "only a little tendency to autotomy."

MYRIOTROCHUS VITREUS.

PLATE VIII, FIGS. 15-20.

Oligotrochus vitreus M. Sars, 1866, p. 200.
Myriotrochus rinkii Auct., 1877-1898, partim.
Myriotrochus vitreus Östergren, 1898*b*, 1903.

LENGTH.—Up to 60 mm.

COLOR.—Perfectly transparent in life, with sometimes a greenish or (near ends of body) reddish tinge; alcoholic specimens are less transparent.

DISTRIBUTION.—Reported only from coast of Norway, from Skäger Rack to Skraawem, in depths of 100–700 m. (Östergren).

Remarks.—Östergren (:03) appears to have clearly established the right of this species to recognition. In addition to the differences between it and the preceding species already mentioned, Östergren emphasizes the form of the longitudinal muscles, which are broad, flat, and thin in *vitreus*, even anteriorly, instead of narrow and much compressed anteriorly, as in *rinkii;* and the tendency of *vitreus* to autotomy.

Myriotrochus minutus.

Myriotrochus minutus Östergren, 1905*b*, p. cxciv, fig. 1 A.

Length.—6–10 mm.

Color.—Practically wanting; body-wall thin and nearly transparent.

Distribution.—Reported only from the coast of Korea, at a depth of 60–65 m. (Östergren).

Remarks.—This little synaptid is of special interest because of its having numerous supporting rods in the tentacles, in which it is unique in the subfamily; and its having the alimentary canal connected with the body-wall in a manner somewhat different from that of any other holothurian. Its geographical position is also unique, no other member of the subfamily occurring anywhere nearly so far south.

Myriotrochus théeli.

Myriotrochus théeli Östergren, 1905*a*, p. clix.

Length.—12–15 mm.

Color.—White, half transparent.

Distribution.—Reported only from northwest of Jan Mayen, 72° 42′ N. and 14° 49′ W., at a depth of about 2,000 m. (Östergren).

Remarks.—This interesting species is notable for the great depth at which it is found, showing that, like Acanthotrochus, it is a true deep-sea form. Only five specimens have been taken.

TROCHODERMA Théel, 1877.

Tentacles 10. Calcareous deposits consist exclusively of wheels with 10–16 spokes; the rim with scattered somewhat pointed knobs, but without teeth projecting horizontally inward. These wheels lie in the skin in so many layers as to make the body-wall quite firm.

This monotypic genus is easily recognized by the form of the wheels, which are quite different from those of any other synaptid.

TROCHODERMA ELEGANS.

PLATE VIII, FIGS. 7-14.

Trochoderma elegans Théel, 1877, p. 11; pl. II.

LENGTH.—10–15 mm.

COLOR.—Silvery white.

DISTRIBUTION.—Reported from Nova Zembla and Sea of Kara (Théel *et al.*).

REMARKS.—The geographical distribution of this species is somewhat doubtful, owing to the unfortunate error of Stuxberg (see Östergren :03, p. 16, footnote) in confusing *Myriotrochus rinkii* with it. It lives in comparatively shallow water, 9–220 m.

ACANTHOTHOCHUS Danielssen and Koren, 1879.

Tentacles 12. Calcareous deposits consist exclusively of wheels, but these are of two perfectly distinct kinds; of these the smaller usually have 11 spokes and 22 or more large inwardly directed teeth, as in Myriotrochus, while the larger usually have 8–10 spokes, and alternating with them 8 outwardly projecting spines.

This remarkable monotypic genus is still known only from the original specimens of its describers.

ACANTHOTROCHUS MIRABILIS.

PLATE VIII, FIGS. 1-6.

Acanthotrochus mirabilis Danielssen and Koren, 1879, p. 115; also 1882, p. 35, pl. VI.

LENGTH.—10–12 mm.

COLOR.—Wanting; skin nearly transparent, "with glittering points."

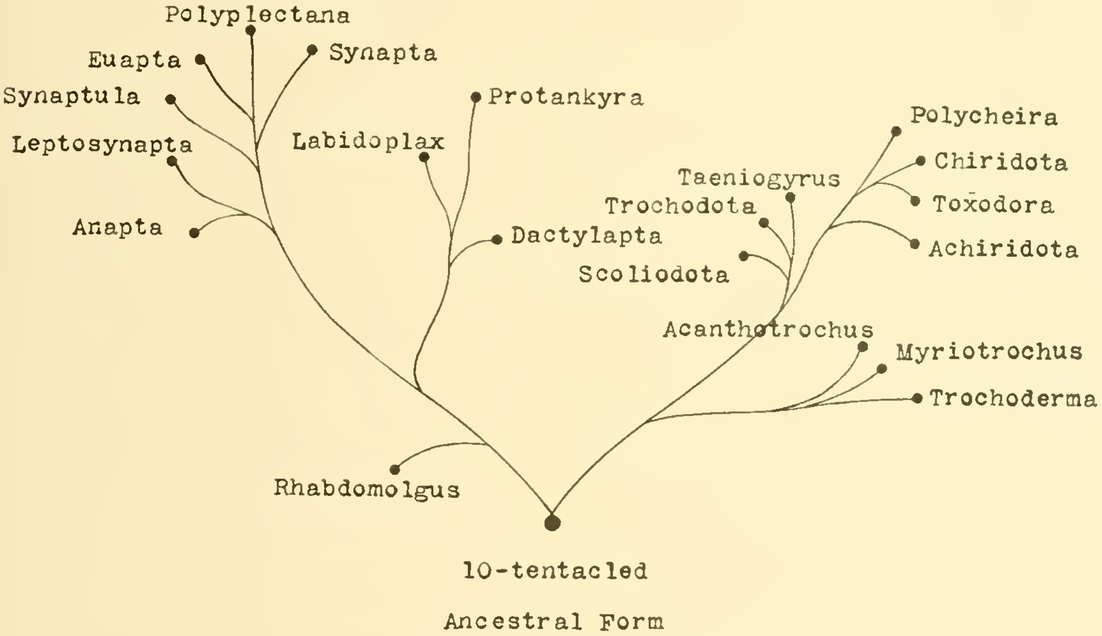
DISTRIBUTION.—Reported only from between Spitzbergen and Norway, in 1,203–2,030 m. (Danielssen and Koren).

REMARKS.—Nothing further is known of this interesting species beyond the descriptions and figures of Danielssen and Koren.

CONCLUDING REMARKS ON THE SYNAPTIDÆ.

INTERRELATIONSHIPS.

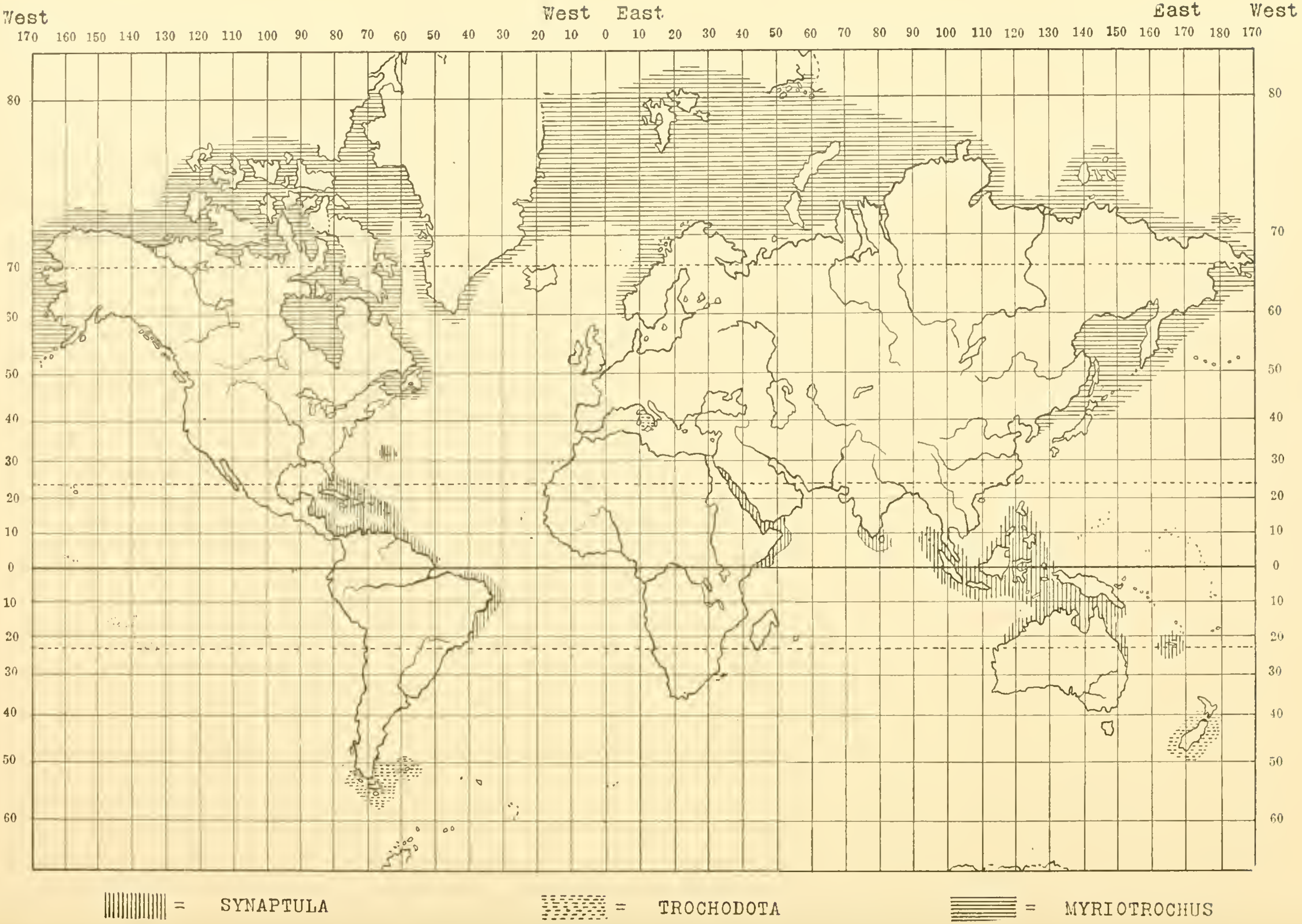
Having thus characterized the 21 genera and 88 species of Synaptidæ known to science at the present day, it may be of interest to attempt to show in graphic form the relationship which they seem to have to each other. There is every reason to believe that the ancestor of the group was a small 10-tentacled apodous holothurian, and there is some reason for believing that the earliest well-formed calcareous particles were wheel-shaped, for such particles are the first to appear in the auricularia of Labidoplax (see Semon, '88). In the face of such knowledge of echinoderm embryology as we have, we can hardly believe that such a condition as occurs in Rhabdomolgus, the entire absence of calcareous particles, is to be regarded as ancestral. Whether the tentacles of the earliest synaptids were digitate or pinnate cannot be positively determined; the earliest tentacles of the Synaptidæ with pinnate tentacles (see Clark, '98*a*) are simple and then pinnate, and of the Chiridotinæ (see Ludwig, '98*b*) are digitate almost from the start; in Labidoplax, however (see Semon, '88), the tentacles are simple before becoming digitate. On the whole, it seems probable that the earliest synaptids had 10 simple tentacles and a few more or less wheel-shaped deposits. From this form have diverged two quite distinct branches, one losing the wheels and developing anchors, the other developing various forms of wheels. The interrelationships of the genera might then be represented as follows:



It will appear then that Rhabdomolgus is the nearest living representative of the ancestral stock, though not necessarily close to it, while Polyplectana, Protankyra, Polycheira, and Acanthotrochus are the most highly specialized forms of their respective branches.

Geographical Distribution.

In considering the distribution of the foregoing genera and species we may well consider simply the littoral regions proposed by Ortmann (*Grundzüge der Marinen Thiergeographie*, 1869), so few of the Synaptidæ are truly abyssal forms and these almost exclusively of the genus Protankyra. We are at once struck by the fact that the Indo-Pacific region is easily the most important geographical area for synaptids, no less than fifteen genera having representatives there, and ten of these (six monotypic, however) may be considered as distinctly Indo-Pacific genera. The Atlantic Boreal subregion has repre-



Map Showing the Distribution of Three Genera of Synaptidae.

sentatives of seven genera, of which four (two monotypic) are really characteristic. The Arctic region is characterized by the three genera (two monotypic) of Myriotrochinæ, and three other genera are represented there. The Antarctic region has two characteristic genera, while four other genera occur there. No synaptids are known from the West American region or the Guinea subregion, and there are no characteristic genera in the East American region nor in either the Mediterranean or Pacific Boreal subregions. One genus, Chiridota, cannot be considered characteristic of any single region; of all synaptid genera it is the most truly cosmopolitan. As regards the abyssal region (over 1,000 m.), Protankyra, Chiridota, Myriotrochus, and Acanthotrochus are represented there, but the two latter are characteristically Arctic forms and only extend a little way into the Boreal subregions, so that we are justified in saying that the only truly abyssal Synaptids known are a few species of Protankyra and Chiridota. The following table will show these facts of distribution in a convenient way. The * indicates that the genus is characteristic of the region, ** that it is not found elsewhere, and the figures in parentheses indicate the number of species occurring in that region.

Indo-Pacific Littoral Region:
Euapta (1).
** Opheodesoma (4).
** Polyplectana (1).
** Synapta (1).
* Synaptula (7).
* Protankyra (17).
* Anapta (2).
** Dactylapta (1).
** Polycheira (1).
** Achiridota (1).
** Scoliodota (1).
Chiridota (6).
Leptosynapta (1).
Labidoplax (1).
Tæniogyrus (1).
Antarctic Littoral Region:
* Tæniogyrus (2).
* Trochodota (2).
Leptosynapta (1).
Anapta (1).
Chiridota (3).
Scoliodota (1).
Atlantic Boreal Subregion:
* Leptosynapta (7).
* Labidoplax (4).
** Rhabdomolgus (1).
Atlantic Boreal Subregion (continued):
** Toxodora (1).
Protankyra (1).
Chiridota (1).
Myriotrochus (2).
Arctic Circumpolar Subregion:
* Myriotrochus (2).
** Trochoderma (1).
** Acanthotrochus (1).
Leptosynapta (1).
Labidoplax (1).
Chiridota (2).
Pacific Boreal Subregion:
Leptosynapta (1).
Chiridota (1).
Myriotrochus (1).
East American Littoral Region:
Euapta (1).
Synaptula (1).
Leptosynapta (3).
Chiridota (1).
Mediterranean Subregion:
Leptosynapta (2).
Labidoplax (2).
Trochodota (1).
Abyssal Region:
Protankyra (7).
Chiridota (2).

We know too little about the range of the great majority of the species to attempt any study of geographical distribution more in detail; but it is interesting to note the striking difference between the Arctic and Antarctic faunas, for, excepting *Chiridota lævis* and *Leptosynapta inhærens,* both of which are very wide-ranging and very poorly delimited, none of the 25 species occurring in the Arctic and Boreal subregions have any near relatives in the Antarctic region, and the 10 species occurring in the latter region are, with one or two possible exceptions, entirely confined within its limits. Moreover, the northern regions have five very characteristic genera, entirely unrepresented south of the equator, while the southern fauna possesses two characteristic genera, each of which seems to have only an aberrant member north of the equator. It is difficult to reconcile these facts with any rational "theory of bipolarity."

PLATE III.

Aphelodactyla molpadioides (Semper).

Adult. natural size. (From Semper, 1868.)

Aphelodactyla molpadioides (Semper)

PART IV.

THE MOLPADIIDÆ.

Order ACTINOPODA Ludwig.

External appendages of the water-vascular system arise only from the well-devoloped radial canals.

Family MOLPADIIDÆ, J. Müller.

More or less elongated, rather stout holothurians, with an anterior, flat, circular oral disc and generally tapering posteriorly into a more or less evident caudal portion; with well developed respiratory trees, but with water-vascular system greatly reduced; 15 (in only one species, 10) circumoral tentacles, simple or digitate, usually with conspicuous ampullæ, are present; radial water vessels are present, but, except for a few very rudimentary papillæ at their posterior termination, they are rarely associated with any outgrowths of the body-surface; circular muscles are interrupted at each radius, and each radial longitudinal muscle usually consists of two parallel bands; no special sense-organs are present, nor are there ciliated funnels on the mesenteries or wall of the body cavity; calcareous deposits, commonly in the form of tables, fusiform rods, or perforated plates, usually present; anchors sometimes occur, but wheels and sigmoid bodies do not; phosphatic deposits (see page 143) often present.

Morphology.[1]

Form and size.—The body is generally of considerable diameter in proportion to its length, the ratio ranging from nearly equal in some young specimens to about 1:10 in some old and fully extended individuals; excluding the caudal appendage, the length is not often more than three or four times the diameter, although of course much depends on the amount of contraction. The caudal appendage is commonly quite evident (see Plates IX, X, XI, XIII), but is entirely wanting in Acaudina and is more or less indistinct in several species of other genera. It is commonly from one-twelfth to one-third of the total length, but may be more than one-half in Caudina and rarely so in Molpadia. The largest member of the family is apparently *Aphelodactyla molpadioides* (Plate III), which is sometimes 210 mm. long and correspondingly stout; *Caudina arenata* undoubtedly reaches a greater length, perhaps 250 mm. when fully

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[1] In the preparation of this section I am particularly indebted to Gerould's admirable report on *Caudina arenata* (1896), which has never been surpassed as a study of holothurian morphology.

extended, but is much more slender. The smallest species (*Eupyrgus pacificus*) is only 6 or 7 mm. long, but the diameter is one-half as much. The great majority of the species, however, approach the maximum rather than the minimum extreme, and few Molpadids, when fully mature and normally extended, are less than 50 mm. long.

Color.—The usual ground color in this family is pale gray, which may be unmarked and even untinted, but is usually shaded with brown, dull red or rosy, and is often spotted or blotched with red, brown, or purple of some shade. The ultimate color effect depends in most cases on the degree of development of the deposits in the skin, for the occurrence of real pigment is unusual. In Acaudina, however, the color is very dark, although there are no colored deposits, and in some species of Molpadia a purple, or less commonly an orange or a brown, pigment is present, which more or less considerably modifies the color. The excessive development of calcareous deposits in a thin skin may give rise to an almost pure white surface, while a similar excessive development of the phosphatic deposits (see p. 143) may make the surface appear deep red, purple, brown, or nearly black; in these latter cases the oral disc and tail are almost always white by contrast. All intergradations occur, even in a single species, between very light color and very dark; in such cases there is reason to believe the older the individual the darker it becomes. Except Acaudina, species lacking phosphatic deposits are seldom dark or noticeably colored, but occasionally a species is met with which has a distinct color. Such, for example, is *Aphelodactyla molpadioides* (Plate III), which Semper figures of a uniform purplish red, and its near relative *A. punctata,* which is blotched with orange. The color is seldom different dorsally from what it is ventrally, but occasionally the upper side is darker. It is not unusual for the anterior end to be more heavily blotched and shaded than is the posterior portion of the animal. The colors seem to be little affected by alcohol or other preserving fluids, except that rosy shades are commonly lost, and the reds, browns, and purples are deepened. The body-wall may be quite thin and translucent, and then the longitudinal muscles show as five deeper bands; but alcohol makes it opaque, and the longitudinal muscles may then be concealed, though their position is usually indicated by the furrows in the body-surface, caused by the contraction of the transverse muscles.

Body-surface.—The surface of the body in the Molpadiidæ is often quite rough, on account of the calcareous deposits in the skin, but where these are inconspicuous or lacking, the surface is commonly smooth and may be even slimy. Verrucæ, such as occur in the Synaptidæ, and pedicels and papillæ are practically unknown. Very rarely, long, slender papillæ occur in the mid-dorsal interambulacrum and hardly more common is it for rudimentary pedicels to occur near the ends of the body. Gland cells occur in the skin, most commonly on the anterior part of the body, and especially on the tentacles, but in only a few cases are they abundant enough to make the surface very slimy. The mucus is, however, frequently abundant enough to cause sand and mud to adhere, and if such individuals are placed in alcohol the mucus is hardened and the mud and sand then persist. In a few cases the calcareous deposits are abundant enough to make the body-wall very firm and even brittle, while in other cases the abundance of phosphatic deposits gives considerable rigidity. In the latter case, however, the surface is quite smooth. As a rule, the skin is much thinner and rougher in the young than in adults, and in some species the young may have a thin and very rough skin, while the fully mature specimen is perfectly smooth and has quite a thick skin.

TENTACLES.—The number of tentacles in the Molpadiidæ is almost invariably 15 (Plate X, fig. 2), except in the singular genus Caraplectana, in which there are only 10 (Plate XIII, fig. 6). Of course individuals are occasionally met with which have 14, and much more rarely one sees a specimen with 16. In Caraplectana there are two tentacles in each interradius, while in all other cases, so far as known, there are not three in each interradius, as might be supposed, but four in the mid-dorsal interradius, three in each of the latero-dorsal interradii, three in one of the ventral interradii, and two in the other. Whether it is the right or left ventral interradius which has three tentacles seems to depend on the individual. The tentacles are always relatively short and rather stout. They are simple and undivided in some species (Plate XII, fig. 22), and are then usually soft and flexible, but may be firm and horny. Most commonly there is a single short digit on each side, near the tip, so that there are apparently three digits with the terminal one largest; occasionally there are two or even, in very large specimens, three digits on each side, those nearest the base being the smallest. In other cases the tentacles bear two pairs of digits of approximately equal size, so arranged that one pair is at the tip, closely followed by the other; there is then no terminal unpaired digit (Plate X, fig. 2). In some cases the terminal pair is distinctly larger than the second, but more commonly if one pair is larger it is the latter. The tentacles are of equal size, though of course they need not always be equally extended in a living, or equally contracted in a preserved specimen. They are hollow, containing as they do the tentacular canals of the water-vascular system. These canals pass directly into the digits, extending to their tips. The wall of the tentacle is made up of a thin cutis overlying a layer of columnar epithelium, beneath which is a thin connective tissue layer, which does not normally contain calcareous deposits. The cavity of the tentacle is lined with an epithelium, and between it and the connective tissue is a layer of longitudinal muscle fibers. Circular muscles are probably not present, although they are said to occur in Molpadia. Exterior to the muscles, on the inner side of the tentacle, is a layer of nervous tissue.

The external epithelium is thickest on the digits, where it may be more than twice as thick as it is on the body; it contains both nerve and gland cells. Tentacle ampullæ are commonly, but not always, present.

Sense-organs.—The only structures in the Molpadiidæ which can be called sense-organs are the tentacles, which are undoubtedly important organs of touch, except possibly in Ceraplectana. The immediate seat of tactile sensations is in sensory nerve cells, which are scattered all through the covering epithelium of the body. They are considerably elongated, and the inner end is probably directly continuous with a nerve fiber; the outer end, however, is not ciliated or peculiar in any way. They are most abundant in the digits, where they are collected into groups forming very simple and primitive "sense-buds" or touch-papillæ.

Nervous system.—The nervous system of a Molpadid is not essentially different from that of any other holothurian. It consists of the customary circumoral ring, flattened antero-posteriorly so as to be from two to five times as wide as deep, five radial longitudinal nerve trunks, 15 tentacle nerves, and 10 bucco-pharyngeal nerves. The circumoral ring is about one-fourth of a mm. in width and one-twentieth to one-tenth in thickness, and lies beneath a connective tissue layer immediately internal to the base of the tentacles. On its inner face there is a deep, narrow furrow. It consists of delicate fibers interspersed with numerous ganglion cells, which are much more abundant than in the radial nerves; the ring is covered on its anterior and inner sides by an evident epithelial layer, the nuclei of which are small and deep-staining and apparently are associated with a non-nervous supporting tissue, fibers of which run among the nerve fibers but across the nerves. The radial nerves consist of two parts, a thick outer band, crescentic in cross-section, and a thin, inner band, closely appressed to the outer, separated only by a thin layer of connective tissue. This inner band shows a median longitudinal furrow throughout most of its length, and anteriorly divides into two branches, which subdivide and innervate the neighboring muscles, both longitudinal and transverse, and thus disappears; posteriorly it terminates in a slight enlargement. The outer band runs backward to the termination of the radius beside the cloacal opening. The muscles, both transverse and longitudinal, are apparently innervated by branches from the inner band, while the outer band chiefly supplies the integument. Both bands send nerves to the rudimentary pedicels at the ends of the ambulacra. The histological structure of the bands is similar to that of the circumoral ring. The tentacle nerves arise from the posterior outer portion of the circumoral ring and run upward on the inner face of the tentacles, forming a wide sheet, thickest mesially, near its base, and diminishing in width and thickness as it passes upward. Its histological structure is similar to that of the radial nerves. It gives off solid branches of fibers running directly to the touch-papillæ and isolated fibers running to single neuro-epithelial cells. The bucco-pharyngeal nerves run radially inward from the nerve ring to the buccal sphincter muscle and then turn backward along the pharynx; they consist simply of nerve-fibers, among which are interspersed ganglion cells; they innervate the oral disc and the pharynx, both muscles and epithelia. The arrangement of the bucco-pharyngeal nerves in the interradii corresponds remarkably to the number of tentacles; there is in any given interradius one less bucco-pharyngeal nerve than the number of tentacles; thus the mid-dorsal interradius has three bucco-pharyngeal nerves, while one of the ventral interradii has only one. Each radial nerve is accompanied on its inner side by a tube-like cavity closed at both ends, called the *hyponeural canal.* A similar space exists on the outer side of the radial, on the upper and inner sides of the circumoral, and on the inner side of the tentacle nerves, and these are known as the *epineural canals.* These canals are lined, at least on the sides away from the nerves, by a very thin epithelium, and are believed by Gerould ('96) (and Greeff, '72, and Herouard, '89) to be normal structures, though other investigators believe them to be artefacts.

Body-wall.—The body-wall of the Molpadids is very variable in thickness, according to the amount of connective tissue it contains. While frequently very thin and translucent, it is in some species remarkably thick, and in old specimens may measure several millimeters in a cross-section. It consists of five parts, as in the Synaptidæ: a cutis and a layer of epithelial cells which with the cutis make up the epidermis; a layer of connective tissue in which lie the calcareous bodies, pigment, etc.; a layer of transverse muscles; in the radii the longitudinal muscles; and an inner epithelium, which lines the body-cavity.

1. *Epidermis.*—The cutis is a thin, transparent structureless layer secreted by the epithelial cells and exhibiting no special peculiarities. The epithelial cells are of the same three sorts which occur in synaptids, ordinary supporting cells, sensory cells, and gland cells. The former are the most abundant and really make up the epidermis; they are vertically elongated, polygonal cells, which taper into a point at the inner end, so that they extend into the connective tissue layer, and thus no sharp line of division between the latter and the epidermis appears. On the digits of the tentacles these epidermal cells are as much as 50 μ in vertical length, but on the anterior part of the body they are only 20 μ, and posteriorly still less. The sensory and gland cells are scattered irregularly in the epidermis, but are much more abundant anteriorly and especially on the tentacles. The former are usually isolated and the inner end tapers into a fiber connected with a ganglion cell lying in the connective-tissue layer; the outer end may taper to a point or not. In the tentacles these sensory cells are associated in groups, forming the touch-papillæ to which reference has already been made. The gland cells are of the kind known as tubular and always occur singly.

2. The *connective-tissue layer* makes up the greater part of the wall, although, as already stated, its thickness varies greatly. Apparently it increases with age. It is thinnest anteriorly, just behind the tentacles, but becomes rapidly thicker, reaching its maximum near the middle of the body and becoming thinner again posteriorly. As in the Synaptidæ, it is made up of fibrous prolongations of bipolar or stellate cells, lying embedded in a homogeneous matrix. As fibers are very abundant, however, while the cells are rather infrequent, it is possible that many of the fibers have no cellular connections. Superficially the fibers are more or less entwined among the calcareous bodies, and so run in all directions; but in the deeper parts of the layer they run more or less parallel to the body surface. The *wandering-cells,* which stain readily with eosin (in Molpadia), but do not take carmine, are scattered in some numbers in the connective-tissue layer and among the epidermal cells. They consist of a mass of highly refractive spherules imbedded with a nucleus in a small quantity of hyaline protoplasm. The shape, as is usual with amœboid cells, is very variable. There are also *pigment-cells* in the conective-tissue layer of some Molpadids, although they are more commonly wanting. They are more or less irregular cells, with numerous fine branches, and contain a coloring matter, most commonly purple or brown, but sometimes reddish, orange, or yellowish. They are often aggregated in certain areas, thus giving rise to spots and blotches of color. In most cases the pigment is not affected by pure alcohol.

The *calcareous deposits* of the body-wall occur in the connective tissue and are only wholly wanting in a few cases. They are most abundant posteriorly, and are often present near the cloacal opening when they are not to be found elsewhere. They are formed by special mesenchyme cells, consist of almost pure carbonate of lime, and first appear as simple rods or X-shaped particles, which by continual growth and more or less regular dichotomous branching give rise to the various kinds of deposits characteristic of the different genera and species. They exhibit a very great variety of form and are accordingly difficult to classify, but we may for convenience group them under five heads: tables, shallow closed cups, perforated plates, fusiform bodies, and anchors. Commonly only one or two of these kinds occur in a single individual or species, but some specimens of Molpadia exhibit all but the second. The *tables* (Plates XI, figs. 9–11; XII, figs. 23–25, 28, 29; XIII, figs. 15–16) exhibit the greatest possible variety of form and are often so irregular and grotesque as to be quite unworthy of their name. In their simplest condition they consist of a ring (forming the disc) from which three or four vertical rods arise, more or less connected with each other by cross-bars (forming the spire), but in some cases the ring is itself incomplete and distorted, and there may be only a rudimentary spire. More commonly the disc is a somewhat circular plate with 4–12 perforations, usually symmetrically arranged and bearing a spire made up of three or four vertical rods more or less closely united by cross-bars. The tables are usually rather small, the diameter of the disc ranging from 60 to 300 μ; the spire is usually about equal to the diameter of the disc, but may be much more. In the discs of some of the largest and most perfect tables there may be as many as 70 perforations. The *shallow, closed cups* (Plate IX, figs. 4, 5, 11, 12, 13) are the least common form of deposits, occurring only in certain species of Caudina. They consist of a strongly concave plate through which are four large, symmetrically placed, equal and similar perforations. A conspicuous cross-shaped piece is so placed in the mouth of this shallow cup that each arm of the cross is immediately over the middle portion of each perforation. The margin of the cup is usually more or less octagonal, and there are often rounded knobs present at the end of each arm of the cross and half way between. When fully and normally developed, these bodies are the most symmetrical and ornamental deposits occurring among the Molpadiidæ, but they are often only partially developed, or they may be hypertrophied, especially in the caudal region. The relative thickness of the cross-arms and the margin of the cup, as compared with the diameter of the perforations, is very variable. The *perforated plates* (Plates IX, figs. 3, 8; X, fig. 4; XII, figs. 2, 5–12, 14) exhibit the greatest diversity in form and appearance; they may be nearly circular, or more or less triangular or square, or they may have one or more conspicuous projections (''arms'' or ''handles''), which may be perforated like the plate itself, or not. When a single handle is present, we have what are called ''racquet-shaped rods,'' and these are generally arranged in groups, called ''rosettes,'' with the large, perforated ends more or less overlying one another at the center. The surface of perforated plates may be provided with stout thorns or irregular projections, usually sharp, but it is commonly quite smooth. The perforations may be few and very small or more numerous and larger; commonly there are from 10–50, but there may be 60 or 70. The size of the plates is quite variable, but their greatest diameter is commonly from 100–400 μ, not including any handle. The *fusiform bodies* or *rods* (Plate XI, figs. 6–8, 13) in their typical form are elongated, rounded particles, with more or less attenuated but blunt ends, slightly flattened and enlarged at the middle and with three or four small perforations in the center of the flattened part. They lie at right angles to the long axis of the body and are often so abundant as to form a more or less distinct layer; they are most likely to be present in the extreme posterior part of the body. On the one hand they pass into the tables by the development of a spire, the enlargement of the flattened area, and the disappearance of the attenuate ends (Plate XI, fig. 12), and intermediate particles in all stages of development are often found. On the other hand they may become flattened and perforated at the ends, and thus pass by gradual transitions into the perforated plates; such intermediate forms are very common.

The *anchors* (Plates X, fig. 8; XII, fig. 5) occur only in the genus Molpadia, in some species of which they occur throughout life, while in others they are present only in youth, and in still others they are apparently never present. They were formerly supposed to be characteristic of a genus "Ankyroderma." They differ essentially from the anchors of the Synaptidæ, and their presence has no bearing whatever on the question of the relationship of that family with the Molpadiidæ. Although in a few species anchors are present in connection with a single perforated plate, in most species where they occur at all they are associated with a rosette of racquet-shaped, perforated plates, the number of which varies from three to eight in each rosette. The anchors lie at nearly right angles to the plates, though they are of course capable of movement, and ordinarily they stand out evidently from the body-surface. The attached end is never flattened and branched or serrate, as in the Synaptidæ, but is enlarged and circular in outline and perforated with several holes, the number and arrangement of which is quite variable. The free end of the anchor is provided with two (rarely three or four) arms, which are coarsely serrate with from two to six teeth. Commonly the anchors are broken off by the rough treatment the animal receives in a dredge or trawl, and the basal parts are then likely to be mistaken for peculiar cups or tables.

Besides the various sorts of calcareous bodies just described, the connective tissue of Molpadids often contains peculiar spheroidal, ovoidal, or ellipsoidal bodies, 10–100 μ, more or less, in diameter, of a characteristic yellow, brown, or red color (Plate XI, fig. 14). The color varies greatly in different individuals, but is apparently lightest in youth and darkest in old age. It first appears as a pale brownish-yellow shade, becomes more and more abundant. For many years the chemical nature of these deposits was unknown and they have commonly been called the "colored bodies," "red bodies," "wine-red bodies," or "colored calcareous bodies;" but as there was reason to think they were not calcareous, the latter name has been little used. These bodies first appear as mere spherical granules, but increase in size by the continued deposit of similar material in concentric layers, and this concentric structure is usually obvious. Oftentimes two, or even three, of these granules become enclosed ultimately in a common layer, so that the colored body seems to have been formed around two (or three) centers simultaneously. One of the remarkable things about these deposits is that they may be formed through the change of calcareous particles. (See Plate XII, figs. 10-12.) Various writers (Théel, '86*a*; Ludwig, '94; Koehler and Vaney, ;05, *et al.*) have noted the gradual coloring of a calcareous deposit and its ultimate disappearance into small groups of "colored bodies." There is no doubt that the number of "colored bodies" increases with the age of the individual, and there is good reason to believe that in many cases at least such increase is accompanied by a constant decrease in the calcareous bodies. (See antea, p. 19.) In young specimens the colored bodies, even if not wholly wanting, are often so small and few that they cannot be seen without magnification; but as the animal grows they become more numerous, are collected together in groups and patches, and appear to the unaided eye as spots or blotches of various shades. In still older specimens these blotches tend to merge together, and gradually the entire body-surface may become a uniform deep purplish red, red brown, or even almost black. If calcareous deposits still persist, they will be found normally outside the deeper-lying "colored bodies." In 1901 Mr. W. L. Sperry, then of Olivet College, kindly undertook for me a chemical examination of these colored bodies, making use of specimens of *M. oölitica, intermedia,* and *musculus.* Just after he had gone far enough to prove that the chemical elements involved were chiefly phosphoric acid and iron, Mörner's (:02) paper appeared with an account of his similar investigations. Mr. Sperry continued his work far enough to confirm Mörner's analyses; so that the composition of these remarkable "colored bodies" may be considered as settled. Mörner gives the result of his analysis as $FePO_3+4\ H_2O=66.2$, $Fe(OH)_3=20.2$ and $CaCO_3=6.4$. Mr. Sperry's analysis differed from this only in a few details, the most interesting of which was the probable presence of Mg. There is also reason to believe that the amount of $CaCO_3$ is subject to much variation; probably when calcareous particles are first transformed into the colored bodies, $CaCO_3$ is the most important substance present, and as the color deepens, it decreases rapidly in amount. Apparently the calcium as well as the CO_2 is excreted as these changes take place. In view of their remarkable composition, we are justified in referring to the "colored bodies" as "PHOSPHATIC DEPOSITS," in distinction from the "calcareous deposits" so characteristic of holothurians. The presence of phosphatic deposits is limited among Echinoderms, so far as is now known, to about 20 species of Molpadids, all but two of which belong to the genus Molpadia. The "round" spicules with a "radiate" appearance, described and figured by Danielssen and Koren ('82) in connection with their account of *Trochostoma thomsonii,* have not been met with by other investigators, and Théel ('86*a*) is doubtless correct in considering them as artifacts.

3. The *transverse muscles* lie just beneath or within the connective-tissue layer, and, unlike the arrangement in the Synaptidæ, are confined for the most part to the interradial areas. The fibers are inserted in the connective tissue a little to the side of each radius, and may be so few that when the animal is extended they do not form a continuous layer. Just behind the tentacles they are more numerous, and are continuous across the radii, thus forming a circular muscle which serves as a sort of anterior sphincter when the tentacles and oral disc are retracted. In Caudina and Aphelodactyla, and probably in all Molpadids where the connective-tissue layer is sufficiently thick, there run out into

that layer, from the transverse muscles, irregularly scattered tubules made up of muscle fibers arranged in the form of a hollow cylinder. While it is not impossible that these are the last vestiges of the ambulacral vessels, such a view seems very doubtful, as the tubules are never connected with the radial water-vessels, but always with the transverse muscle. Gerould ('96) thinks that they serve to support the transverse muscles and to unite more firmly the various parts of the integument. Semper ('68) mistook them for rudimentary ambulacral vessels, and Danielssen and Koren ('82) and Sluiter ('80) have apparently fallen into a similar error; yet it should be added that Gerould failed to find similar tubules in the skin of either *Molpadia antarctica* or *Ankyroderma jeffreysii* (*M. oölitica* juv. ?); both of these species, however, have a very thin skin.

4. The *radial longitudinal muscles* are arranged in pairs in most of the Molpadiidæ, but in Eupyrgus and Himasthlephora they form a single band, as in the Synaptidæ. (See Plates XII, fig. 27, and XIII, fig. 4.) They lie on each side of the radial water-vessel, but anteriorly the interradial edges of each pair of muscles curve inward until they meet, while the adradial edges also merge together just beneath or inside the radial vessel, and thus the two muscles form a single hollow tube, which loses its lumen where it is attached to the radial plate of the calcareous ring. This single muscle band may be of considerable length and more or less laterally compressed; the connection between the edge attached to the body-wall and the edge extending into the body-cavity may be reduced to a mere sheet of connective tissue (see Perrier, :04*a* and :05) or may even be severed entirely. As the inner portion is connected with the calcareous ring, we should have in the latter case what have been called *retractor* muscles. But the formation of such retractors appears to be a very uncommon, if not an altogether exceptional, event, possibly only occurring in certain individuals, perhaps very old ones, and the presence or absence of such retractors cannot be considered as having any value in taxonomy. Moreover, when strongly contracted the ordinary longitudinal muscles may appear as though they were special retractors, and in such cases the presence or absence of "retractor muscles" becomes a matter of personal opinion of the investigator. Posteriorly the muscles of each radial pair become semicylindrical trunks which may simply lie side by side or actually coalesce. They finally terminate in the connective tissue about the cloacal opening.

5. The *inner epithelium* is the innermost layer of the body-wall, and consists of flat, polygonal cells, which are everywhere provided with cilia.

Body-cavity.—The body-cavity of the Molpadiidæ is very capacious and shows no particular peculiarities. In those forms which have a caudal appendage the body-cavity within that appendage is generally reduced, and is nearly filled up by the strands of muscular and connective tissue connecting the alimentary canal and the body-wall. So far as known, the body-cavity is never in normal communication with the outside, but it is connected through the madrepore body and stone-canal with the water-vascular system, and the fluid with which it is filled is probably not essentially different from that in the water-vessels.

Calcareous ring.—The calcareous ring in the Molpadiidæ is as a rule very well developed and in the great majority of cases is remarkably wide, the radial pieces (except in Eupyrgus (Plate XII, fig. 19), Himasthlephora (Plate XIII, fig. 2) and Gephyrothuria) being provided with conspicuous bifurcate posterior prolongations (Plate XII, fig. 3). So far as known, there are always five radial and five interradial pieces which make up the ring, the latter being much the smaller. The supposed exceptions in "*Embolus pauper*" and "*Liosoma arenicola*" are obviously based on mutilated or imperfect specimens, or else on hasty or careless examination. There is usually no appreciable asymmetry in the ring, though occasionally the ventral half is somewhat better developed than the dorsal. The interradial pieces are much smaller than the radial, are symmetrical, slightly concave behind, and have a single median point in front; on each side of this point the plate is a little flattened or hollowed for the reception of a tentacle ampulla or the attachment of the basal part of the tentacle canal. The radial pieces are perfectly symmetrical only in Ceraplectana (Plate XIII, fig. 7), where each has a single anterior median point to which the longitudinal muscle is attached; no tentacles are associated with the radial pieces in this genus. In all the other genera the radial pieces are much broader than the interradial and are provided with two anterior projections, which, however, are not just alike. One is broader than the other and serves for the attachment of the longitudinal muscle (Plate IX, fig. 2); it is sometimes perforated for the passage of the radial nerve (?). The lateral radial pieces of both sides are so placed that the attachment of the muscle is on the lower or ventral projection, while a tentacle ampulla or the base of a tentacle canal lies just dorsal to it. The ventral radial piece has the muscle attached sometimes to the right, sometimes to the left projection, but the tentacle canal is always between the projections. No cartilaginous ring, posterior to the calcareous one, ever occurs in the Molpadiidæ.

Water-vascular system.—The circular canal lies just posterior to the calcareous ring, with which it is often more or less united by strands of connective tissue. Its lumen is a millimeter, more or less, in diameter, while its wall is exceedingly thin. The wall consists of an epithelial layer of ciliated cells, continuous with that elsewhere in the body-cavity; a layer of connective tissue consisting chiefly of fibers running parallel to the direction of the canal and containing numerous wandering cells; a thin, structureless membrane; a layer of muscle fibers which run around the canal (at right angles to its direction) and are thus truly "circular" muscles, and an internal epithelium of flat, ciliated cells. From the circular canal arise five radial and two interradial tubes; the former become the "radial canals" of the body-wall and give rise to the tentacle canals, while the latter are the stone-canal and polian vessel. The stone-canal is always single and unbranched in the Molpadiidæ; it leaves the circular canal in the median dorsal interradius and lies between the two layers of the dorsal mesentery; it is an irregular, twisted tube, proportionately small, running forward and upward, to terminate within the body-cavity in a whitish madrepore plate or body. This madreporite is flattened on one side and more or less convex on the other; it contains a central cavity which is directly continuous with the lumen of the stone-canal and opens into the body-cavity through numerous pore-canals, which may be more or less branched. According to Danielssen and Koren ('82), in Molpadia the madreporite is not at the end of the stone-canal, but the latter terminates in the body-wall beyond it. The stone-canal and madreporite consist of connective tissue covered externally with the flat, ciliated epithelium of the body-cavity and lined internally with a layer of still more conspicuously ciliated cells. In the stone-canal these latter cells are low and cubical on the side next the mesentery, but become much higher on the opposite side; the cilia which they carry are about equal to the height of the cell. According to Danielssen and Koren, the stone-canal of Molpadia contains abundant calcareous deposits, but in *Caudina arenata* these are wholly wanting. The madreporite, however, always consists chiefly of closely interlocked, irregularly branching, calcareous bodies. The polian vessel, like the stone-canal, is always single and unbranched in the Molpadiidæ; it leaves the circular canal in the left ventral interradius. It varies considerably in size, but is always relatively small. The histological structure is similar to that of the circular canal, only the layer of circular muscle fibers is much thicker. The radial canals are largest where they leave the circular canal, and become rapidly smaller by giving off three branches, from which the tentacle canals are formed. Each radial canal runs forward on the inner or axial side of a radial piece of the calcareous ring, just anterior to which it gives off the tentacle canals, either one on each side at the same level, and then the third one further up, or all three at different levels; then it bends backward along the inner or axial side of the hyponeural canal and runs to the extreme posterior tip of the body, where it terminates in one, three, or more rudimentary ambulacral appendages. In its histological structure the radial canal differs from the circular canal chiefly in the absence of any circular muscles; the external covering of a ciliated epithelium is also lacking after it turns backward in the body-wall, save as it is indirectly covered on its inner side by the lining of the body-cavity. On the side of the radial vessel next to the hyponeural canal there are present some longitudinal muscle fibers between the connective tissue and the epithelium lining the radial canal, and a few of these may accompany the vessel nearly to the circular canal, in which region they would of course lie on the inner or axial side. The tentacle canals are not peculiar histologically (see p. 137), but are provided with valves consisting of connective tissue and radial muscle fibers covered with epithelial cells on both sides. These valves are situated with the concave side toward the tentacle, and thus prevent the passage of fluid *from* the tentacle canals. Gerould ('96, p. 47) says the valve is in the "radial canal near its junction with a tentacular vessel," which might mean that there is one valve or that there are three valves in each radial canal; but in his explanation of Plate VI, fig. 77, he says the section is through "a tentacular canal * * * showing the valve of the tentacle," which indicates that there are 15 of these valves, as we would expect, placed one in each tentacle canal. In most Molpadids each tentacle canal not only runs forward with the tentacle, but extends backward on to the outside of the calcareous ring to which it is closely attached (see Plates X, fig. 1; XI, fig. 3). Commonly this backward extension is prolonged considerably past the posterior margin of the ring and hangs free in the body-cavity as a "tentacle-ampulla." These ampullæ are not histologically peculiar, save that the longitudinal muscles of the tentacles extend backward only into the outer anterior wall. The occurrence of well-marked ambulacral appendages is confined to the genera Himasthlephora (Plate XIII, fig. 1) and Gephyrothuria, where each of the two dorsal radial vessels gives rise to a very few (2–5) ambulacral canals, which are provided with ampullæ (Plate XIII, figs. 3, 4) and connect with the remarkable lash-like papillæ characteristic of those two genera. In Gephyrothuria and all other Molpadids the radial canals run backward to the cloacal opening, where they terminate in "anal papillæ." These papillæ are often very insignificant, but may be very distinct; their walls generally contain an unusual number of calcareous bodies, but may be wholly free from them. Their presence or apparent absence in preserved specimens is dependent not only on the amount of contraction, but on individual diversity and possibly to some extent on age. Although commonly single, the anal papillæ may be accompanied by two, or even more, somewhat smaller lateral ambulacral vessels, so that there is a small group of papillæ at the end of each radius, and even when the anal papillæ are very small and apparently single, a pair of lateral vessels may be present beneath the skin, as Gerould has shown to be the case in *Caudina arenata*. In histological structure these vessels and the anal papillæ are similar to the pedicels of other holothurians; the wall consists of a thin, connective-tissue membrane, a layer of longitudinal muscles and a lining epithelium; the anal papillæ have an outside layer of connective tissue containing blood sinuses and often calcareous bodies and are covered with the ordinary body-wall epithelium. In Himasthlephora the group of pedicel-like outgrowths are at the *base* of the caudal appendage, and rudimentary pedicel-like bodies also occur at the anterior end of the body, but apparently none of these are now in connection with the radial canals. The fluid contained in the water-vascular system is probably not essentially different from that in the body-cavity, since there is constant communication possible through the madreporite, but there are a much larger number of corpuscles and wandering cells in the contents of the water-vascular system. The corpuscles are yellowish when seen singly, but in mass appear to be red. The lumen of the polian vessel is sometimes nearly filled with dark-brown, apparently dead, wandering cells.

Alimentary canal (Plate X, fig. 1).—The *mouth* is a circular opening in the center of the oral disc at the anterior end of the body and is connected with the stomach by a straight, rather short tube, which is commonly called the *pharynx*, although it corresponds to the œsophagus of the Synaptidæ and is not specially modified in any way. The *stomach* is simply a slight enlargement of the alimentary canal and is relatively short (say one-tenth of the total length). It opens posteriorly into the *small intestine*, which extends backward only a short distance and then bends abruptly forward for a greater or less distance, finally turning backward, ventral to the other viscera, as a *large intestine*, which runs to the posterior tip of the body. The hinder part of the large intestine is rather abruptly enlarged where it receives the respiratory trees and forms the *cloaca*, the length of which is closely associated with the development of the caudal appendage. The various sections of the canal as here given are not, as a rule, sharply set off from each other, although, according to Gerould, they can be easily distinguished in living or freshly killed specimens of Caudina. They all have a very similar histological structure, consisting of an outer epithelium continuous with that of the body-cavity, a thin layer of connective tissue, a muscular layer, a thick layer of connective tissue, and a lining epithelium. The relative development of these layers differs in the different parts of the canal. The pharynx when relaxed is somewhat larger at the mouth than where it joins the stomach, but may be wholly closed anteriorly by the well-developed sphincter muscle, composed of circular muscle fibers which gradually thin out on the oral disc. Posteriorly, the muscle layer of the pharynx contains longitudinal fibers within the circular series; the epithelial lining of the pharynx contains many gland cells, is covered by a delicate cuticle, and is thrown into longitudinal folds. The pharynx is held in position by 10 longitudinal series of connective-tissue strands containing muscle fibers; these unite it with the inner surface of the calcareous ring, and are called *suspensors* by Gerould. In the wall of the stomach the longitudinal muscle layer is very well developed, as is the circular series, while the lining epithelium, consisting of high columnar and gland cells, is covered with a delicate cuticle.

In the small intestine the longitudinal muscle layer is practically wanting, while the lining epithelium is remarkable for the absence of gland cells and cuticle. In the large intestine the epithelial lining is much the same, as it is also in the cloaca, but in the latter the longitudinal muscle layer is functionally replaced by about 20 isolated, irregularly arranged, small longitudinal muscles lying outside the circular layer. The numerous strands connecting the cloaca with the body-wall are similar in structure to the suspensors of the pharynx already referred to. In Eupyrgus the walls of the cloaca are strengthened by five large calcareous plates lying in the interradii (Plate XII, figs. 18, 26), while in Aphelodactyla the cloacal wall contains irregularly branched calcareous particles (Plate X, fig. 6). Throughout the alimentary canal, wandering cells in various forms (perhaps stages of development) are abundant, particularly in the internal epithelial layer. The mesentery which supports the alimentary canal consists of a very thin sheet of connective tissue containing isolated muscle fibers running in various directions and covered on both sides by the epithelium of the body-cavity. That part which supports the pharynx, stomach, and first part of the small intestine is attached to the body-wall on the right side of the dorsal interradius; the part which supports the forward-running section of the small intestine passes over into the left dorsal interradius, close beside the left dorsal radial muscle; when the large intestine bends backward, the mesentery bends sharply to the left and crosses into the *right* ventral interradius, where sooner or later it terminates. In *Caudina arenata* it only gives attachment to the large intestine for a short distance, but the latter is supported by "two sheets of separate muscular strands," arising in the posterior part of the right and left dorsal interradii, close to the right and left ventral radial muscles.

Respiratory trees (Plates X, fig. 1; XII, fig. 26).—The respiratory trees consist of two branches, the *right* and *left*, which either arise separately from the enlarged part of the cloaca or have a common opening into that organ; in the latter case there may be quite a distinct common trunk of greater or less length. The right branch consists of a single main tube, with more or less numerous and conspicuous lateral out-growths, and may run forward clear to the calcareous ring. The left branch, when fully developed, consists of two main tubes, one of which is associated with the large intestine, and may be called *ventral*, while the other lies in close connection with the blood plexus of the small intestine, and may be called *dorsal*. Although the right branch is commonly larger than either the left dorsal or left ventral alone, the left branch as a whole has a much greater capacity than the right. In Eupyrgus (Plate XII, fig. 26), however, the left branch is undivided and only equals the right in size, both being quite rudimentary, and a similar condition exists in Gephyrothuria and Himasthlephora. The histological structure of the respiratory trees is strikingly like that of the intestine. The outermost layer is a thin epithelium of very flat, irregularly polygonal, ciliated cells, followed by a thin layer of connective tissue. Then comes a muscle layer, the fibers of which run in all directions parallel to the surface, but the innermost are circular and are more numerous than the outer oblique and longitudinal fibers; then follows a thick connective tissue layer, and lastly an inner epithelium. Presumably the less developed the trees are, the less well developed will the muscle layer be. There are no openings by which the trees can communicate with the body-cavity, but all the branches end blindly.

Cuvier's organs (Plate X, fig. 10).—The occurrence of these organs in the Molpadiidæ is still open to considerable doubt. They have only been reported in a few specimens of Caudina from Chile, and no account of their finer structure has yet appeared. They are said to consist of a small tuft of spherical bodies of a brown color, somewhat like a bunch of grapes in form, attached to the cloaca near the base of the respiratory trees. That these organs are homologous with the true Cuvier's organs of other holothurians is by no means sure.

Blood system.—The arrangement of the hæmal lacunæ is very similar to what it is in the Synaptidæ, but has been studied carefully only in *Caudina arenata*. In this species Gerould ('96) recognizes four parts to the system: circular lacunæ, intestinal lacunæ, lacunæ of the reproductive organs, and tentacular and radial lacunæ. "The circular lacunæ, which form the center of the system, occupy the connective tissue of the wall of the stomach immediately behind the circular canal of the water-vascular system." They occur in the numerous out-growths of the outer layer of connective tissue of the stomach. The ring is therefore diffuse and ill-defined. The intestinal vessels occur, one on the dorsal, the other on the ventral side of the alimentary canal. Gerould does not say whether they are connected with the circular lacunæ or not, but as he says they contain numerous blood-corpuscles, while other parts of the system do not, it would appear that there is no direct connection. No statement is made either as to connection between dorsal and ventral vessels, but presumably they are connected by lacunæ in the intestinal wall. The ventral vessel on the stomach and first part of small intestine is connected by several cross-branches with that of the second section of the intestine, while at the anterior bend of the intestine the two parts of the ventral vessel are connected by a delicate sheet of anastomosing vessels. "The two parts of the dorsal intestinal vessel are likewise connected by anastomosing cross-vessels." The lacunæ of the reproductive organs run longitudinally in the connective tissue of the wall; no statement is made as to their connections. The radial and tentacular vessels arise from the circular lacunæ on the inner or axial side of the tentacle canals and run outward into the tentacles; the main vessel bends backward with the radial canal and runs clear to the cloacal opening, lying between the radial water-vascular and hyponeural canals; at the extreme posterior end of the body a circular lacuna surrounds the cloacal opening and unites the radial vessels. None of the lacunæ or vessels has any epithelial lining or any other indication of definite walls, save that the intestinal vessels have the superficial appearance of true vessels; the interior, however, is "filled with loose strands and cells of connective tissue." The fluid within the system is a colorless plasma with occasionally wandering cells, and in the intestinal vessels numerous blood-corpuscles which give the vessels in the living animal a pinkish color.

Reproductive system.—The reproductive organs of the Molpadiidæ consist of the same parts which occur in other holothurians—*i. e.*, a genital duct and tufts of genital tubules. The duct opens to the exterior in the mid-dorsal interradius just back (1–5 mm.) of the tentacles, and the outlet is often indicated by a more or less prominent genital papilla, of a somewhat conical shape and sometimes as much as 2–3 mm. in length. The duct runs downward from the tip of this papilla into the dorsal mesentery, and then backward for some little distance (5–25 mm.) to the point where it divides, and terminates in tufts of genital tubules hanging free in the body-cavity, one on each side of the mesentery (Plate XI, fig. 3). The wall of the duct consists chiefly of connective tissue, lying in which are the longitudinal muscle fibers and wandering cells; outside is the usual flattened peritoneal epithelium, while the interior of the tube is lined with a strongly ciliated, columnar epithelium. In *Caudina arenata* (according to Gerould, '96) this inner epithelium is composed of elongated, spindle-shaped *collar-cells,* the flagella of which are conspicuously long. At the outer end of the duct is a small sphincter muscle of a few circular fibers, while at the opposite end, where the duct divides, a circular muscle layer outside the connective-tissue layer is present in each branch. The genital duct of the male is usually much smaller near the outer end than posteriorly, where there is sometimes a spindle-shaped enlargement. The genital tubules make up a tuft of 6–8 or more on each side of the mesentery, the number of tubules probably increasing with age. The tuft of the left side is sometimes the larger. The tubules may be very short (5–10 mm.) or long, at times reaching clear to the posterior end of the body-cavity; they may be simple and undivided or dichotomously branched. Their wall is made up of the usual peritoneal epithelium, a thin layer of circular muscle fibers, a layer of connective tissue, in which are conspicuous blood lacunæ, and an inner germinal epithelium, which is not uniform and continuous throughout, but scattered in more or less irregular masses. As the sexes are always separate in the Molpadiidæ, the product of this epithelium will be either eggs or spermatozoa, as the case may be. In *Caudina arenata* the sexes can be distinguished by the color of the tubules, which, however, is due to their contents and not to any pigment. In the mature male the tubules are light yellow, while in the female they are pale brown.

EMBRYOLOGY.

Nothing whatever is known of the embryology of the Molpadiidæ, save that Gerould ('96) has studied the oögenesis (and to some extent the spermatogenesis) of *Caudina arenata*. The mature ovum is about 200 μ in diameter, and has a conspicuous and peculiar micropyle. The mature spermatozoan is about 60 μ long, with the head about 3.6 μ in diameter.

PHYSIOLOGY.

Almost nothing is yet known of the vital activities of the Molpadiidæ, for few zoölogists have ever had the opportunity of carrying on extended observations on living specimens. Sluiter ('88) has kept specimens of *Aphelodactyla punctata* alive in aquaria, and Gerould ('96) has had similar success with *Caudina arenata*, but neither has published any extensive account of the physiology or habits of these species.

MOTION.—The movements of the Molpadiidæ are accomplished by muscular contraction, aided by the fluids in the tentacles and body-cavity. It is possible that in some cases (such as in young Molpadiæ) the calcareous particles may assist; but certainly, in many cases, the deposits of the body-wall play no part. Movement forward is possible only when the animal is buried in the sand or mud. If placed on the surface, the first movements are downward, and continue until the animal is buried. The movement, either downward or forward, is accomplished partly by swallowing the sand or mud immediately in front of the oral disc, but chiefly by backward and forward radial movements of the tentacles; these movements are effected by the alternate contraction of the longitudinal muscles of their outer and inner sides. The contractions of the muscles of the body-wall do not appear to play any important part in progressive movements, but are actively concerned in respiration (*q. v.*). The rate of progressive movement is exceedingly slow, perhaps averaging about 1 mm. per minute.

DIGESTION AND ABSORPTION.—The food passing into the stomach doubtless undergoes the first stages of digestion there; but, if we may infer anything from the distribution of the blood-vessels, the chief activity of the alimentary canal is in the small intestine. In that region and the first part of the large intestine probably all the absorption occurs, but nothing is really known as to the physiology of the digestive system.

CIRCULATION AND NUTRITION.—Here again we have to infer from structure, for we know nothing definitely. The extensive hæmal system would seem to indicate that the absorbed food material is transported by it to all parts of the body, but there is obviously no true circulation of the fluid, the plasma simply moving outward into the tissues, bearing the essential food. The indigestible material finally passes into the cloaca and is thence washed out by the currents of water from the respiratory trees.

Respiration.—According to the observations of Gerould ('96), the tentacles seem to play an important part in obtaining the all-essential oxygen for the use of the body. The fluid contained in the water-vascular system contains numerous colored corpuscles which appear to react toward oxygen like true blood-corpuscles, and there is a continuous circulation of the fluid, at least in the tentacles. The flow is forward on the inner side to the tip of the terminal pair of digits, and then back and outward to the tip of the other pair; then backward into the ampulla. "When aëration becomes poor, the tentacles and buccal region become distended with the water-vascular fluids and the posterior part of the body becomes pale and contracted." Elsewhere (page 10) Gerould says: "The color, which depends upon the state of aëration of the blood, varies from pink to a purplish hue." Apparently the word "blood" is used here to include all the fluids of the body which contain blood-corpuscles (water-vascular, body-cavity, and hæmal). But respiration is also greatly facilitated by the so-called respiratory trees, and it is probably chiefly from these that the body-cavity and hæmal fluids get their oxygen. Indeed, when we consider the habit of most Molpadids of lying buried in mud and sand, with only the tip of the tail above the surface, it seems probable that the tentacles play an important part in respiration only under unusual conditions. Both Sluiter ('88) and Gerould ('96) are agreed that water is forced out of the respiratory trees and drawn into them through the cloacal opening "by the alternate contraction and relaxation of these organs and of the wall of the body. The latter, by reason of its natural rigidity, resumes its normal shape when its circular muscles are relaxed, and so increases the capacity of the body-cavity, thus bringing about an influx of water. These movements are accompanied by the correlated opening and closing of the cloacal opening through the alternating contractions of the radial and sphincter muscles." Sluiter says that in Aphelodactyla there were two or three respiratory movements per minute, and Gerould found that in Caudina the same is true; he says further that the cloacal opening was "generally kept open 18–20 seconds, and then closed for 13–17 seconds," and that while there is some irregularity in the length of the periods, that "of dilation always slightly exceeds that of closure." Aside from the fact that such regular respiratory movements would not be likely to occur if the function of the "trees" was purely excretory, the intimate relation between that organ and the intestinal hæmal vessels, which contain numerous blood-corpuscles, would lead us to believe that the bringing in of oxygen was one of its important functions. Very possibly oxygen may also be obtained through the skin by corpuscles in the radial water-vascular canals and particularly near their posterior termination.

Excretion.—That the respiratory trees function to some extent as excretory organs seems very probable, not only because they are the most obvious organs to which such a function could be assigned, but because the same organs in pedate holothurians are known to play that part. Excreta is probably gathered not only from the fluid of the body-cavity, but from the hæmal system also. The presence of wandering cells in large numbers throughout the body is evidence that excretion by means of those peculiar cells is continually going on. Whether the change of calcareous deposits into phosphatic bodies is associated with excretion is still to be demonstrated.

Sensation.—Aside from the sense of touch, Molpadids are not known to possess any capacity for sensation. No observations have been recorded that show reaction to any other than mechanical stimuli, except Sluiter's ('88) statement that Aphelodactyla shows its oral end above the mud only at night. If this is really the case, it might indicate a reaction to light, which would be very interesting, as no light-detecting organs are known to occur in the family. It is probable that the tentacles and the cloacal papillæ are the most important seats of the tactile sense.

Regeneration.—No observations have been recorded as to the possibility of regeneration among the Molpadiidæ.

Reproduction.—The method of reproduction is exclusively sexual and the sexes are always separate. No viviparous species are known nor any which care for the young in any way. Nothing whatever is known as to the extrusion, fertilization, or segmentation of the eggs, nor as to the time, place, and conditions of breeding. In *Caudina arenata,* Gerould ('96) found that the spermatozoa were mature and extruded in February, March, and April, but he failed to secure mature ova.

Ecology.

The Molpadiidæ are all marine animals and have a bathymetrical range from a little below low-water mark to at least 3,900 m. The great majority, however, occur only at depths of more than 100 m., and consequently little is known of their habits. Although occurring in all parts of the world, they seem to be most abundant in the Indo-Pacific region, while comparatively few are known from the tropical and subtropical Atlantic. They are common in both the Arctic and Antarctic oceans, though the number of species in those regions is not large. So far as is known, the Molpadids show great similarity of habitat and habits and are found only on soft sandy or, more commonly, muddy bottoms. Here they lead an almost exclusively subterranean life, only disturbed by the rare appearance of a dredge or trawl, or the occasional intrusion of some fish in search of a meal. Those which live in shallow water near shore are occasionally disturbed by heavy gales, which ultimately succeed in digging them out and washing them up on shore; probably four-fifths of the specimens of *Caudina arenata* which have been collected have been the victims of such gales. The food of the Molpadids seems to be exclusively the organic matter which they digest out of the sand and mud which passes into the mouth with every forward movement. Whether this mud is sucked in or pushed in by the tentacles is not known. Apparently the Molpadids are the least active of all holothurians, and it would seem to be the case that they often lie unmoved for hours, if not days, at a time. Sluiter ('88) says that his specimens of Aphelodactyla in captivity were more active at night than during the day, as they then showed the oral disc and tentacles above the mud; it is probable, however, that this change of position was due to the condition of the water (amount of oxygen, etc.) rather than to absence of light. The shallow-water species of Caudina and Aphelodactyla seem to thrive well in aquaria, with proper care, and it is to be hoped that we may soon have more information in regard to their habits and physiology. The Molpadids are often eaten by bottom-feeding fishes, but are not known to have other enemies. No parasites have yet been described of which they are hosts. The Molpadiidæ are of no value whatever to man in any direct way, though as an article of food for fishes they may play a slight part in benefiting him. Nothing whatever is known of their geological history.

TAXOLOGY.

The classification of the Molpadiidæ herein adopted and the reasons therefor are fully discussed on pages 17–21, and the principles which have governed the acceptance or the rejection of species are essentially the same as those which were used in connection with the Synaptidæ. (See antea, pp. 68–70.) Here as there, the form and distribution of the calcareous particles is the most important character for distinguishing species, but in the Molpadiidæ the phosphatic deposits are also to be taken into account. Color, size, and body-form are usable characters in some cases, and the texture of the body-wall is also of importance at times. Of characters for distinguishing genera the number and form of the tentacles and digits, the presence or absence of ampullæ and posterior projections on the radial pieces of the calcareous ring, and the presence or absence of a caudal appendage are the best; but size and the development of phosphatic deposits are sometimes to be considered. Most of the genera here recognized are quite distinct groups, but it must be acknowledged that Caudina and Molpadia intergrade, while it is extremely likely that Himasthlephora is a synonym of Gephyrothuria. The situation among the species is much worse, for both Molpadia and Caudina contain badly confused species and groups of species and Aphelodactyla is little better off. It is sincerely hoped, however, that the attempt here made to bring some kind of order out of this chaos may prove a useful foundation for the future work, which shall satisfactorily solve all of the perplexing riddles which the taxology of this family presents.

Key to the Genera of Molpadiidæ.

A.—Body surface with no appendages whatever; skin usually with either calcareous or phosphatic deposits, or both: calcareous ring usually with posterior prolongations; tentacles usually with ampullæ.

B.—Tentacles 15, soft.

C.—Tentacles with 3-7 digits.

D.—Posterior end of body tapering, usually with a more or less conspicuous caudal appendage; calcareous particles various.

Tentacles with 3-7 short, blunt digits, counting the distinct terminal portion (plate XI, fig. 1); caudal appendage (plate XIII, fig. 14) usually less (sometimes more) than one-third of total length, sometimes not distinctly set off from body, which generally has colored phosphatic deposits in skin .... Molpadia

Tentacles with 2 pairs of rather long, pointed digits (plate X, fig. 2); terminal digit practically wanting; caudal appendage (plate IX, figs. 1, 6, and 9) one-third or more of total length, usually abruptly distinct from body, which very rarely has colored phosphatic deposits in skin .... Caudina

DD.—Posterior end of body blunt and rounded, without a trace of a caudal appendage; calcareous particles, thick plates with a few sharp projections and small perforations.................................. Acaudina

CC.—Tentacles simple, without digits (plate XII, fig. 22).

Tentacles without ampullæ; radial pieces of calcareous ring, without posterior prolongations; size very small, under 25 mm................. Eupyrgus

Tentacles with ampullæ; radial pieces of calcareous ring with posterior prolongations; size large, 40-200 mm. .... Aphelodactyla

BB.—Tentacles 10, horny and undivided (plate XIII, fig. 6)............. Ceraplectana

AA.—Body surface with a few whiplash-like appendages in mid-dorsal interambulacrum; no calcareous or phosphatic deposits; calcareous ring with no posterior prolongations; tentacles without ampullæ.

Caudal appendage long and slender; tentacles with 4 digits...... Himasthlephora

No caudal appendage (or perhaps a rudimentary one); tentacles with only 2 digits. Gephyrothuria

MOLPADIA Cuvier, 1817.

Haplodactyla Grube, 1840 (non Semper).
Liosoma Stimpson, 1857 (non Brandt).
Embolus Selenka, 1867.
Trochostoma Danielssen and Koren, 1877.
Ankyroderma Danielssen and Koren, 1879.

Tentacles 15, with one, sometimes two, rarely three, pairs of digits and a terminal digit which is commonly the largest of all. Body rather stout, usually with a distinct but short caudal portion, which is generally much less than one-third of the total length. Radial pieces of calcareous ring with conspicuous bifurcate posterior prolongations. Calcareous deposits in the form of tables, often very imperfect; perforated plates, and more or less fusiform rods. In many cases anchors are also present in connection with either a single irregular plate or a group of 2-8 plates, which are often racquet-shaped and form a rosette from which the anchor rises. Phosphatic deposits of a yellow, brown, or deep-red color are very commonly present.

This large and widespread genus is most unsatisfactorily known and we are only just beginning to realize the difficulty of distinguishing real specific limits within it. Of the 27 species here listed only seven are known from any considerable number of specimens, while of the remaining 20, six are known from only a single specimen each, and eight others from fewer than five specimens. Some will probably prove to be forms (perhaps different ages) of a single species, while in other cases, such as *musculus*, there are probably several distinct species included under one name. There is room for wide difference of opinion as to the validity of many species here admitted, and of many of the combinations of species, previously held to be distinct, here made. There can be little question, however, that, in some of the species at least, the presence of anchors is associated with immaturity and that with increasing age there is a gradual transformation of the calcareous deposits, beginning with the anchors and rosettes, into the peculiar, colored, phosphatic bodies. Of the significance of this change we know nothing. (For a full discussion of the evidence, see antea, p. 18). The species of Molpadia occur only in deep water and on muddy or fine sand bottoms. The bathymetrical range is from 35 to 3,900 m., but they rarely occur in less than 200 and not commonly in more than 2,000 m. Apparently cold water and a soft bottom are essential to them. It would be well if we could leave out of account in the following key all reference to the anchors and their plates, but in the present state of our knowledge that cannot be done. They have, however, been ignored as far as possible. I have been unable to find any descriptions in any of Verrill's publications of three species attributed to him, namely, *Trochostoma abyssicola*, *Trochostoma ayresii*, and *Ankyroderma limicola*. They seem to be "*nomina nuda*" and are consequently ignored. I am unable to identify Cuvier's type species (*holothurioides*) with any of the species known today, but I have very little doubt that the specimen was an example of *musculus*. As there *is* room for doubt, however, it seems to me unwise to attempt to replace the universally used name by the earlier one. On the other hand, I cannot include Cuvier's species in my key or otherwise, for from a modern point of view it has no distinctive characters. I have therefore placed it doubtfully as a synonym of *musculus*. In using the following key it should be borne in mind that young individuals of any species may lack phosphatic deposits, while very old specimens may lack calcareous deposits. In at least one species (*musculus* as here defined), and possibly in others, phosphatic deposits appear to be absent at times in otherwise normal adults. More than ordinary care should therefore be exercised.

Key to the Species of Molpadia.

A.—Anchors wanting, or, if present, with only 2 arms and associated with a rosette of 3-8 perforated plates (plate XII, fig. 5).

- *B.*—Phosphatic deposits present, often in abundance.
  - *C.*—No true supporting rods, fusiform bodies or elongated perforated plates present, though the discs of the tables may be narrowed and drawn out into a rod at each end.
    - *D.*—Tables of body often very irregular and distorted; sometimes wholly wanting, the disc seldom with more than 8 holes (those in the tail may have 20-30 holes).
      - *E.*—Tables with a more or less distinct disc, having 2-8 or more (usually 3-6) holes, often with irregular outline and marginal projections (plate X, fig. 14).
        - *F.*—Tables of moderate size, the disc 90-350 μ in diameter, usually with only one spire.
          - *G.*—Tables often wanting in skin of body, present in tail; disc quite asymmetrical; spire of moderate height and often with teeth or branches at top.
            - Discs of tables in tail narrowed and elongated, the ends drawn out into rods; spire usually of a single rod (plate X, fig. 14) .... OÖLITICA
            - Discs of tables not specially narrowed nor elongated; spire very irregular .... CONCOLOR
          - *GG.*—Tables present in skin of body; disc rather symmetrical, with 3-6 or more holes; spire high (plate X, fig. 15; plate XII, fig. 15).
            - Discs of tables in tail not specially narrowed nor with numerous holes .... INTERMEDIA
            - Discs of tables in tail somewhat narrowed and drawn out at the ends, with numerous (10-30) holes (plate X, fig. 15*c*) .... ANDAMANENSIS
        - *FF.*—Tables very small, the disc less than 70 μ in diameter, often with 3 or 4 small, incomplete spires (plate X, fig. 16). SIMILIS
      - *EE.*—Tables of body less regular, often without distinct disc or spire, or with the rods composing the disc not united at their outer ends.
        - *F.*—Tables of the body-wall over 150 μ across, with a disc composed of 6 or more slender diverging rods usually not united at their outer ends .... AFFINIS
        - *FF.*—Tables much smaller, not provided with such a disc.
          - Body tables more or less circular, about 60-70 μ in diameter; caudal tables well formed, with conspicuous spire. .BORETZII
          - Body tables very irregular, 90-100 μ across; caudal tables not specially different (plate XIII, figs. 15 and 16)....AMORPHA
    - *DD.*—Tables more regular, with very high spire, and the disc more or less circular, with 12-40 holes.................................. TURGIDA
  - *CC.*—Supporting rods, fusiform bodies, or elongated perforated plates present, at least in the tail (plate XI, figs. 6, 7, 8, and 13).
    - *D.*—Fusiform bodies rod-like, usually with narrow, rounded, unperforated, and undivided ends, occurring all over the body, sometimes flattened and widened in the tail.................................. MUSCULUS

DD.—Fusiform bodies with flat, widened ends, or replaced by more or less elongated perforated plates.

E.—Fusiform bodies largely replaced by big perforated plates (plate x, fig. 18).

Some of the tables with discs having 40-60 holes (plate x, fig. 17) .... MAROCCANA

No such tables..... .... LORICATA

EE.—Fusiform bodies transformed into very flat rods or narrow plates, with an expanded middle portion.

Ends of the flat rods expanded and perforated (plate x, fig. 19). PERFORATA

Ends of the narrow plates not expanded and perforated. PAUPERA

BB.—No colored phosphatic deposits present in the skin.

C.—Skin thin, often translucent, and usually more or less rough; tail usually abrupt and slender.

D.—No supporting rods or elongated fusiform bodies present in caudal region.

E.—Tables very small, regular, with disc about 100 μ in diameter, usually with 3, but often with more, holes; spire 150 μ high, or even more. BLAKEI

EE.—Tables much larger and spires proportionally much lower.

F.—Skin very thin and delicate, gray, with more or less yellowish-brown coloring anteriorly and dorsally; deposits in body-wall, except in caudal region, usually wanting in specimens over 40 mm. long; in caudal region (and in body-wall of young specimens), tables with more or less circular discs, perforated by 6 or more large holes, are generally present.....ANTARCTICA

FF.—Skin not so thin and delicate; not so colored; tables abundant in body-wall.

Tables with rounded, regular discs, with 3-6 (rarely more) circular holes .... PARVA

Tables with more or less irregular disc; holes usually oval, with outer end somewhat pointed...............ARCTICA

DD.—Conspicuous supporting rods present in caudal region.

E.—Large, smooth, irregular plates, with 60-70 holes present..AGASSIZII

EE.—No such plates.

F.—Spires of tables and of caudal supporting rods also, with a greatly expanded and spiny top ....ELONGATA

FF.—Spires not commonly with an expanded and spiny top.

Supporting rods of caudal region with wide ends and a prominent spire (plate x, fig. 20); tables with a tapering spire, commonly of a single piece (plate x, fig. 21). GRANULATA

Supporting rods with tapering ends and a low central projection.

Tables with a spire of 3 or 4 rods united by 4 or 5 cross-bars (plate x, fig. 22)......................DISPAR

Tables not provided with such a spire.......MUSCULUS

CC.—Skin thick, smooth, and leathery; posterior end of body tapering, but a distinct caudal appendage is wanting.................................. ARENICOLA

AA.—Anchors present, but if associated with more than a single plate, some of them have 3 or 4 arms.

- *B.*—Anchors with only 2 arms and associated with a single plate.
  - *C.*—Anchor-plates large, about 400 μ long (plate x, fig. 23).
    - Many tables with trifid base, the ends of each of the 3 arms expanded and perforated (plate x, fig. 24) .... BREVICAUDATA
    - None of the tables with trifid base .... MARENZELLERI
  - *CC.*—Anchor-plates small, about 130 μ long (plate x, fig. 9).
    - Tables with more or less irregular, often trifid base.......... CONCOLOR juv.
    - No tables at all present.................................... TRIDENS
- *BB.*—Anchors commonly with 3 or 4 arms (plate x, fig. 25).............. POLYMORPHA

MOLPADIA OÖLITICA.

PLATE X, FIG. 14.

Chirodota oölitica Pourtales, 1851, p. 13.
Molpadia borealis Sars, 1859, p. 174.
Molpadia oölitica Selenka, 1867.
Embolus pauper Selenka, 1867, p. 359.
Trochostoma thomsonii Danielssen and Koren, 1878, pp. 229-256; pls. I-III.
Trochostoma (Molpadia) boreale Danielssen and Koren, 1879, pp. 124-126, 137; pls. V and VI, figs. 1-5.
? *Ankyroderma jeffreysii* Danielssen and Koren, 1879, pp. 128-133, 135-137; pls. V and VI, figs. 11-19.
Trochostoma thomsonii maculatum Danielssen and Koren, 1882, p. 94; pl. XIII, figs. 5-6.
Trochostoma boreale Hoffman, 1882.
Trochostoma (Molpadia) oöliticum Danielssen and Koren, 1882.
Trochostoma oölithicum Lampert, 1885.
Trochostoma oöliticum Théel, 1886*a*.

LENGTH.—100–135 mm., the diameter of the body about one-fourth as much; the caudal appendage short and not often abruptly distinct.

COLOR.—In life grayish green and violet are the prevailing colors, while in preserved specimens dull gray and reddish or dark brown predominate; the oral disc and caudal appendage are noticeably light-colored in contrast. The exact coloration depends on the development of the phosphatic bodies; where these are few, the general color is gray, with little brown, but when these are abundant the color becomes more and more brown; in some specimens these deposits become so numerous that the body is almost black.

DISTRIBUTION.—Reported from numerous stations in the North Atlantic and Arctic oceans, from Florida Reef (Pourtales) and West Indies (Théel) to Spitzbergen and north thereof (Ludwig); also eastward through Barents and Kara seas to Cape Chelyuskin, Siberia (Stuxberg); in the eastern Atlantic it is not known south of 62° N., while in the western Atlantic and Arctic oceans it is not known north of Labrador or west of the Faroes. Its real home seems to be the Arctic Ocean, north of Europe and western Siberia, with a long southwestward extension to Newfoundland, Florida, and the West Indies. The reported occurrence at Point Barrow, Alaska (Murdock), would seem to indicate a circumpolar range.

Remarks.—This is not only the longest-known but perhaps also the best-known species, thanks to the careful investigations of Danielssen and Koren (see their report, 1882, pp. 42–65 and 67–76, and Plates VII–XIII). It seems probable that, in spite of their care, differences were emphasized and intergrading features neglected, so that no less than three species were made by them out of a few specimens of this single form. Of course it is by no means certain that *Ankyroderma jeffreysii* is identical with the Trochostomas, but there is little reason to doubt it. The specimens of Ankyroderma reported have been mostly under 50 mm. and 75 mm. is the maximum given. On the other hand, Danielssen and Koren refer to specimens of Trochostoma 10 and 20 mm. long; they do not say, however, whether the calcareous deposits of these specimens were examined. There can be no question that *borealis* and *oölitica* are identical, for the latter is simply based on individuals in which the phosphatic deposits are excessively developed. The calcareous particles of all ages are fully figured by Danielssen and Koren.

Molpadia concolor.

Trochostoma concolor Koehler and Vaney, 1905, p. 91; pl. v, fig. ix. Calcareous particles, pl. xiii, figs. 16-18.

Trochostoma concolor caudatum Koehler and Vaney, 1905, p. 92. Calcareous particles, pl. xiii, figs. 19-22.

Ankyroderma contortum Koehler and Vaney, 1905, p. 100. Calcareous particles, pl. xiv, figs. 8-13.

Ankyroderma intermedium Koehler and Vaney, 1905, p. 102. Calcareous particles, pl. xv, figs. 19-25.

Length.—125–150 mm., with a diameter of 45–60; in the adult, the caudal appendage is not sharply distinct, but in young specimens it may be one-fourth of the total length.

Color.—Grayish, more or less tinged and marbled with chestnut-brown, orange-red, or bluish violet; in adults the latter tint is very marked; oral disc and caudal appendage whitish.

Distribution.—Reported from the coast of Kistna and Gulf of Bengal, three stations of the "Investigator" (Koehler and Vaney).

Remarks.—This species, though representing *oölitica* in the Indian Ocean, appears to be quite distinct from the northern form. The specimens collected by the "Investigator," although few in number, seem to show the transition from young to adult form very well. It should be stated, however, that one of the specimens described as *A. intermedium* was 115 mm. long and is therefore of maximum size for an Ankyroderma. The variety of color shown by these specimens is noteworthy, but we know very little yet about the constancy of color in the Molpadiidæ, and what little we do know makes us skeptical of its value for specific distinctions. The calcareous particles of all ages are fully figured by Koehler and Vaney.

MOLPADIA INTERMEDIA.

PLATE XII, FIGS. 5-15.

Trochostoma intermedium Ludwig, 1894, p. 161. Calcareous deposits, pl. XVI, figs. 7-21.

LENGTH.—110–140 mm., the caudal appendage about 20–25 per cent of the total length.

COLOR.—Gray or yellowish gray, more or less spotted, blotched and concealed by the reddish-brown or reddish-violet color caused by the phosphatic deposits.

DISTRIBUTION.—Reported from Gulf of Panama and Gulf of California (Ludwig) and numerous stations along the Pacific coast of North America (Clark, antea).

REMARKS.—This is undoubtedly the common Molpadia of the North Pacific, and while it is nearly related to *oölitica,* it is very readily distinguishable. It is one of the species in which the young are provided with anchors and rosettes (antea, pp. 18 and 33), and even large specimens often show the presence of a few.

MOLPADIA ANDAMANENSIS.

PLATE X, FIG. 15.

Trochostoma antarcticum Lampert, 1889 (non Théel, 1886*a*).

Trochostoma andamanense Walsh, 1891, p. 203.

Trochostoma scabrum Sluiter, 1901, p. 119. Calcareous particles, pl. X, fig. 9.

Trochostoma scabrum spinosa Sluiter, 1901, p. 119. Calcareous particles, pl. X, fig. 10.

Trochostoma andamanense Koehler and Vaney, 1905, p. 90. Calcareous particles, pl. XIII, figs. 11-15.

LENGTH.—90–150 mm., of which the caudal appendage is about 8–12 per cent.

COLOR.—"Dirty flesh-color with closely placed deep chocolate spots, the crown (tentacles) being a sort of raw-meat color" (Giles, in Walsh, loc. cit.). "In spirit, the ground color has become greenish gray and the spots are more or less blood-red. The tentacles are yellow and between each two there is, near the base, a blue-black triangular mark" (Walsh, loc. cit.). Curiously enough, Koehler and Vaney do not refer to the color, so that we do not know whether the remarkable coloration of the tentacles and oral disc given by Walsh is a constant feature or not. Sluiter describes the color very much as it occurs in other members of the genus—more or less yellowish brown, brownish red, or dark violet, according to the individual; the color of the body varies evidently with the development of the phosphatic deposits; the caudal appendage is always white or whitish.

Distribution.—Reported from New Guinea (Lampert); Andaman Sea (Walsh); four of the "Siboga" stations in the East Indies (Sluiter), and six of the "Investigator" stations in the Gulf of Bengal and near Ceylon (Koehler and Vaney).

Remarks.—Although Walsh considered this species near to *antarctica,* and Sluiter, and Koehler and Vaney regard it as nearly related to *granulata,* it appears to be quite distinct from either, and well characterized by the presence of the phosphatic deposits and the peculiar but well-formed tables of the caudal region. Considering the meagerness of Walsh's description and the absence of any figures, it is not strange that Sluiter failed to recognize *andamanensis* in his East Indian specimens. There can be little question, however, of the identity of the two forms; nor can there be much doubt that the little "Trochostoma" from New Guinea brought home by the "Gazelle" and considered by Lampert ('89) to be *antarctica,* really is *andamanensis.*

Molpadia similis.

Plate X, Fig. 16.

Ankyroderma simile Théel, 1886*a,* p. 40; pl. XI, fig. 2. Calcareous particles, pl. II, fig. 5.

Length.—100–110 mm.

Color.—Dirty gray and yellowish brown.

Distribution.—Reported only from Yokohama, Japan, 621 m. (Théel).

Remarks.—This is one of the species known from only a single specimen, but it appears to be quite unique, unless indeed it should prove to be the adult of *roretzii;* the small size of the tables is a striking point of resemblance between the two.

Molpadia affinis.

Ankyroderma affine Danielssen and Koren, 1879, pp. 133-137; pls. V and VI, figs. 22-28.

Length.—50–75 mm.

Color.—Gray or grayish green; the oral disc and caudal appendage whitish.

Distribution.—Reported from north of Norway (Danielssen and Koren); Kara Sea (Clark. antea); and Caribbean Sea (Théel). The range possibly coincides with that of *oölitica.*

Remarks.—I was at first inclined to consider this species as simply a form of *oölitica* or possibly *arctica,* but the calcareous tables seem to be quite unique, and the species is certainly as valid as many others in this perplexing genus. As Ludwig (:00*a*) does not distinguish it from *jeffreysii,* we cannot tell exactly what the northern distribution of *affinis* is.

MOLPADIA RORETZII.

Haplodactyla roretzii v. Marenzeller, 1877, p. 29; pl. IV, fig. 1.
Ankyroderma roretzii v. Marenzeller, 1881, p. 124. Calcareous particles, pl. IV, fig. 4.

LENGTH.—55 mm., of which the caudal appendage is 12; diameter about 30 mm.

COLOR.—Dark violet-brown, with the caudal appendage white.

DISTRIBUTION.—Reported only from Japan (v. Marenzeller).

REMARKS.—This is another species known from only a single specimen, and while it appears to be distinct from *similis,* it will not be at all surprising if they prove to be identical. Théel ('86*a*) is undoubtedly right in considering the tables with a single, and always broken, spire figured by von Marenzeller as the basal portions of the anchors, which von Marenzeller seems not to have found.

MOLPADIA AMORPHA.

PLATE XIII, FIGS. 14-22.

Molpadia amorpha Clark (antea, p. 31).

LENGTH.—100–115 mm., of which the tail is only one-tenth; diameter 30–40 mm.

COLOR.—Gray, more or less spotted or blotched with dark purplish, especially anteriorly, where the color may be nearly uniformly dark.

DISTRIBUTION.—Reported only from off the southern coast of Chile in 200–350 m. (Clark).

REMARKS.—This species seems to be quite constant in its characters, so far as adults are concerned. As no young specimens are available, it is not known whether anchors and plates ever occur.

MOLPADIA TURGIDA.

Molpadia turgida Verrill, 1879*a*. p. 473.
Trochostoma turgida Verrill, 1885*b*.
Trochostoma turgidum Théel, 1886*a*.

LENGTH.—90–125 mm.

COLOR.—Reddish or purplish brown; skin thin, semi-translucent.

DISTRIBUTION.—Reported from Massachusetts Bay, 72–180 m., Gulf of Maine, Casco Bay, Bay of Fundy, off Nova Scotia, and Gulf of Saint Lawrence (Verrill).

Remarks.—No one seems to have seen this species except the describer and he unfortunately has given us no figures. The tables, however, seem to be quite characteristic and it is probable that the species is entirely distinct from *oölitica.*

Molpadia musculus.

Plate XI.

?*Molpadia holothurioides* Cuvier, 1817, vol. iv, p. 24.
Molpadia musculus Risso, 1826, p. 293.
Haplodactyla mediterranea Grube, 1840, p. 42.
Haplodactyla musculus Semper, 1868.
Molpadia violacea Studer, 1876, p. 454. Calcareous particles, Théel, 1886*a*, pl. ii, fig. 4.
Ankyroderma musculus Petit, 1883.
Ankyroderma perrieri Petit, 1883, p. 162.
Ankyroderma hispanicum Petit, 1883, p. 163.
Trochostoma violaceum Théel, 1886*a*.
Ankyroderma danielsseni Théel, 1886*a*. p. 39. Calcareous particles, pl. ii, fig. 6.
Ankyroderma musculus Ludwig, 1891*a*. p. 569. Calcareous particles, pl. xxix.
Ankyroderma danielsseni Ludwig, 1894, p. 164. Calcareous particles, pl. xvii, figs. 1-9.
Ankyroderma spinosum Ludwig, 1894, p. 171; pl. xvii, fig. 10. Calcareous particles, pl. xviii, figs. 1-12.
Ankyroderma musculus Perrier, 1903, p. 529.
Ankyroderma musculus Koehler and Vaney, 1905, p. 95.
Ankyroderma musculus acutum Koehler and Vaney, 1905, p. 97. Calcareous particles, pl. xiv, figs. 4-7.

Length.—100–160 mm., of which the tail is 10–25 per cent; the diameter is about one-fifth of the total length.

Color.—Very variable; gray and red-brown, with more or less of a violet tinge; in old specimens the color may be very dark, the gray being entirely concealed, while in young specimens the color may be uniformly gray; with or without a yellow-brown cast.

Distribution.—Reported from the Mediterranean and North Atlantic (Ludwig, Koehler, Perrier); Kerguelen Islands (Studer); southern Chile (Théel); Gulf of Panama, Galera Point, Cocos Island, Acapulco, and Gulf of California (Ludwig); off Chile, the Galapagos Islands, and southern California; and in Monterey Bay, California, 36–54 m. (Clark); seven "Siboga" stations in D. E. I. (Sluiter); Andamans, Kistna, Ceylon, and Gulf of Bengal (Koehler and Vaney). Apparently cosmopolitan, excepting only the Arctic and North Pacific oceans.

Remarks.—Ludwig is authority for the identity of Risso's, Grube's, and Petit's species, while the collections of the United States National Museum leave no doubt of the identity of *violaceum* and *danielsseni.* Perrier asserts the identity of *musculus* and *danielsseni,* and Koehler and Vaney not only maintain the correctness of his position, but add Ludwig's *spinosum* to the list of synonyms. For my part, I believe that at least three species are confused under the above synonymy; but as Perrier, and Koehler and Vaney have had far more material of *musculus* for study than is accessible to me, I defer to their judgment. It seems to me very likely that *musculus* is a small species, confined to the Mediterranean Sea and eastern Atlantic Ocean, which never outgrows its Ankyroderma stage, while *violaceum* is a quite different and much larger species. As for *spinosum,* I believe it, too, will prove to have constant specific characters. Some of the specimens of *danielsseni* in the National Museum collection are remarkable for the apparent absence of phosphatic deposits, and I think it quite possible that these are really a fourth species. But these questions can only be settled when a large amount of material of all ages from the Mediterranean Sea, Atlantic, South Pacific, tropical Pacific, Indian and south Indian oceans can be brought together and carefully compared.

MOLPADIA MAROCCANA.

PLATE X, FIGS. 17, 18.

> *Ankyroderma maroccanum* R. Perrier, 1898, p. 1666; 1903, p. 533. Calcareous particles, pl. XXII. figs. 9-15.

LENGTH.—Not given; presumably 20-35 mm.

COLOR.—Not given; presumably grayish, more or less mottled with red-brown or violet.

DISTRIBUTION.—Reported only from off Cape Ghir, Morocco, 2,210 m. (R. Perrier).

REMARKS.—Although four specimens of this form were taken, it is by no means certain that the differences between it and the preceding species are constant; but, as Perrier says, in the present state of our knowledge the two are well separated from each other.

MOLPADIA LORICATA.

> *Ankyroderma loricatum* R. Perrier, 1898, p. 1666; 1903, p. 535. Calcareous particles, pl. XXII, figs. 23-28.

LENGTH.—55 mm., of which the tail is 7; diameter, 10-15 mm.

COLOR.—Very deep red-brown; tail grayish.

DISTRIBUTION.—Reported only from off Senegal, 1090–2324 m. (R. Perrier).

REMARKS.—Of this form three specimens were taken by the "Talisman" in 1883. It is very close to the preceding species, with which it may be identical, and its separateness from *musculus* is therefore open to question. The latter was taken by the "Talisman" at a neighboring station off Senegal, but in much shallower water.

MOLPADIA PERFORATA.

PLATE X, FIG. 19.

Ankyroderma perforata Sluiter, 1901, p. 121. Calcareous particles, pl. x, fig. 8.

LENGTH.—Up to 140 mm., of which the tail is about one-seventh; diameter, 30 mm.

COLOR.—Grayish; in mature specimens, with red-brown spots.

DISTRIBUTION.—Reported only from four "Siboga" stations in D. E. I. (Sluiter).

REMARKS.—This appears to be one of the species in which anchors are present even in adults. The rosettes are made up of 3–5 racquet-shaped rods, which are widened at the free end and are perforated throughout. The colored phosphatic deposits are said by Sluiter to be absent in the specimens 40 mm. or less in length. The form of the tables and supporting rods seems to be very characteristic.

MOLPADIA PAUPERA.

Trochostoma pauperum Koehler and Vaney, 1905, p. 93. Calcareous particles, pl. XIII, fig. 23.

Trochostoma ecalcareum Koehler and Vaney, 1905, p. 94. Calcareous particles, pl. XIII, fig. 24.

? *Ankyroderma musculus undulatum* Koehler and Vaney, 1905, p. 99. Calcareous particles, pl. XV, fig. 13.

LENGTH.—68–75 mm., of which the very short tail is less than one-twelfth; diameter, about 30 mm.

COLOR.—Clear gray or grayish, with the tail reddish or violaceous; the skin, on its inner surface, is said to be dark violaceous.

DISTRIBUTION.—Reported only from "Investigator" stations 279 (540 m.) and 280 (803 m.), Gulf of Bengal; perhaps also station 250 (800 m.) (Koehler and Vaney).

REMARKS.—This is apparently a species much like *oölitica* in the rapid loss of calcareous deposits and excessive development of the phosphatic bodies. The supporting rods of the tail are very characteristic and it seems quite possible that the small Ankyroderma reported by Koehler and Vaney from station 250 as a variety (*undulatum*) of *musculus* is really the young of the present species. There appears to be no good reason for separating *ecalcareum* from *pauperatum*, as only one specimen was taken, and the absence of deposits may have been accidental.

MOLPADIA BLAKEI.

Trochostoma blakei Théel, 1886*b*, p. 16. Calcareous table. fig. 8.

LENGTH.—60–75 mm., of which about one-tenth is tail.

COLOR.—Whitish, grayish, or very pale brownish.

DISTRIBUTION.—Reported from near Grenada, 1,720 m. (Théel); coast of Senegal, 3,655 m. (R. Perrier), and Gulf of Mexico, 2,126 m. (Clark).

REMARKS.—This is a remarkably well-characterized species, but as Théel neglects to give any dimensions for the curious little tables, it has been easy to mistake some specimens of *parva* for *blakei*. Several specimens of *parva* were labeled *blakei* by me, and I then decided the two were synonymous, and it was only when I found a specimen of the true *blakei* that I realized my mistake. Perrier's (:03) specimen was very small, but the tables are characteristic, at least as far as the dimensions go. The differences he points out between his specimen and Théel's are interesting and may possibly prove to be specific.

MOLPADIA ANTARCTICA.

Trochostoma antarcticum Théel, 1886*a*, p. 44. Calcareous particles, pl. II. fig. 7.

LENGTH.—Up to 92 mm., the tail only 3–5, and the diameter 20–25.

COLOR.—Gray, colored or blotched with yellowish brown, especially anteriorly and dorsally.

DISTRIBUTION.—Reported from southern coast of Chile (Théel, Clark); Gulf of Mexico (Théel), and off Alexander Land, Antarctic Ocean (Herouard).

REMARKS.—Théel has expressed some doubt as to the validity of this species, but it is clear from the material in the United States National Museum that the southern form is quite distinct from either *arctica* or *borealis*. As for the three specimens from the Gulf of Mexico, which Théel ('86*b*) assigns to *antarctica*, I am strongly inclined to believe they represent quite a distinct, and probably undescribed, species. The species *arctica* and *antarctica* are nearly allied and young specimens might easily be confused, but specimens over 50 mm. are readily distinguished. The skin in *antarctica* is very thin and delicate, and even specimens 14 mm. long have no anchors or rosettes, so the species apparently has no *ankyroderma* stage. The single specimen which Herouard (:01) had, seems to have been of this species, although he implies that the absence of calcareous deposits was due to decalcification. Regarding Lampert's ('89) record of this species from New Guinea, see under *andamanensis*.

MOLPADIA PARVA.

Trochostoma arcticum Marenzeller, var. *parva* Théel, 1886*b*, p. 17.
Trochostoma arcticum Marenzeller, var. *cœruleum* Théel, 1886*b*, p. 17.

LENGTH.—60–80 mm., of which about one-tenth is tail.

Color.—Yellowish gray, often with a violet tinge, especially anteriorly; in some specimens the violet color is very marked.

Distribution.—Reported from off Grenada, 749–996 m. (Théel); south of Nantucket, 2,695 m., and Caribbean Sea, 1,613 m. (Clark).

Remarks.—The difference between the calcareous deposits of this species and *arctica* is so obvious and apparently so constant that it does not seem likely the two species can be identical. In some specimens of *parva* the tables are remarkably uniform in having only 3 holes in the disc. Such tables resemble in form those of *blakei*, but are very much larger and the spire is much lower in proportion.

Molpadia arctica.

Haplodactyla arctica v. Marenzeller, 1877*b*, p. 29; pl. iv, fig. 1.
Trochostoma arcticum Danielssen and Koren, 1879, p. 126.
Trochostoma boreale Ludwig, 1900*a*, partim.

Length.—Up to 190 mm. when fully extended, of which the tail is scarcely one-tenth; diameter about 30 mm.

Color.—Whitish, grayish or brownish gray, more or less strongly tinged with violet.

Distribution.—Reported from north of Nova Zembla (v. Marenzeller); Kara Sea (Théel); Finmark (Danielssen and Koren). Apparently an Arctic species, confined to the cold waters north of Europe.

Remarks.—Ludwig's opinion that this species is identical with *boreale* Danielssen and Koren does not seem to me justified by the material at hand. The skin in *arcticum* is thin and rough and always lacks phosphatic deposits, so that the general appearance is quite different from the other Arctic species. So far as recorded, no specimens have been taken which are evident connecting links between the two forms, and for the present at least it seems to me they ought to be kept separate. So far as known, this species never has anchors or rosettes.

Molpadia agassizii.

Ankyroderma agassizii Théel, 1886*b*, p. 19.

Length.—80 mm., of which the tail is one-fourth.

Color.—Light grayish, inclining to violet.

Distribution.—Reported only from Bequia, 2,712 m., and from an unknown West Indian station, 1,904 m. (Théel).

Remarks.—This notable species is well characterized by its thin, rough, brittle body-wall, filled with perforated plates. There are also tables, somewhat like those of *arctica*, present, and anchors and rosettes. The rods making up the rosettes have the large end perforated with 25 or more holes. A thick layer of fusiform supporting rods with the middle enlarged and perforated is found in the tail.

MOLPADIA ELONGATA.

Trochostoma elongatum Koehler and Vaney, 1905, p. 92; pl. I, fig. 5. Calcareous particles, pl. XIV, figs. 1-3.

LENGTH.—49 mm., of which the tail is more than half; the diameter of the body is only 8 mm.

COLOR.—Grayish.

DISTRIBUTION.—Reported only from the Gulf of Bengal, 1,660 m. (Koehler and Vaney).

REMARKS.—In the remarkable development of the tail, this species approaches Caudina, but the calcareous deposits are quite like Molpadia. Only one specimen is known; it is said to show only 10 tentacles, but apparently no dissection was made to determine the actual number present. Of course, if there are only 10, the species does not belong in Molpadia, and it becomes an interesting question whether it is nearly allied to Ceraplectana.

MOLPADIA GRANULATA.

PLATE X, FIGS. 20-21.

Trochostoma granulatum Ludwig, 1894, p. 158. Calcareous particles, pl. XV, figs. 7-9, and pl. XVI, figs. 1-6.

LENGTH.—75–110 mm., of which the tail is about one-seventh.

COLOR.—Dusky yellowish or yellowish gray to brownish yellow; sometimes very dark at the ends; skin thin, translucent, and rough.

DISTRIBUTION.—Reported from three "Albatross" stations off coast of Central America, 2,848–4,017 m. (Ludwig); near Amboina, 798 m. (Sluiter), and near Ceylon, 3,443–3,585 m. (Koehler and Vaney). Apparently distributed in the deep parts of the tropical Indian and Pacific oceans.

REMARKS.—Although only a few specimens of this species are known, they come from such widely separated localities and show such diversity in size (26–110 mm.) that it is probably safe to say that *granulata* does not have anchors and rosettes at any age. Koehler and Vaney consider this species very near *andamanensis* Walsh, but the differences appear to be more striking than the resemblances.

MOLPADIA DISPAR.

PLATE X, FIG. 22.

Ankyroderma dispar Sluiter, 1901, p. 122. Calcareous particles, pl. X, fig. 6.

LENGTH.—30 mm., of which the tail is nearly one-third.

COLOR.—Not given; skin thin and rough.

DISTRIBUTION.—Reported only from near Celebes, 462 m. (Sluiter).

REMARKS.—This is another of the species known from only a single individual, and as that one is obviously immature, it is possible that it will prove to be the young of some previously known species.

MOLPADIA ARENICOLA.

PLATE XII, FIGS. 1, 2.

Liosoma arenicola Stimpson, 1857, p. 525.
Trochostoma arenicola Théel, 1886*a*.

LENGTH.—110–135 mm., with the diameter one-third or one-fourth as much.

COLOR.—Dirty whitish, blotched with tawny reddish.

DISTRIBUTION.—Reported only from the vicinity of San Pedro, California (Stimpson, Théel, Clark), where it appears to be quite common.

REMARKS.—This species, remarkable for its limited distribution, is well characterized by the color, the absence of a distinct caudal appendage, the thick, smooth skin, and the absence of calcareous deposits in the body-wall. In most individuals numerous branched rods and perforated plates are to be found in the skin of the posterior tip of the body, but in old specimens even these may be wanting. Phosphatic deposits are apparently never present. Stimpson's error in saying the calcareous ring consists of five pieces is so obvious, it seems strange Lampert ('85) should have copied it without comment.

MOLPADIA BREVICAUDATA.

PLATE X, FIG. 24.

Ankyroderma brevicaudatum Koehler and Vaney, 1905, p. 99. Calcareous particles, pl. XV, figs. 1-10.

LENGTH.—18–25 mm., with the diameter about 15 mm.; the tail is 3–6 mm. long.

COLOR.—Grayish, somewhat spotted with red.

DISTRIBUTION.—Reported only from one "Investigator" station in the Gulf of Bengal, 330 m. (Koehler and Vaney).

REMARKS.—Although four specimens of this species were taken, they are apparently young, and we probably do not yet know the adults; but the calcareous deposits are quite unique and make the species easily recognizable.

MOLPADIA MARENZELLERI.

PLATE X, FIG. 23.

Ankyroderma marenzelleri Théel, 1886*a*, p. 41. Calcareous particles, pl. III, fig. 1.

LENGTH.—26 mm.

COLOR.—Reddish violet, dappled.

DISTRIBUTION.—Reported only from near New Zealand, 1,260 m. (Théel).

REMARKS.—This unique species is based on a single incomplete individual, which is so well characterized by its calcareous deposits that it could not be assigned to any other species. Besides the tables and the remarkable anchor-plates, which usually have three rather long arms, numerous phosphatic deposits are present. The caudal portion of the type specimen was lost or destroyed when it was taken.

MOLPADIA TRIDENS

PLATE X, FIGS. 8, 9.

Ankyroderma tridens Sluiter, 1901, p. 122. Calcareous particles, pl. x, fig. 7.

LENGTH.—Up to 80 mm., of which the tail is about one-fourth.

COLOR.—Gray, with numerous small red-brown spots.

DISTRIBUTION.—Reported only from the Dutch East Indies, 330–462 m. (Sluiter).

REMARKS.—This is a most interesting species, remarkable for the absence of all calcareous deposits save anchors and plates and the presence of numerous phosphatic deposits, thus reversing the usual condition, where numerous phosphatic deposits are associated with the disappearance of anchors and plates. Sluiter's account of the appearance of the deposits is further evidence to show that calcareous particles in Molpadia become transformed into the colored phosphatic bodies.

MOLPADIA POLYMORPHA.

PLATE X, FIG. 25.

Ankyroderma polymorphum Koehler and Vaney, 1905, p. 103. Calcareous particles, pl. XIV, figs. 14-19.

LENGTH.—50 mm., of which the tail is 15; the diameter of the body is only 10 mm.

COLOR.—White, tinged with reddish.

DISTRIBUTION.—Reported from the Gulf of Bengal, 1,242–1,656 m. (Koehler and Vaney).

REMARKS.—As only a single specimen of this form was taken, one cannot avoid the suspicion that it may be only a young and aberrant *concolor*. It is impossible to tell from the description given whether the anchors are associated with a single plate or with a rosette of such plates.

CAUDINA Stimpson, 1853.

Molpadia Müller, 1850; Semper, 1868; non Cuvier, 1817.

Tentacles 15, with 2 pairs of digits, the distal pair longer than the proximal; no terminal unpaired digit. Body rather stout, more or less tapering posteriorly and usually with a distinct caudal portion, which is generally one-third of the total length or even more. Radial pieces of calcareous ring with conspicuous, bifurcate, posterior prolongations. Calcareous deposits of very various kinds, with no particular kind characteristic of the genus. Phosphatic deposits are usually entirely wanting and are known to occur in only one species.

The holothurians composing this genus may usually be recognized by the form of the body, but there is no doubt that the differences between Caudina and Molpadia are very slight and of little significance. The geographical distribution of the genus is interesting; three species are confined to the eastern coast of the United States, two occur on the North American Pacific coast, and the three others occur on the coast of Chile, one of these ranging to New Zealand, Australia, the East Indies, and Japan. Little is known of their habits, save that they live buried in sand or mud with the tip of the caudal region exposed; they burrow by means of the tentacles, aided by movements of the body, and feed on the organic matter in the sand or mud, which they take into the mouth. Besides the following eight species, "*Trochostoma albicans glabra*" (Théel, 1886*a*, p. 46), which appears to be closely related to *C. albicans,* should probably be recognized as a ninth species.

Key to the Species of Caudina.

A.—No colored phosphatic deposits in skin.
  B.—Calcareous deposits in the form of tables with perforated discs and conspicuous spires (plate x, figs. 11, 12).
    Discs of tables 90-140 μ in diameter: spire rather low and irregular, usually of 4 somewhat converging rods . . . . ARENATA
    Discs of tables 150-270 μ in diameter; spire rather high and pointed, of 3 converging rods . . . . ALBICANS
  BB.—Calcareous deposits not tables.
    C.—Calcareous deposits more or less well formed, shallow cups perforated by 4 holes and closed by a cross, the bars of which are just over the holes, the relative proportions of solid parts and holes varying very greatly (plate IX, figs. 4, 5, 11, 12, 13).
      D.—Nearly all the cups complete and symmetrical, with rounded knobs on margin (fig. 4).
        Caudal appendage very distinct . . . . CHILENSIS
        Caudal appendage not apparent, the body simply tapering to a blunt point . . . . OBESACAUDA
      DD.—Nearly all the cups incomplete and more or less asymmetrical, without knobs (figs. 11-13) . . . . CONTRACTACAUDA
    CC.—Calcareous deposits more or less flat, perforated plates of no particular form.
      Plates with sharp projections on the surface (plate x, fig. 13) . . CALIFORNICA
      Plates almost perfectly smooth (plate IX, fig. 8) . . . . PLANAPERTURA
AA.—Colored phosphatic deposits present in skin . . . . PIGMENTOSA

CAUDINA ARENATA.

PLATE X, FIGS. 1, 2, 11.

Chirodota arenata Gould, 1841, p. 345.
Chirodota arenata Ayres, 1852*a*, p. 143.
Caudina arenata Stimpson, 1853, p. 17.
Caudina arenata Gerould, 1896, pp. 17-74; pls. III-X.

LENGTH.—100–175 mm., rarely up to 250 mm.; caudal appendage usually about 35–40 per cent of total length.

COLOR.—In life, pink to purplish; in preserved specimens, milky white to pale brown, usually grayish.

DISTRIBUTION.—Reported from Newport, Cuttyhunk and Vineyard Sound, Chelsea Beach, Revere Beach, and Massachusetts Bay (Gould, Pourtales, Verrill, Kingsley, Gerould, et al.); Grand Manan (Ludwig); Milne Bank, Northumberland Strait and Pointe du Chêne, New Brunswick (Whiteaves).

REMARKS.—Although this species has been taken in large numbers at Revere Beach, Mass., and in smaller numbers at Newport, R. I., and Chelsea Beach, Mass., nearly all these specimens have been picked up on the shore after severe storms. Few specimens have ever been dredged. Gerould's ('96) explanation of this is undoubtedly correct; the animals live buried in rather firm sand, only the tip of the tail being at the surface, so that an ordinary trawl or dredge does not reach them; but, as they live in comparatively shallow water (1–35 meters), a heavy sea gradually washes them out of the sand and casts them upon the shore. Gerould's admirable paper is a complete account of all that we know about this species.

CAUDINA ALBICANS.

PLATE X, FIG. 12.

Trochostoma albicans Théel, 1886*a*, p. 44; pl. XI, fig. 3. Calcareous particles, pl. III, fig. 2.
Trochostoma albicans var. *glabra* Théel, 1886*a*, p. 46.
Caudina arenata var. *armata* Théel, 1886*b*, p. 17.
Caudina arenata var. *armata* Gerould, 1896, p. 19. Calcareous particles, pl. III, figs. 34-37.

LENGTH.—75–115 mm., of which 20–35 are caudal appendage.

COLOR.—In preserved specimens, grayish or whitish.

DISTRIBUTION.—Reported from off the east coast of the United States between Cape Cod and Cape Hatteras, in 1,600–2,235 m. (Théel, Clark); near New Zealand, 1,260 m. (Théel); off coast of Senegal, 3,200 m. (R. Perrier), and Gulf of Bengal, 486–738 m. (Koehler and Vaney).

REMARKS.—It is only with the greatest hesitation that I venture to unite two species, placed by so careful a worker as Théel in separate genera; but I am entirely at a loss to find any satisfactory ground upon which they can be separated. Of course if the difference in tentacles were constant, it would separate them easily; but I feel sure that this supposed difference is due entirely to difference in the amount of contraction, and the similarity of the calcareous deposits is so striking, I cannot doubt that *armata* is a synonym of *albicans*. Although resembling the preceding species, this deep-water form is easily recognized by the characteristic tables. As no connecting specimens are known, there is no reason why it should not be given full specific rank. I feel quite sure that the specimens from New Zealand are specifically distinct, and that those from the Indian Ocean are either like the New Zealand form or are a third species.

CAUDINA CHILENSIS.

Molpadia chilensis J. Müller, 1850, p. 139. Calcareous particles, 1854, pl. VI, fig. 14, and pl. IX, fig. 1.
Molpadia australis Semper, 1868, p. 233. Calcareous particles, pl. XXXIX, fig. 14.
Molpadia coriacea Hutton, 1872, p. 17.
Microdactyla caudata Sluiter, 1880, p. 348; pl. VI, fig. 1.
Caudina ransonnetii v. Marenzeller, 1881, p. 126. Calcareous particles, pl. IV, fig. 5.
Caudina meridionalis Bell, 1883, p. 58. Calcareous particle, pl. XV, fig. 1.
Caudina caudata Ludwig, 1883, p. 158.
Caudina coriacea Théel, 1886*a*, p. 47. Calcareous particles, pl. III, fig. 4.
Caudina rugosa R. Perrier, 1904*a*, p. 16. Calcareous particles, 1905, pl. IV, figs. 10-12.
Caudina pulchella R. Perrier, 1905, p. 117. Calcareous particles, pl. V, figs. 14-17.
Caudina coriacea brevicauda R. Perrier, 1905, p. 121; fig. N in text.

LENTH.—60–150 mm., of which the caudal appendage may be more than half.

COLOR.—Milk white to yellowish brown.

DISTRIBUTION.—Reported from Chile (J. Müller); Picton Island, Chile (R. Perrier); New Zealand (Hutton, Théel, et al.); Australia (Semper, Lampert); East Indies (Sluiter); China (v. Marenzeller), and Japan (Ludwig). Apparently the most widely ranging member of the genus, occurring throughout the southern and western portions of the Pacific Ocean.

REMARKS.—The form of the body in this species is apparently quite variable, the caudal appendage in some specimens exceeding half the total length, while in other cases it is apparently much less and correspondingly inconspicuous; thus Müller ('50), Semper ('68), and Lampert ('85) make no reference to a caudal appendage, though the last two say the body has the usual "Haplodactyla" form. According to Semper's figure ('68, Plate IX), this would indicate a caudal appendage only about one-fourth of the length. A comparison of the descriptions and of the figures of the calcareous deposits given by Müller, v. Marenzeller, and Théel leaves little doubt that they were dealing with individuals of a single species, while Lampert's comments on *australis* and *coriacea* show that Semper's species is the same. Ludwig has given cogent reasons for declining to accept Sluiter's genus Microdactyla at its face value, and we are safe in considering that remarkable holothurian as a strongly contracted *chilensis*. Perrier's descriptions and figures (:05) throw a great deal of light on the proportions and anatomy of this interesting species. Although M. Perrier had only seven specimens at hand, he regards them as representing five distinct forms, one being the type specimen of *ransonnetii*, one the type of *rugosa*, one the type of *pigmentosa*, two type and topotype of *pulchella*, and two type and topotype of *coriacea brevicauda*. Unfortunately, however, he fails to make clear any characters, upon which reliance can be placed, for separating these so-called species; for size, color, proportions, and texture and surface of the body-wall are all characters which vary greatly with the individual and with the method of killing and preserving. Moreover, too close similarity in deposits must not be expected in such a variable group as the Molpadiidæ, and while we may for the present recognize *pigmentosa* (q. v.), all of M. Perrier's other names appear to fall into the above given list of synonyms. Any other course would necessitate a new name for every specimen which showed any individual variation—a factor in the case for which M. Perrier apparently fails to allow. Müller ('50) describes and figures ('54) some remarkable organs in his type of *chilensis* which he calls Cuvier's organs, but that they are homologous with the Cuvier's organs of the Holothuriidæ is exceedingly doubtful. (See antea, p. 150.) It is very interesting to note that Perrier's specimen of *pigmentosa* shows the same curious structures. It is somewhat exasperating that the name *chilensis* must be retained for a species which is most common apparently in New Zealand and occurs in the East Indies and Japan.

CAUDINA OBESACAUDA.

PLATE XI, FIGS. 1-5.

Caudina obesacauda Clark (antea, p. 38).

LENGTH.—115 mm., of which the tail may be estimated at about one-third.

COLOR.—Pale brown.

DISTRIBUTION.—Reported only from Marco, Florida, and Galveston, Texas. (See antea, p. 38.)

REMARKS.—This species is very near the preceding, and were it from New Zealand or Australia instead of Florida, it would be difficult to show any real difference between it and *chilensis*, for it is very doubtful whether the difference in the form of the body is of any significance. Until we have further light on the shape of the body in *chilensis*, *obesacauda* may retain a dubious independence.

CAUDINA CONTRACTACAUDA.

PLATE IX, FIGS. 9-13.

Caudina contractacauda Clark (antea, p. 38).

LENGTH.—70 mm., of which more than one-third is caudal appendage.

COLOR.—Very pale brown.

DISTRIBUTION.—Reported only from near the Aleutian Islands (Clark).

REMARKS.—Although undoubtedly near the two preceding species, this form may be readily recognized by the very different calcareous deposits. It may be considered the North Pacific representative of *chilensis*.

CAUDINA CALIFORNICA.

PLATE X, FIG. 13.

Caudina californica Ludwig, 1894, p. 155. Calcareous deposits, pl. xv, figs. 1-6.

LENGTH.—98 mm., of which 42 are caudal appendage.

COLOR.—Yellowish gray.

DISTRIBUTION.—Reported only from the vicinity of Lower California, 2,850 m. (Ludwig); 85 m. (Clark, antea).

REMARKS.—This is a well-marked and perfectly distinct species, of which only the few specimens in the National Museum are known. The small specimen, collected in only 85 m. of water, may belong to a different and hitherto-undescribed species, but in view of the very scanty material, it seems wiser to consider it a young *californica*. The plates in this small specimen are mostly less than half as large as in the type and have only 2–8 holes, which are very large in proportion to the size of the plate. The knobs on the surface of the plate are rounded or blunt, instead of being sharp. The plates are not at all crowded, but lie rather evenly distributed through the skin.

CAUDINA PLANAPERTURA.

PLATE IX, FIGS. 6-8.

Caudina planapertura Clark (antea, p. 37).

LENGTH.—67 mm., of which 27 are caudal appendage.

COLOR.—Gray with minute light-brown blotches, which are so numerous dorsally as to give a brownish tinge there.

DISTRIBUTION.—Reported only from Wellington Island, Chile, 350 m.

REMARKS.—This species is remarkably distinct from any other member of the genus, owing to the smooth, perforated plates, but superficially it closely resembles *arenata*.

CAUDINA PIGMENTOSA.

Caudina pigmentosa R. Perrier, 1904*a*, p. 16.

LENGTH.—125 mm., of which 55 are caudal appendage.

COLOR.—Grayish red.

DISTRIBUTION.—Reported only from Tierra del Fuego (Perrier).

REMARKS.—This is indeed, as Perrier says, a most remarkable and interesting species, a puzzling connecting link between Caudina and Molpadia. The tentacles and caudal appendage, as well as the basis of the curious deposits, ally it with Caudina, while the red phosphatic layers of the deposits are very much like Molpadia. The longitudinal muscles show a tendency to form retractors where they join the calcareous ring, and most remarkable of all is the presence of a bunch of Cuvier's organs similar to those which Müller describes for *chilensis*. It is not impossible that this is simply an old and abnormal (perhaps diseased) specimen of *chilensis*, but we are not justified at present in assuming that such is the case. Were it not for the red deposits, however, it is not probable that any one would question the reference of this individual to *chilensis*.

ACAUDINA, gen. nov.

(*a*, privative, + *caudina:* in reference to the marked difference from *Caudina*.)

Tentacles 15, with only two small digits. Body cylindrical, stout, not having a caudal portion and not even tapering posteriorly. Radial pieces of calcareous ring with very conspicuous, bifurcated, posterior prolongations. Calcareous deposits in the form of thick plates, with few, small perforations and a number of conspicuous, sharp projections. Phosphatic deposits wanting.

This genus is established for the following remarkable species, which is very different in color, form, and calcareous deposits from any other member of the family. Its relationships are very doubtful, though the calcareous particles seem to ally it more closely with Caudina than with any other genus.

ACAUDINA DEMISSA.

PLATE XII, FIGS. 3, 4.

Molpadia demissa Sluiter, 1901, p. 110; pl. III, fig. 4. Calcareous particles, pl. X, fig. 11.

LENGTH.—160 mm., the diameter about 45.

COLOR.—Dark brown-violet, with irregularly scattered, oval clear spots, caused by aggregations of the calcareous plates.

DISTRIBUTION.—Reported only from Madura Strait, northeast Java, 330 m. (Sluiter).

REMARKS.—Although Sluiter had only a single specimen, he made such good use of that one that we have a very satisfactory knowledge of the morphology of this noteworthy holothurian.

EUPYRGUS Lütken, 1857.

Echinosoma Semper, 1868.

Tentacles 15, simple and without digits or ampullæ. Body tapering posteriorly into a short but distinct caudal appendage. Radial pieces of calcareous ring with no posterior prolongations, or with very slight ones on those of the ventral side. Longitudinal muscles simple and unpaired. Calcareous deposits in the form of tables with perforated disc and high spire. Phosphatic deposits wanting.

This interesting genus of very small holothurians was long monotypic, but Östergren (:05*b*) has recently added a second species. Although the tentacles lack digits, Eupyrgus has little in common with Aphelodactyla and its relationships are quite obscure. It is even a debatable question whether it has not sprung from a different ancestry than that of the other Molpadiidæ. The type species is a distinctly Arctic animal, but the recently discovered one is found farther to the south. Verrill's ('85*b*) *Echinosoma abyssicola*, recorded from off the New England coast in 3,718 m., is a simple *nomen nudum*, and is very possibly an Echinocucumis or perhaps a Sphærothuria.

KEY TO THE SPECIES OF EUPYRGUS.

Some or all of the calcareous tables stout, with disc 190-300 μ in diameter, perforated with 20-30 (often fewer, rarely more) holes .... SCABER
Tables more slender, with base 125-250 μ, perforated with 40-60 (rarely fewer, often more) holes .... PACIFICUS

EUPYRGUS SCABER.

PLATE XII, FIGS. 16-27.

Eupyrgus scaber Lütken, 1857, p. 22.
Echinosoma hispidum Semper, 1868, p. 44.

LENGTH.—9–12 mm., with a diameter of about 5.

COLOR.—Grayish.

DISTRIBUTION.—Reported from between Port Hood, Cape Breton and eastern point of Prince Edward Island, and off Bonaventure Island (Whiteaves); Salmon Bay, Caribou Island and Long Island, Cateau Bay (Packard); southern Labrador (Verrill); Greenland (Lütken, et al.); Spitzbergen (Ljungman, Théel, et al.); Barents Sea (D'Urban et al.); Kara Sea (Stuxberg); Finmark (Norman); and coast of Alaska (Clark, antea); in depths of 7–480 m.; also from Indian Ocean (Walsh).

REMARKS.—Although long known, this species has been little studied and no good figures of the animal or its deposits were published until recently (Norman

:03). Semper ('68) gives some good anatomical details, including a figure of the cloaca, which shows the presence of five large calcareous plates, forming "anal teeth" such as occur in *Thyone briareus* and some other holothurians. The reported occurrence of this species in the Indian Ocean in comparatively shallow water, by Walsh ('91), is open to serious doubt, although Alcock (:02) seems to consider the record correct. Koehler and Vaney (:05) make no reference to either the species or the record, which is rather remarkable. In view of the fact, for which they vouch, that Walsh mistook a Protankyra for an Ankyroderma, we may be pardoned for doubting his identification of an Indian holothurian as Eupyrgus. In the Standard Natural History (Lockington '85), *Eupyrgus scaber* is classed as an Apneumonous Apoda, and is said to be "the simplest of all holothurians," although Semper's figures were published nearly 20 years before. It is unfortunate that such a blunder should occur in what is really a "standard" natural history.

EUPYRGUS PACIFICUS.

PLATE XII, FIGS. 28-29.

Eupyrgus pacificus Östergren, 1905*b*, p. CXCVI. Calcareous particles, fig. 1*b*.

LENGTH.—3–7 mm., with a diameter of 2–3.

COLOR.—Not given, but presumably grayish.

DISTRIBUTION.—Reported only from coast of Korea, 60–65 m. (Östergren).

REMARKS.—As Östergren has compared his specimens, of which there were three, with specimens of *scaber* of the same size, there is little reason to question the validity of this species. It is possible, however, that a more complete knowledge of individual diversity in *scaber* and of its geographical range may show that *pacificus* is identical with it, particularly since *scaber* is now known to occur along the Alaskan coast.

APHELODACTYLA, nom. nov.

(ἄφελος, not rough, simple, + δάκτυλα (poetic plural) fingers; in reference to the undivided tentacles.)

Haplodactyla Semper, 1868; non Grube, 1840.

Tentacles 15, simple and without digits, but with ampullæ. Body more or less tapering posteriorly, but there is no distinctly set-off caudal appendage. Calcareous ring very broad, the radial pieces with evident, but short, posterior prolongations. Calcareous deposits often wanting (usually present at extreme posterior end), and when present relatively insignificant, in the form of small oval or dumbbell-shaped bodies or perforated plates. Phosphatic deposits wanting.

Semper's ('68) great monograph, with its wealth of anatomical detail, first introduced this interesting genus to zoölogists, but he unfortunately made use of Grube's name, which was really a synonym of Cuvier's genus Molpadia. As Semper's mistake has not hitherto been corrected, it is now necessary to give the genus a new name. Geographically, Aphelodactyla is interesting because of its very limited distribution. Although nine species or varieties have been named, they are all from the East Indian region, extending only to Ceylon on the west and to Waigiou Island, near New Guinea, on the southeast; curiously enough, the same species occurs at these two extremes. All are shallow-water forms, occurring from about low-water mark to only about 60 m. The species are all imperfectly known and it would not be surprising if future study of sufficient material should show that there are only two, or perhaps three, distinct species in the genus.

KEY TO THE SPECIES OF APHELODACTYLA.

A.—Skin more or less opaque and pigmented.
  B.—Calcareous particles sometimes wanting, sometimes present only near cloacal opening, sometimes frequent, especially posteriorly, in the form of small oval bodies, and more or less irregular, perforated plates (plate X, figs. 4, 5).
    Color uniform reddish violet or purplish; plates when present rather regular, thick, with few small perforations .... MOLPADIOIDES
    Color clear violet, marked with orange; plates when present very irregular, sometimes with numerous perforations .... PUNCTATA
  BB.—Calcareous particles small, oval, or thick C-shaped, or dumbbell-shaped, bodies. AUSTRALIS
AA.—Skin more or less glassy and transparent, sometimes without pigment.
  Calcareous particles wholly wanting.................................. PELLUCIDA
  Calcareous rods with projecting knobs present near cloacal opening......HYALOEIDES

APHELODACTYLA MOLPADIOIDES.

PLATES III AND X, FIGS. 3-7.

Haplodactyla molpadioides Semper, 1868, p. 41; pls. IX; X, figs. 2*a*, 4, 5, 9; pl. XIII, 1-3.

Haplodactyla molpadioides sinensis Semper, 1868, p. 43. Calcareous particles, pl. X, fig. 2; pl. XIII, fig. 4.

Haplodactyla ecalcarea Sluiter, 1901, p. 118.

LENGTH.—Up to 210 mm., with a diameter about one-fourth as much.

COLOR.—Uniform reddish violet or purplish.

DISTRIBUTION.—Reported from Bohol and Cebu, Philippines (Semper); China (Semper); Sumbawa, D. E. I. (Sluiter), and Ceylon (Bell).

REMARKS.—Although so beautifully figured and well described by Semper, this species is still very unsatisfactorily known. Few specimens are in collections and its relationships to other members of the genus are still much in doubt. The single small specimen (35 mm.) taken by the "Siboga," and which Sluiter named *ecalcarea*, seems to be most probably a young individual of this species.

APHELODACTYLA PUNCTATA.

Haplodactyla punctata Sluiter, 1888, p. 209. Calcareous particles, pl. II, figs. 31-35.

LENGTH.—Up to 160 mm.

COLOR.—Clear violet with orange blotches and spots; tentacles colorless, speckled with orange.

DISTRIBUTION.—Reported only from Batavia Bay and Samana Bay, D. E. I. (Sluiter).

REMARKS.—Thanks to Sluiter's ('88) investigations, we really know something about this species, which appears to be distinct from *molpadioides,* though a sufficient series of specimens may show that the two are identical. It is common in the mud of Batavia Bay, where it lives with only the cloacal opening above the surface. It lives well in an aquarium, but remains buried in the mud, showing the anterior end only at night. Respiration is slow, the contractions and expansions of the cloaca only occurring two or three times per minute. The calcareous deposits show a great deal of diversity in form.

APHELODACTYLA AUSTRALIS.

Haplodactyla holothurioides Selenka (non Cuvier), 1868, p. 115. Calcareous particles, pl. VIII, figs. 13, 14.
Haplodactyla australis Semper, 1868, p. 233.
Haplodactyla andamanensis Bell, 1887*a*, p. 139.

LENGTH.—75–105 mm.

COLOR.—Coffee-brown, dusky brown, or reddish gray.

DISTRIBUTION.—Reported from Waigiou, northwest of New Guinea (Selenka); Timor and Padang (Ludwig); Andaman Islands (Bell), and Ceylon (Thurston, Ludwig). Apparently the most widely distributed of the genus.

REMARKS.—Very little is known of this species, beyond the existence of a few specimens in European museums. I follow Ludwig in considering *andamanensis* synonymous with *australis,* as he has examined several specimens and his long experience makes him a safe guide; but the differences between *australis* and *molpadioides* are not much greater than those which were supposed to separate *australis* and *andamanensis*, so I am by no means sure that the present species is tenable beyond question.

APHELODACTYLA PELLUCIDA.

Haplodactyla molpadioides pellucida Semper, 1868, p. 42. Anatomical details, pl. X, figs. 1, 3, 6.
Haplodactyla pellucida Sluiter, 1901, p. 117.

LENGTH.—40–75 mm.

COLOR.—Not given; "glassy, translucent" (Sluiter); Semper figures (Plate X, fig. 3) a bright brownish-yellow pigment cell from the skin.

Distribution.—Reported from Bohol and Cebu, Philippines (Semper); Saleyer, D. E. I. (Sluiter).

Remarks.—There seems very little reason for separating this species from *molpadioides*, but Sluiter, who has probably studied more specimens of this genus than any other zoölogist, considers it recognizable, and we may well defer to his judgment until further evidence is in. The reproductive glands are said to be unbranched and the calcareous ring much narrower than in *molpadioides*.

APHELODACTYLA HYALOEIDES.

Haplodactyla hualoeides Sluiter, 1880, p. 345; pl. v.

Haplodactyla hualoeides Sluiter, 1880, p. 345; pl. v.

Length.—35 mm.

Color.—Colorless and glassy, like Salpa.

Distribution.—Reported from Batavia (Sluiter); Amoy (Ludwig), and Samana Bay, D. E. I. (Sluiter).

Remarks.—Although only four specimens of this remarkable species are known, it would appear to be very distinct from any other member of the family. The reproductive organs are well developed, so there is no good reason for considering it immature. Besides the deposits near the cloacal opening, Ludwig found branched rods in the walls of the genital tubes.

CERAPLECTANA Clark (antea, p. 39).

Tentacles 10, simple, unbranched, horny and pointed, provided with normal ampullæ. Body nearly cylindrical, but tapering posteriorly into a well-developed caudal appendage. Radial pieces of calcareous ring with marked, but not deeply forked, posterior prolongations. Calcareous deposits in the form of irregular branched plates or straight rods, perforated near the middle, and usually with a single, sharp, outwardly directed spine. Phosphatic deposits present.

The relationships of this curious genus are evidently with Molpadia, as shown by the shape of the body, the calcareous ring, and the deposits in the skin, but the tentacles are very distinctive. Koehler and Vaney (:05) report a Molpadia from the Gulf of Bengal (*elongata*) in which only 10 tentacles showed, but they say nothing of the form or structure of those; the use of the word "dix" looks very much like a slip of the pen, as no comment is made on the unusual number.

CERAPLECTANA TRACHYDERMA.

Plate XIII, Figs. 5-13.

Ceraplectana trachyderma Clark (antea, p. 39).

Length.—Up to 80 mm., of which about one-fourth is tail; diameter, 10–20 mm.

Color.—Gray mottled with numerous small patches of red-brown.

Distribution.—Reported only from "Albatross" Station 3603, near the Aleutian Islands, 3,188 m. (Clark).

Remarks.—This is one of the "Albatross' " most interesting discoveries in the way of holothurians and adds another to the long list of remarkable animals acquaintance with which science owes to that vessel. The three specimens taken occurred on a bottom of "blue ooze."

HIMASTHLEPHORA Clark (antea, p. 40).

Tentacles 15, with four digits of which the terminal pair are the largest; without ampullæ. Body nearly cylindrical, rather stout, terminating abruptly in a long, slender caudal portion. Mid-dorsal interambulacrum with 4–6 whip-lash-like papillæ. Rudimentary pedicel-like outgrowths near both the anterior and posterior ends of the body. Genital papilla prominent, 2 mm. or more in length. Respiratory trees small and delicate. Longitudinal muscles simple, flattened and unpaired. Calcareous ring of 10 pieces, rather stout and synapta-like with no posterior prolongations. No calcareous or phosphatic deposits in skin. Careful examination of two specimens failed to show a stone-canal.

The specimens on which this genus is based were collected in 1886 and examined by me in 1900. In 1905 appeared the description of the following genus, and it occurred to me at once that the "Investigator's" novelty is very closely allied to this one discovered by the "Albatross," if not actually congeneric with it. The most obvious difference between the two is in the shape of the body—that is, the presence or absence of a caudal appendage. I considered it present very plainly in the four "Albatross" specimens, while Koehler and Vaney consider it wanting in the two "Investigator" specimens. I am now unable from the available material to satisfy myself beyond doubt on this point. An apparent caudal appendage was present in all four specimens, but the condition of the material was such that even the stained sections prepared would not permit me to determine whether the appendage was a normal outgrowth covered with skin or an evagination of part of the alimentary canal, which is unfortunately ruptured and macerated beyond satisfactory examination. The position of the clusters of pedicel-like outgrowths at the base of the appendage is suspicious, and a study of the description and figures given by Koehler and Vaney increases the suspicion that the apparent tail is not a normal outgrowth. On the other hand, its presence in all four specimens and its general appearance argue in favor of its being a caudal appendage, especially since the respiratory trees were in their normal position in the body-cavity. If the appendage were an evagination, it seems as though the respiratory trees must have been injured or disturbed. Aside from this doubtful appendage, Himasthlephora differs from Gephyrothuria in the number of digits on the tentacles, the presence of a prominent genital papilla, the smaller number of dorsal papillæ, and the presence of rudimentary pedicel-like outgrowths. None of these differences, however, will stand very critical examination, and if the two species are shown, by the collection and study of further material, to be alike in the presence or absence of a caudal appendage, it seems to me very probable that they are congeneric, and Himasthlephora must become simply a synonym of Gephyrothuria. As regards the relationship of these interesting holothurians to other genera, it seems to me clear that they are closely related to Caudina, although in the unpaired longitudinal muscles, the absence of tentacle-ampullæ, of posterior prolongations on the radial pieces of the calcareous ring, and of phosphatic deposits they resemble Eupyrgus. They certainly belong to the Molpadiidæ. The number and form of the tentacles and the general appearance is very characteristic, and the presence of rudimentary ambulacral appendages is not of nearly sufficient importance to warrant the formation of a new family. Gerould ('96) long since demonstrated their presence in *Caudina arenata*. It might be possible to form a subfamily of Himasthlephora and Gephyrothuria, but in the present imperfect state of our knowledge of these forms, such a step seems to me inadvisable and undesirable.

HIMASTHLEPHORA GLAUCA.

PLATE XIII, FIGS. 1-4.

Himasthlephora glauca Clark (antea, p. 40).

LENGTH.—28 mm., of which 9 is tail; diameter about 8 mm.

COLOR.—Uniform pale gray; tentacles and genital papilla brownish.

DISTRIBUTION.—Reported only from "Albatross" Station 2678, off the coast of Georgia, 1,316 m. (Clark).

REMARKS.—Nothing remains to be added to the remarks on page 41, save that this species appears to be much smaller and more dully colored than the following, although the specimens were apparently sexually mature. They occurred on a bottom of "light gray ooze," with which they must have corresponded in color almost exactly.

GEPHYROTHURIA Koehler and Vaney, 1905.

Tentacles 15, with only two (?) digits, without ampullæ. Body nearly cylindrical, rather stout, with no caudal portion (?). Mid-dorsal interambulacrum with 7–9 whiplash-like papillæ. Pedicel-like outgrowths and genital papilla wanting. Calcareous ring without posterior prolongations. Calcareous and phosphatic deposits wanting.

The peculiarities of this genus have been fully discussed in connection with the preceding, to which it is at least most closely related.

GEPHYROTHURIA ALCOCKI.

Gephyrothuria alcocki Koehler and Vaney. 1905, p. 79; pl. v. figs. 6-8.

LENGTH.—Up to 50 mm., with a diameter of 17.

COLOR.—Rosy.

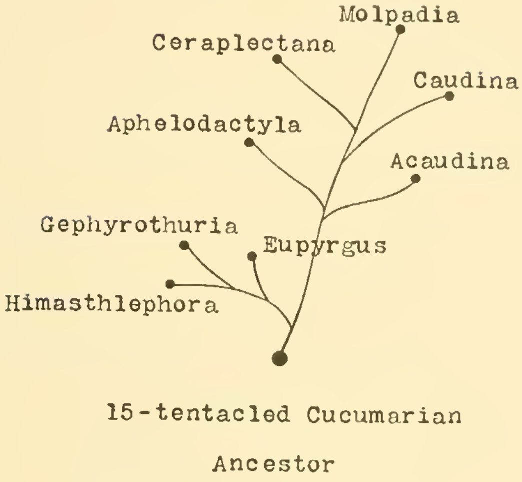
DISTRIBUTION.—Reported only from "Investigator" Station 278, near Ceylon, 3,442 m. (Koehler and Vaney).

REMARKS.—The larger size and brighter color distinguish this from the similar species of the American coast, aside from the generic differences already discussed. The tentacles were so much contracted that it could not be decided satisfactorily what the number of digits is.

CONCLUDING REMARKS ON THE MOLPADIIDÆ.

INTERRELATIONSHIPS.

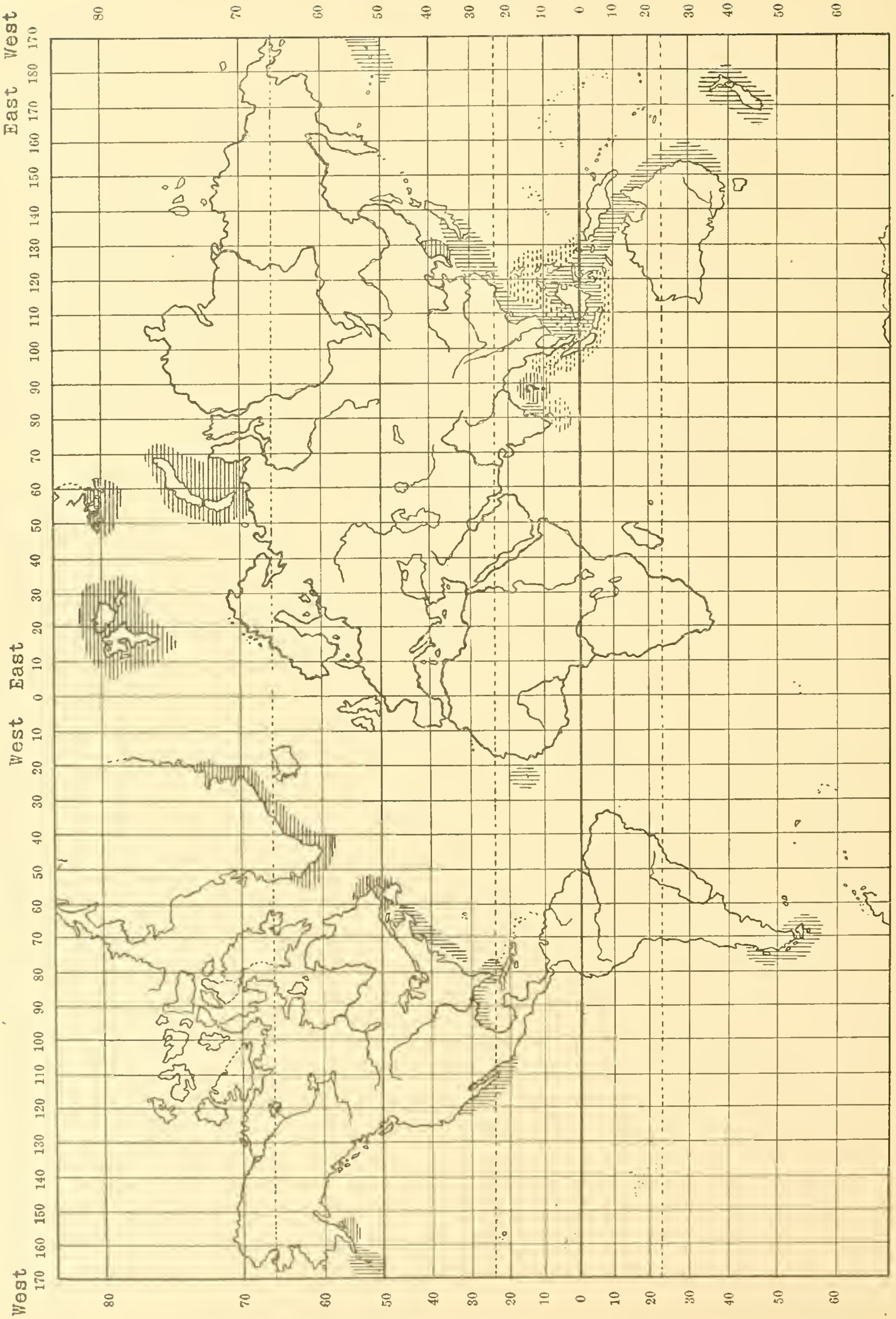
Having thus characterized the 8 genera and 46 species of Molpadiidæ known to science at the present day, it may be worth while to attempt to show in graphic form the relationship which they have to each other. There is good reason for believing that the ancestor of the group was a 15-tentacled pedate holothurian, probably one of the Cucumariidæ, or at any rate most nearly related to that family. Beyond this point our arrangement of the genera is largely a matter of personal opinion; but there will probably be general agreement that Himasthlephora is nearest to such an ancestral form, because of its still possessing rudiments of pedicels, as well as dorsal papillæ, and its lack of tentacle ampullæ; Gephyrothuria is of course very little further removed. But the absence of calcareous deposits in the skin and of posterior prolongations to the radial pieces of the calcareous ring in these genera are probably not ancestral, but are more recent modifications. We may rank Acaudina next because of the shape of the body, and follow with Caudina, the species with long and distinct tails being farthest from the original form. It is natural to consider Aphelodactyla as a modified Caudina, but it is probably just as near to Acaudina. The connection between Caudina and Molpadia is obvious and the dividing line is hard to draw, while Ceraplectana is apparently a striking modification of the latter. As for Eupyrgus, there is room for wide difference of opinion, but it is apparently a much modified genus, which may have had a different origin from the rest of the family, or may have been derived from a form near Gephyrothuria. Assuming that the latter has been the more probable course of development, the relationships of the genera might then be represented as follows:



GEOGRAPHICAL DISTRIBUTION.

In considering the distribution of the foregoing genera we will use the same system that served us in the discussion of the Synaptidæ, even though a large proportion of the Molpadiidæ are abyssal forms. We are at once struck by the fact that there is no one particular region characterized by an exceptional number of genera, although three occur in the Pacific Boreal subregion and four in the Indo-Pacific region; of the latter, two are characteristic, but of the former there are none, although we might ignore the depth at which Ceraplectana occurs and consider it a fourth and characteristic genus. Besides Ceraplectana, two genera are exclusively Abyssal and two others occur in that region. The most widely distributed genus, Molpadia, occurs in practically all parts of the world where collections at depths of 200 m. or more have been made, and Caudina also has a wide range, though it is properly a littoral genus with only two abyssal species, and a distribution much like Chiridota (see p. 133); but Molpadia is strictly littoral only in the case of a very few species, and chiefly in the Arctic or Antarctic regions. The following table will show these facts of distribution in a convenient way; an * indicates that the genus is characteristic of the region, ** that it is not found elsewhere; the figures in parentheses indicate the number of species occurring in that region or subregion:

Abyssal Region:
  * Molpadia (16).
  ** Ceraplectana (1).
  ** Gephyrothuria (1).
  ** Himasthlephora (1).
  Caudina (2).
Indo-Pacific Littoral Region:
  ** Aphelodactyla (5).
  ** Acaudina (1).
  Caudina (1).
  Molpadia (12).
Atlantic Boreal Subregion:
  Eupyrgus (1).
  Molpadia (4).
  Caudina (1).
Arctic Circumpolar Subregion:
  Eupyrgus (1).
  Molpadia (2).
Pacific Boreal Subregion:
  Eupyrgus (2).
  Caudina (1).
  Molpadia (3).



▥ = CAUDINA

▒ = APHELODACTYLA

▤ = EUPYRGUS

Map Showing the Distribution of Three Genera of Molpadiidæ

Antarctic Littoral Region:
Caudina (3).
Molpadia (3).

East American Littoral Region:
Caudina (1).
Mediterranean Subregion:
Molpadia (1).
West American Subregion:
Molpadia (2). ?
Guinea Subregion:
Molpadia (1). ?

We know too little of the range of the great majority of the species to make profitable or worth while any attempt at a study of their distribution. It might be added, however, that the Molpadiidæ afford no support to the so-called "theory of bipolarity," for the southern species of Molpadia and Caudina are perfectly distinct from the northern forms, and there is no representative of Eupyrgus or of Ceraplectana in southern seas.

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EXPLANATION OF PLATES

Figures on the following plates, which are not new, are credited to the author from whom they are taken, but such figures are not always copies; they are sometimes reduced in size and the shading is often modified; occasionally details are changed to make the figure more representative of the species which it illustrates. Where the magnification of the original figure was not given, it has been estimated as nearly as possible from the data available, but a question-mark indicates the uncertainty.

PLATE I. (See frontispiece, facing page 11.)

Synapta maculata (Chamisso and Eysenhardt).

Figure 1. Anterior end of adult, with verrucæ, natural size. (From Semper, 1868.)
2. Anterior end of adult, without verrucæ, natural size.

PLATE II. (See page 42.)

Figure 1. *Anapta gracilis* Semper.
2. *Protankyra similis* (Semper).
3. *Chiridota rigida* Semper.
All natural size and from Semper, 1868.

PLATE III. (See page 135.)

Aphelodactyla molpadioides (Semper).

Adult, natural size. (From Semper, 1868.)

Plate IV.

Synaptinæ.

Figures 1–7. *Protankyra duodactyla,* sp. nov.

Figure 1. Adult. × 3.
2. Radial and interradial pieces of calcareous ring. × 20.
3. Anchor. × 156.
4. Anchor-plate, as they most commonly appear. × 156.
5. Fully developed anchor-plate. × 156.
6. Early stage of development of anchor-plate. × 156.
7. Supporting rods from tentacles. × 156.

Figures 8–11. *Protankyra abyssicola* (Théel).

Figure 8. Anchor. × 85.
9. Anchor-plate. × 85.
10. Tentacles. × 20.
11. Supporting rods from tentacles. × 156.

Figures 12–14. *Protankyra brychia* (Verrill).

Figure 12. Anchor. × 55.
13. Anchor-plate. × 55.
14. Miliary granules. × 156.

Figures 17–19 and 26. *Synapta maculata* (Cham. & Eys.).

Figure 15. Anchors. × 95.
16. Miliary granules. × 95.

Figures 17–19 and 26. *Synapta maculata* Cham. & Eys.

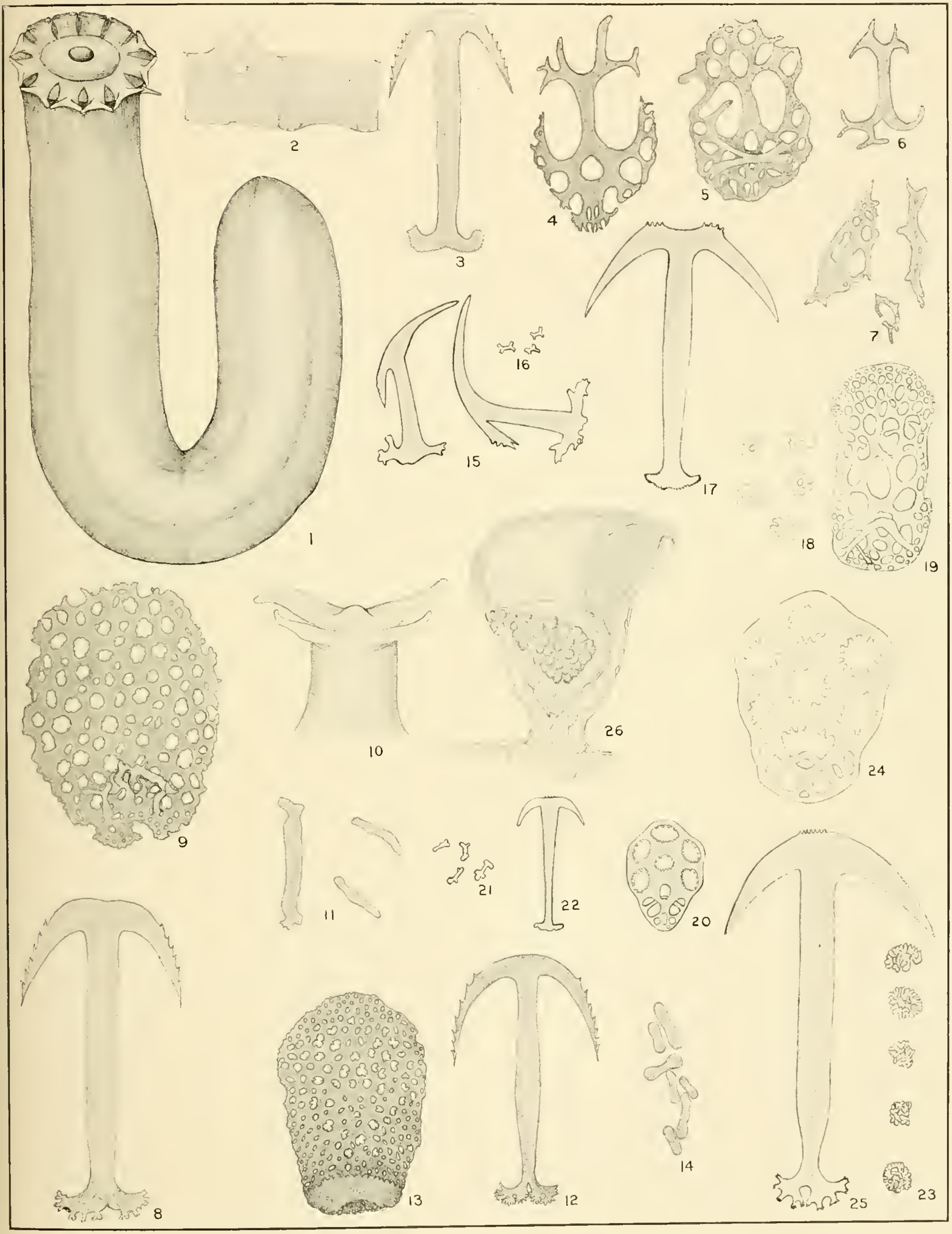
Figure 17. Anchor. × 65 (?). (From Théel, 1886*a.*)
18. Miliary granules or rosettes. × 400 (?). (From Théel, 1886*a.*)
19. Anchor-plate. × 65 (?). (From Théel, 1886*a.*)
26. Ciliated funnel from body-cavity. × 500. (From Semper, 1868.)

Figures 20–22. *Polyplectana kefersteinii* (Selenka). × 95. (From Semper, 1868.)

Figure 20. Anchor-plate.
21. Miliary granules.
22. Anchor.

Figures 23–25. *Euapta lappa* (Müller). (From Théel, 1886*a.*)

Figure 23. Miliary granules or rosettes. × 300 (?).
24. Anchor-plate. × 225 (?).
25. Anchor. × 225 (?).



SYNAPTINÆ

PLATE V.

SYNAPTINÆ.

Figures 1–13 and 22. *Leptosynapta acanthia* (Clark). Except Fig. 22, from Clark, 1899*a*.

Figure 1. Large anchor. × 90.
2. Large anchor-plate. × 90.
3. Small anchor. × 90.
4. Small anchor-plate. × 90.
5. Abnormal anchor. × 90.
6. Double plate with twin anchors. × 90.
7. Miliary granules from anterior part of body. × 450.
8. Miliary granules from posterior part of body. × 450.
9. Supporting rods from tentacles. × 450.
10. Interradial and radial pieces of calcareous ring. × 10.
11. Small ciliated funnel from body-cavity. × 90.
12. Large ciliated funnel from body-cavity. × 90.
13. Part of body laid open to show stomach and line of ciliated funnels. Natural size.
22. Gustatory organs on tentacles. *a.* Group of 5, seen from above. *b.* One, seen from side. × 70.

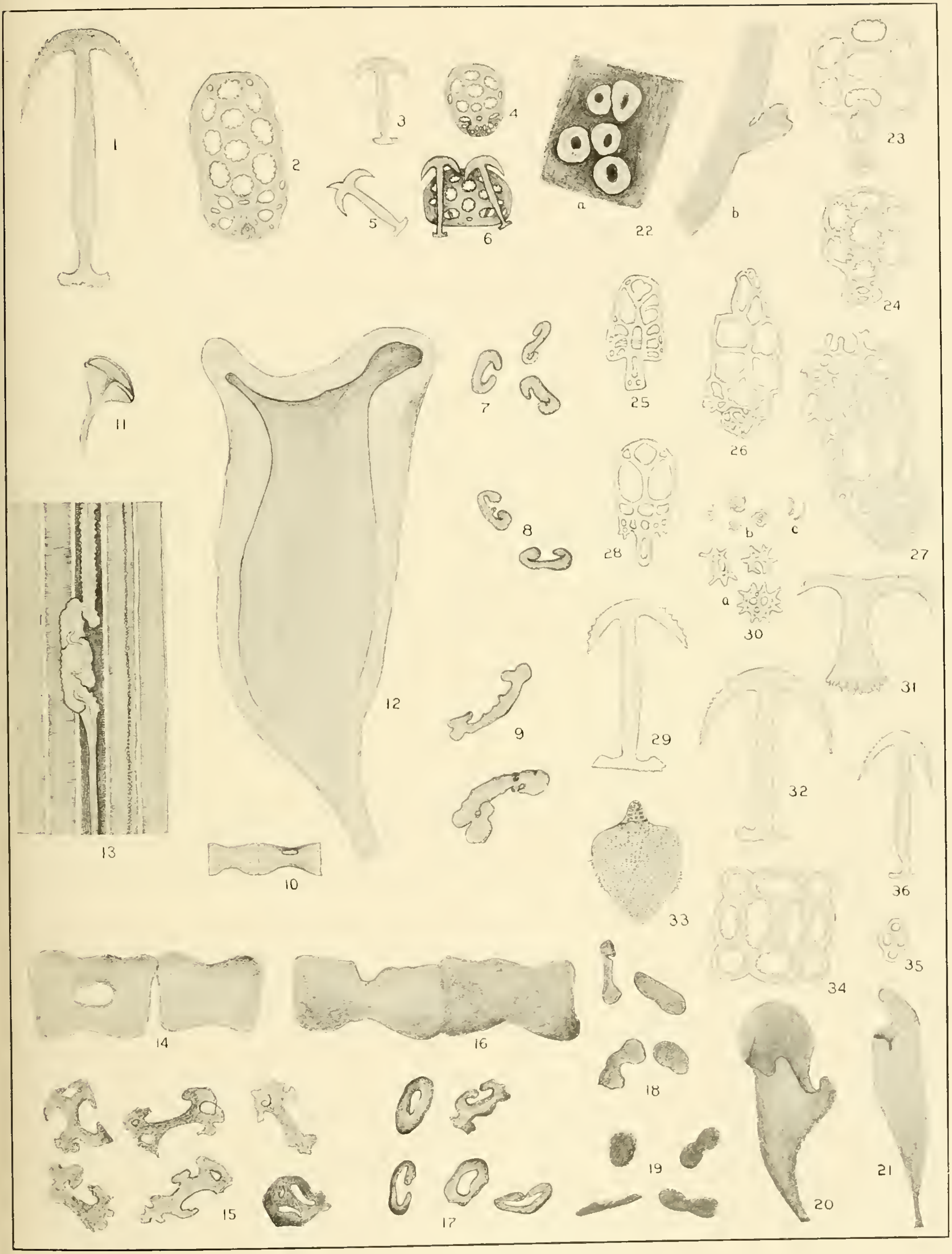
Figures 14, 18, 19, and 20. *Leptosynapta inhærens* (O. F. Müller). (From Clark, 1899*b*.)

Figure 14. Radial and interradial pieces of calcareous ring. × 45.
18. Supporting rods from tentacles. × 450.
19. Miliary granules from longitudinal muscles. × 450.
20. Large ciliated funnel from body-cavity. × 125.

Figures 15, 16, 17, and 21. *Leptosynapta roseola* Verrill. (From Clark, 1899*b*.)

Figure 15. Supporting rods from tentacles. × 450.
16. Radial and interradial pieces of calcareous ring. × 45.
17. Miliary granules from longitudinal muscles. ×450.
21. Large ciliated funnel from body-cavity. × 337.

Figure 23. Anchor-plate of *Labidoplax buskii* (McIntosh). (From Brady and Robertson, 1871.)
24. Anchor-plate of *Euapta glabra* (Semper). × 95. (From Semper, 1868.)
25. Anchor-plate of *Labidoplax dubia* (Semper). × 95. (From Semper, 1868.)
26. Anchor-plate of *Protankyra challengeri* (Théel). × 170 ? (From Théel, 1886*a*.)
27. Anchor-plate of *Labidoplax sluiteri* Fisher. × 100 ? (From Sluiter, 1901.)
28. Anchor-plate of *Labidoplax dubia* (Semper). × 200 ? (From Théel, 1886*a*; *incerta*.)
29. Anchor of *Protankyra verrilli* (Théel). × 110 ? (From Théel, 1886*a*.)
30. Miliary granules of *Protankyra bidentata* (W. and B.). (*a.* From Théel, 1886*a*; *distincta*. × 400 ? *b.* From Semper, 1868; *molesta*. × 95. *c.* From Ludwig, 1875; *distincta*. × 70.)
31. Anchor of *Protankyra autopista* (v. Mar.). × 150. (From v. Marenzeller, 1881.)
32. Anchor of *Protankyra insolens* (Théel). × 50 ? (From Théel, 1886*a*.)
33. Anchor-plate of *Protankyra rodea* (Sluiter). × 25. (From Sluiter, 1890.)
34. Accessory perforated plate of *Protankyra ludwigii* (Sluiter). × 300. (From Sluiter, 1890.)
35. Accessory perforated plate of *Protankyra asymmetrica* (Ludwig). × 180. (From Ludwig, 1875.)
36. Anchor of *Protankyra asymmetrica* (Ludwig). × 70. (From Ludwig, 1875.)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SYNAPTINÆ

PLATE VI.

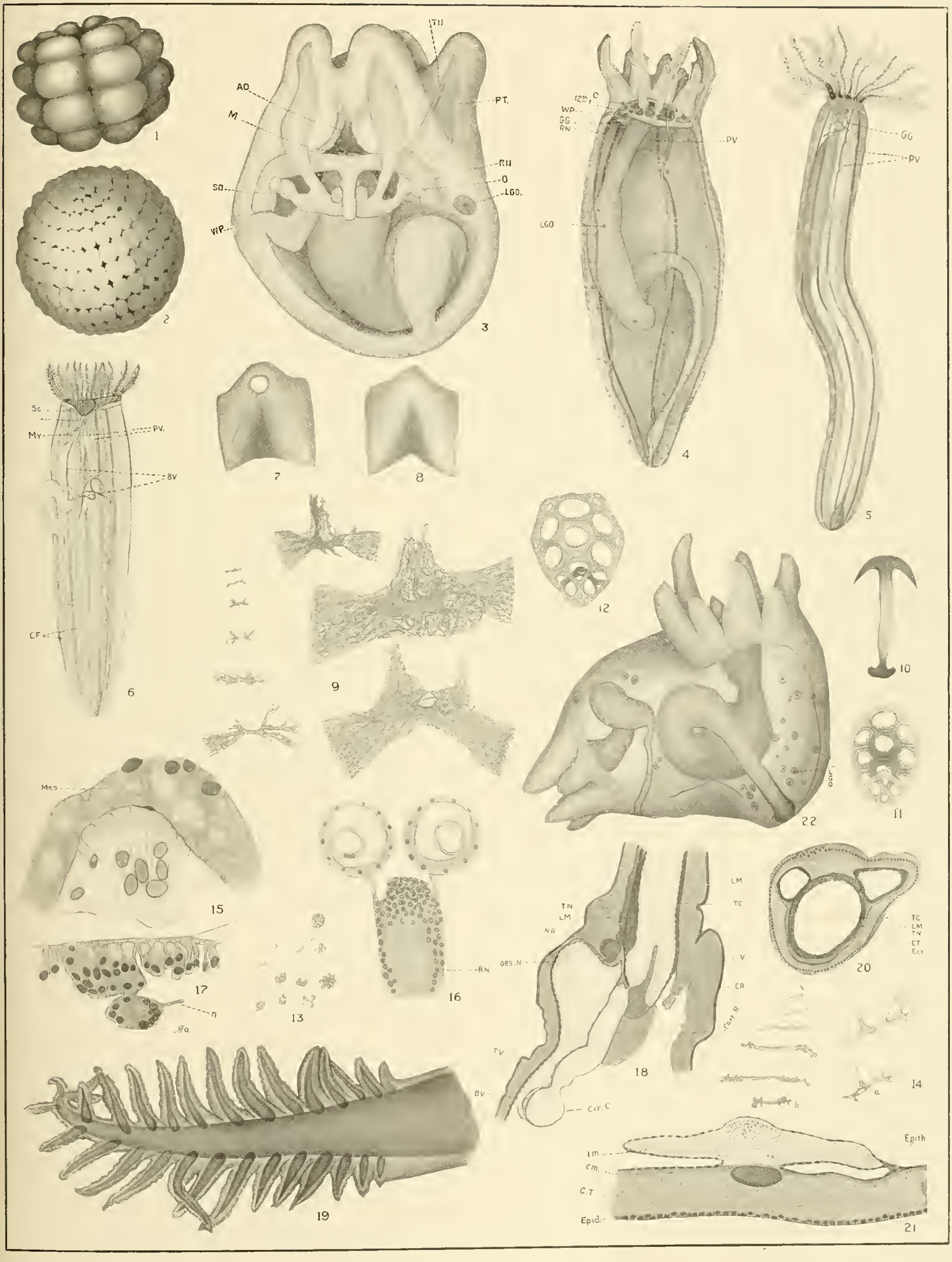
SYNAPTINÆ.

Synaptula hydriformis (Lesueur). (From Clark, 1898*a*.)

Figure 1. Segmenting egg; 32-cell stage. × 225.
2. Blastula. × 225.
3. Pentactula larva. × 225.
4. Ten-tentacled young. × 22.
5. Adult animal. Natural size.
6. Adult, opened to show inner organs. Natural size.
7. Radial piece of calcareous ring. × 35.
8. Interradial piece of calcareous ring. × 35.
9. Stages of development of a piece of the calcareous ring. × 225.
10. Anchor. × 120.
11. Anchor-plate. × 120.
12. Anchor-plate. × 120.
13. Miliary granules. × 225.
14. Calcareous rods. × 225. *a*. From around madrepore plate. *b*. From tentacles of a 10-tentacled larva.
15. Vertical section through eye-spot. × 950.
16. Horizontal section through positional organs and nerve. × 500.
17. Vertical section through a sense-papilla and its ganglion. × 500.
18. Vertical section through base of a tentacle, to show arrangement of parts. × 35.
19. Tentacle. × 22.
20. Cross-section of young tentacle, to show separation of digit-canals from tentacle-canal. × 225.
21. Cross-section of body-wall. × 80.
22. Monstrous twin larva. × 225.

The following explanatory letters are used on this plate:

AO=atrial opening.
BV=blood-vessel.
CF=ciliated funnels.
CM=circular muscles.
CR=calcareous ring.
CT=connective tissue.
Cart. R.=cartilaginous ring
Cir. C.=circular canal.
Ect.=ectoderm.
Epid.=epidermis.
Epith.=epithelium.
GG=genital gland.
ga.=ganglion.
LM=longitudinal muscles.
LGO=larval glandular organ.
M=mouth.
Mes.=mesenchyme.
My.=mesentery.
NR=nerve ring.
N=nerve.
Oes. N.=œsophageal nerve.
O=positional organs.
PT=primary tentacle.
PV=polian vessels.
RN=radial nerve.
SC=stone canal.
SO=secondary outgrowth of hydrocoel.
TC=canal of tentacle.
TN=tentacle nerve.
TV=tentacle blood-vessel.
V=valve.
WP=water pore.



SYNAPTULA HYDRIFORMIS (Lesueur)

PLATE VII.

CHIRIDOTINÆ.

Figures 1–4. *Trochodota venusta* (Semon). (From Semon, 1887.)

Figure 1. Adult animal. × 30.
2. Piece of calcareous ring. × 120.
3. Sigmoid body. × 500.
4. Supporting rod from tentacle. × 500.

Figure 5. Sigmoid bodies of *Scoliodota japonica* (v. Marenzeller). × 200 (?). (From Théel, 1886*a*.)

Figures 6 and 7. *Trochodota purpurea* (Lesson). × 230. (From Ludwig, 1898*b*.)

Figure 6. Sigmoid bodies.
7. Supporting rod from tentacle.

Figures 8–13. *Tæniogyrus contortus* (Ludwig). (Fig. 8 from Théel, 1886*a*; others from Ludwig, 1898*b*.)

Figure 8. Wheel. × 250 (?).
9. Sigmoid body, with ends curved in planes at right angles to each other. × 230.
10. Sigmoid body, with ends curved in same plane. × 230.
11. Sigmoid body, same as Fig. 9, seen from side. × 230.
12. Supporting rod from tentacle. × 230.
13. Oral disc of larva at 7-tentacled stage, showing origin of sixth and seventh tentacles simultaneously in the lateral interradia. × 48.

Figures 14–18. *Polycheira rufescens* (Brandt). (From Semper, 1868.)

Figure 14. Tree-like cluster of ciliated funnels from body-cavity (*Chirodota variabilis* Semper). × 95.
15. Wheel (*Chirodota variabilis* Semper). × 260.
16. Curved rods from skin (*Chirodota variabilis* Semper). × 260.
17. Part of calcareous ring (*Chirodota variabilis* Semper). × 5 (?)
18. Tentacle. *a* = half expanded; *b* = contracted (*Chirodota panænsis* Semper). × 5 (?)

Figures 19–23. *Anapta gracilis* Semper. (From Semper, 1868.)

Figure 19. Calcareous deposits from skin. × 260.
20. Radial and interradial pieces of calcareous ring. × 5 (?)
21. Tentacle, showing digits and gustatory organs. × 10 (?)
22. One gustatory organ from side. × 230 (?)
23. Ciliated funnel from body-cavity. × 95.

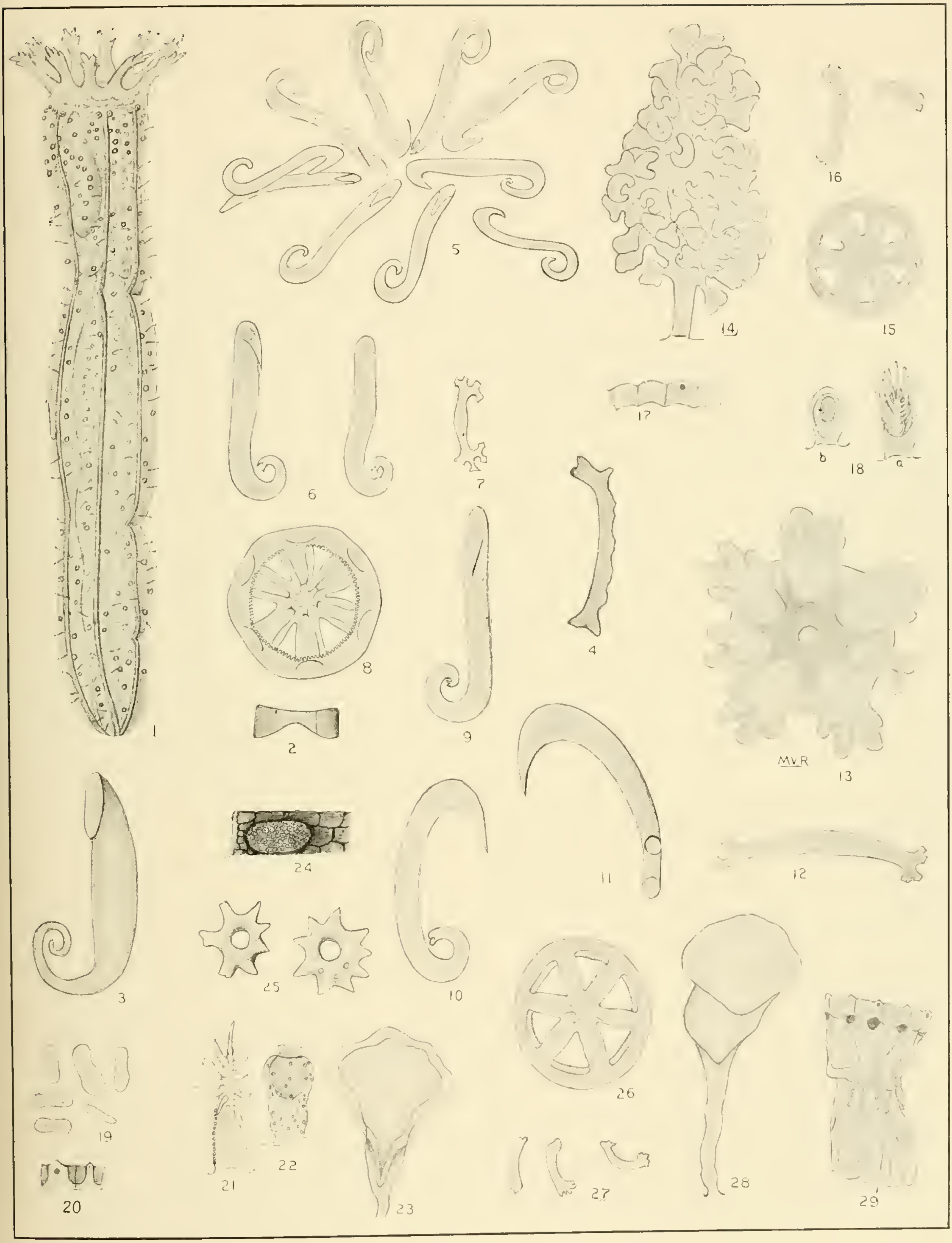
Figures 24 and 25. *Chiridota marenzelleri* R. Perrier. (From R. Perrier, 1905.)

Figure 24. Wheel-papilla. × 10.
25. Stellate miliary granules. × 330.

Figures 26–29. *Chiridota rigida* Semper. (From Semper, 1868.)

Figure 26. Wheel. × 260.
27. Curved rods from skin. × 260.
28. Ciliated funnel from body-cavity. × 260.
29. Calcareous ring, œsophagus and water-vascular ring, with its appendages. × 10 (?)

PLATE VII



CHIRIDOTINÆ

PLATE VIII.

MYRIOTROCHINÆ.

Figures 1–6. *Acanthotrochus mirabilis* Dan. and Kor. (From Dan. and Kor., 1882.)

Figure 1. Adult. Natural size.
2. Adult. × 5 (?)
3. Tentacle. × 100 (?)
4. Small wheel. × 300 (?)
5. Large wheel. × 185 (?)
6. Calcareous ring, anterior view. × 35 (?)

Figures 7–14. *Trochoderma elegans* Théel. (From Théel, 1877.)

Figure 7. Adult. Natural size.
8. Tentacle, with calcareous ring, positional organs, and radial nerve. × 100 (?)
Figures 9–12. Successive stages in development of wheel. × 300 (?)
Figure 13. Wheel, seen from the side. × 425 (?)
14. Calcareous ring, side view. × 35 (?)

Figures 15–20. *Myriotrochus vitreus* (M. Sars.). (From Kor. and Dan., 1877.)

Figure 15. Adult, partly contracted. Slightly enlarged.
16. Adult, fully extended. Slightly enlarged.
Figures 17–19. Wheels. × 140 (?)
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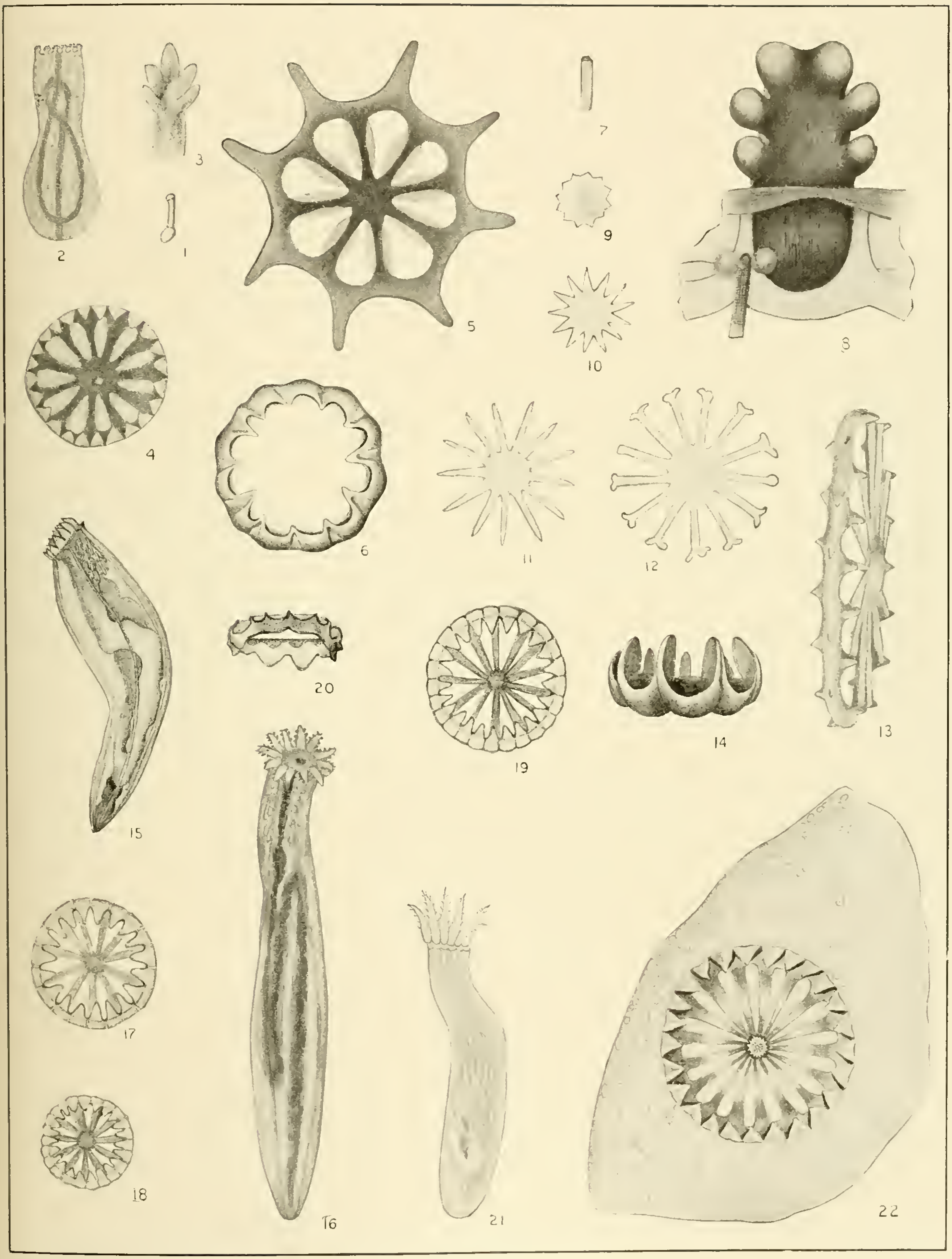
22. Wheel in normal position in skin. × 175 (?)



MYRIOTROCHINÆ

PLATE IX.

CAUDINA.

Figures 1–5. *Caudina obesacauda,* sp. nov.

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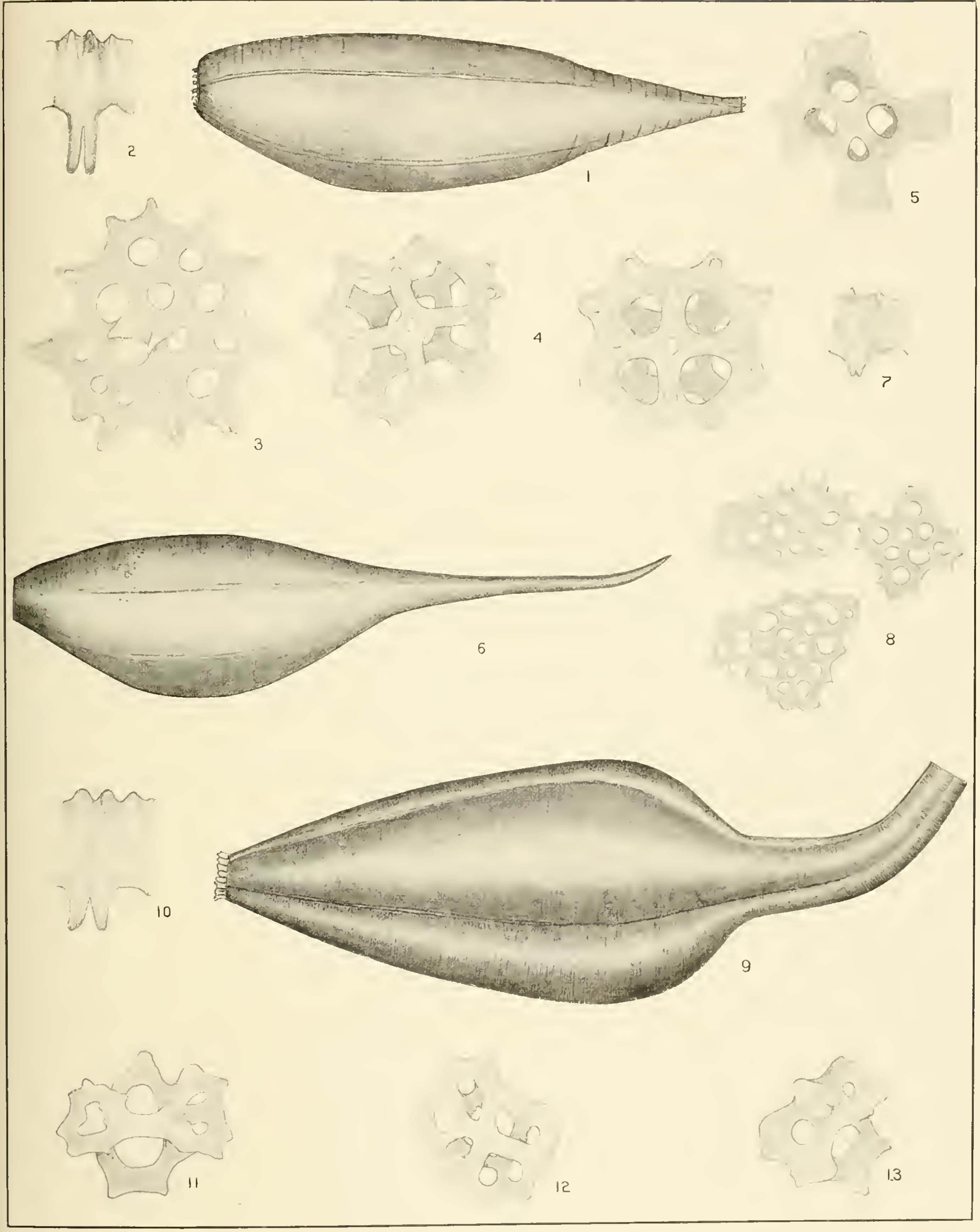

CAUDINA

PLATE X.

MOLPADIIDÆ.

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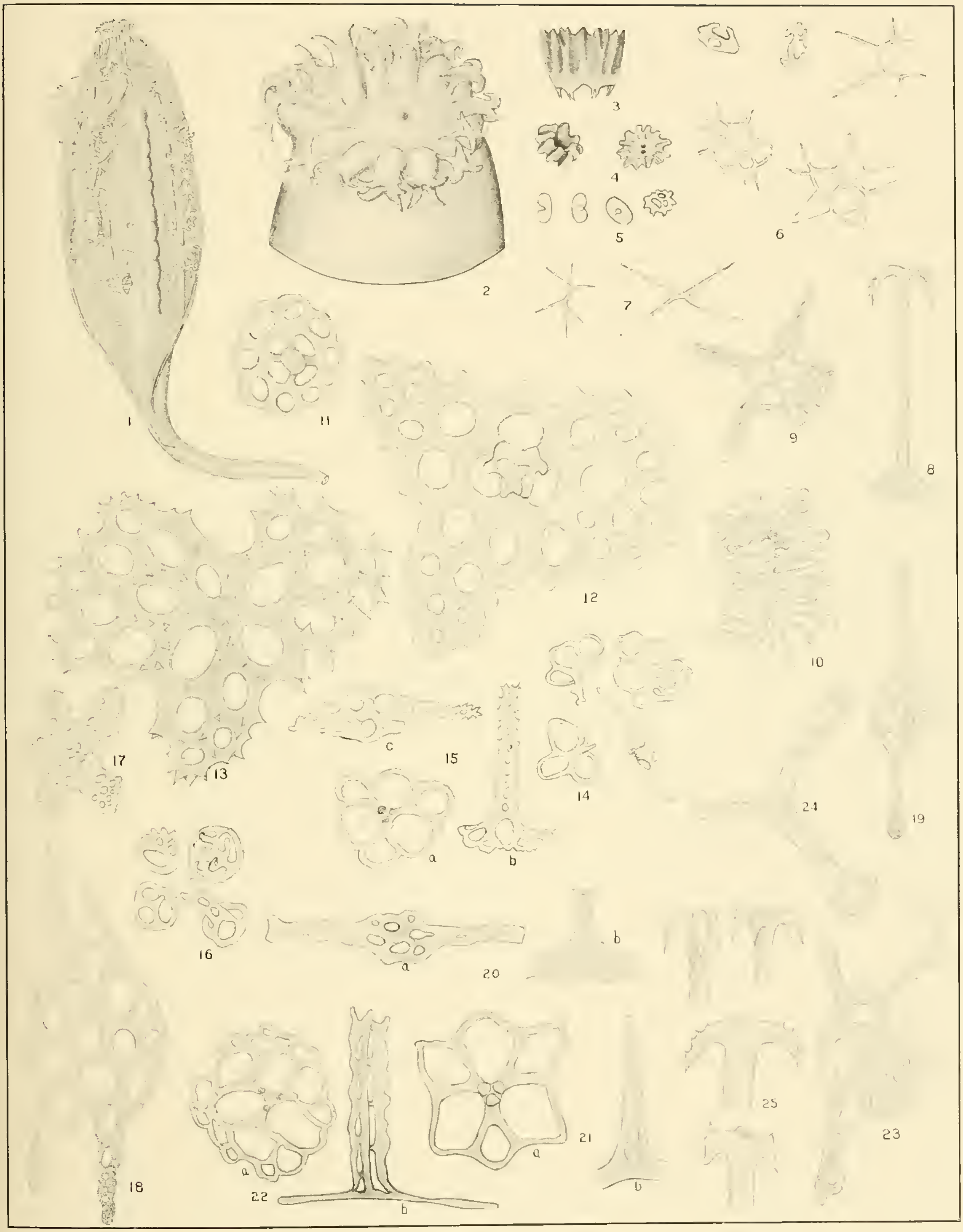
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18
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a
b
b

MOLPADIIDÆ

PLATE XI.

MOLPADIIDÆ.

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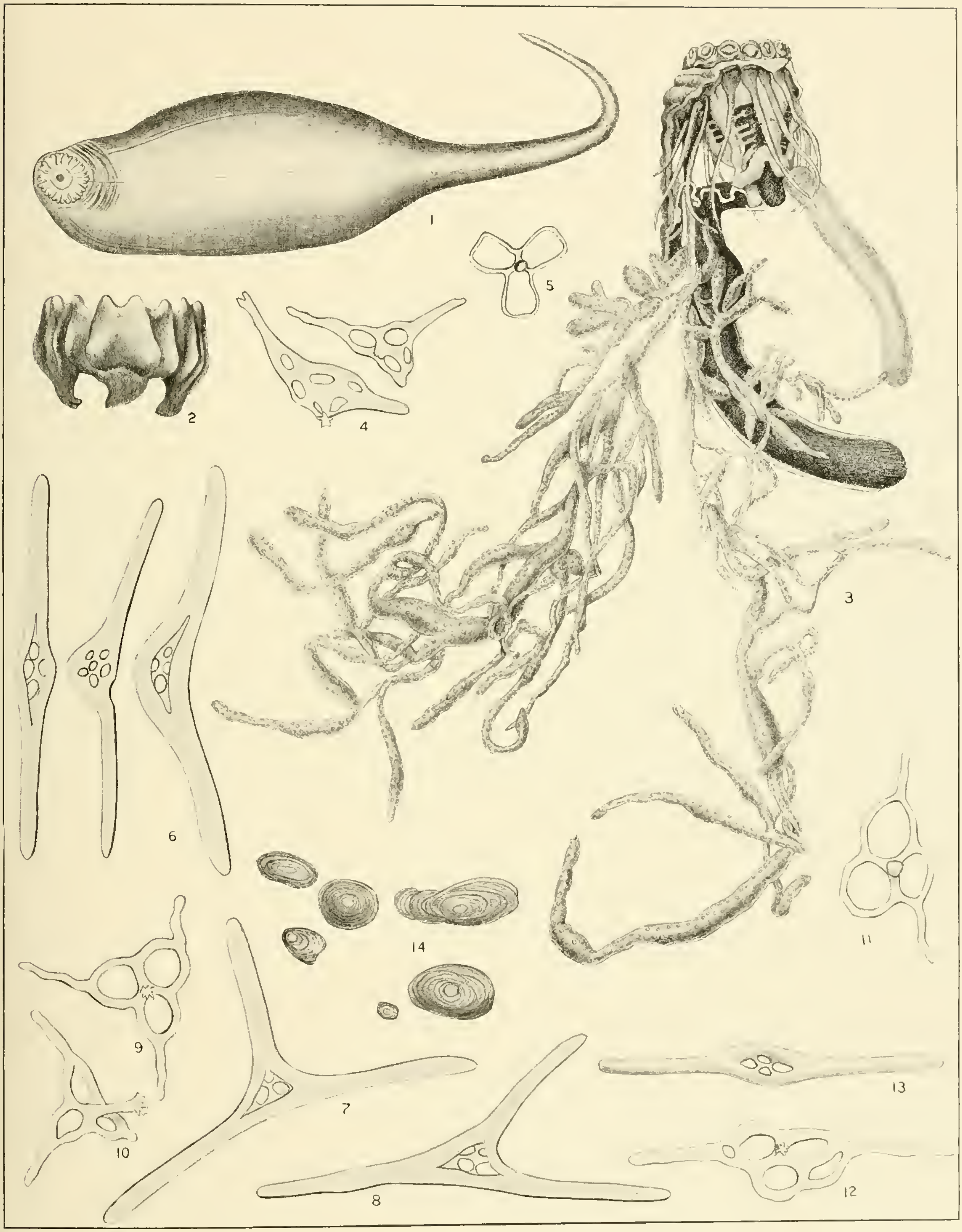

MOLPADIA MUSCULUS

PLATE XII.

MOLPADIIDÆ.

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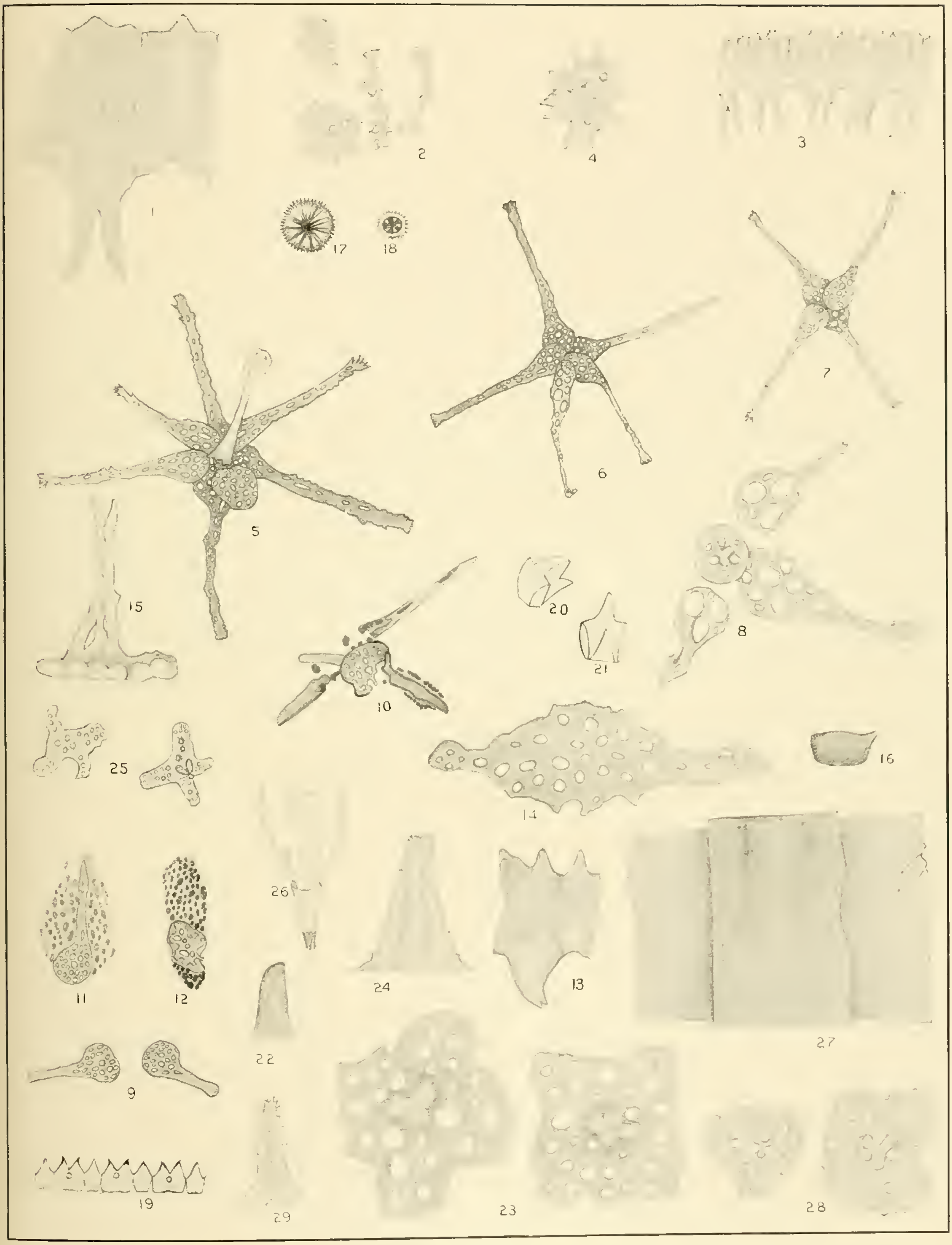

MOLPADIIDÆ

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MOLPADIIDÆ.

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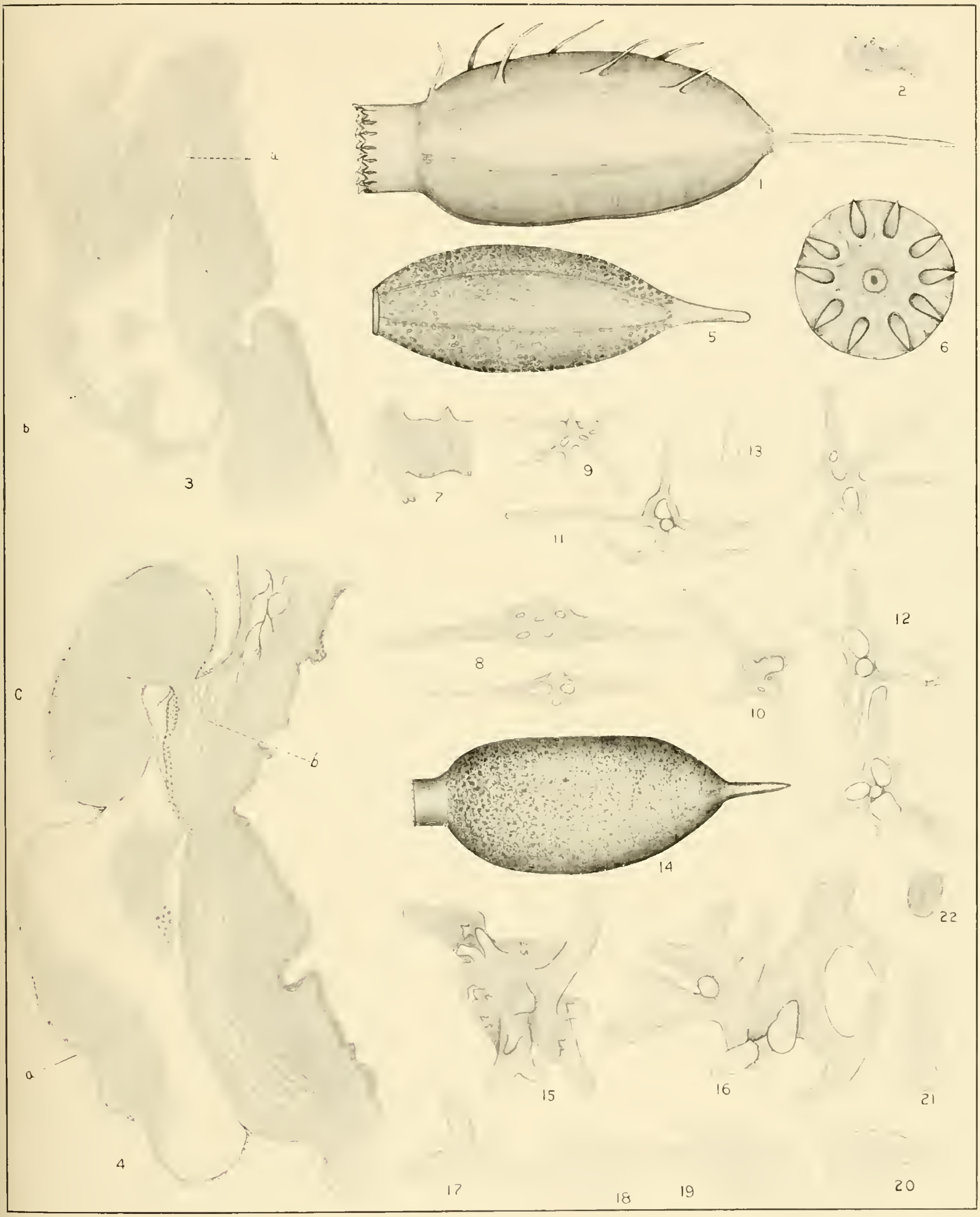

MOLPADIIDÆ

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Pages on which the descriptive accounts of families, genera and species occur are indicated by black-faced type.

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE
VOLUME 35, NUMBER 3

A CONTRIBUTION TO THE COMPARATIVE HISTOLOGY OF THE FEMUR

BY

J. S. FOOTE, M. D.
Professor of Pathology, Creighton Medical College, Omaha, Nebraska

EDITED BY ALEŠ HRDLIČKA

(No. 2382)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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Commission to whom this memoir
has been referred:

Aleš Hrdlička
Frank Baker
George Arthur Piersol

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

ADVERTISEMENT

The present memoir by J. S. Foote, M. D., Professor of Pathology at Creighton Medical College, entitled "A Contribution to the Comparative Histology of the Femur," records original observations begun by the author in 1909 in a study of cross-sections of the femora of about six hundred different animals, including amphibians, reptiles, birds, mammals, and man, with a view to determine what variations of bone structure may exist and their signification.

In accordance with the rule adopted by the Smithsonian Institution, the work has been submitted for examination to a commission consisting of Dr. Aleš Hrdlička, of the United States National Museum; Dr. Frank Baker, of the National Zoological Park; and Dr. George Arthur Piersol, of the University of Pennsylvania, who recommended its publication in the present series.

The work is published in cooperation with the Creighton University, Omaha, Nebraska.

Charles D. Walcott,
Secretary.

Smithsonian Institution,
Washington, *December, 1915.*

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ACKNOWLEDGMENT

This work has been largely of a pioneer nature. The zoological classification of animals has furnished the principal guide in the selection of bones and in the general plan of study. Beginning with the amphibians and closing with man, one femur after another has been examined until sufficient data have been accumulated to establish, to a reasonable degree, definite bone types and type combinations which were then employed as a structural basis for comparative study.

In an investigation of this character, covering a period of more than five years and involving many details, it will not be surprising if imperfections are found; but all possible effort was made to eliminate those that could be detected.

The study has brought to light a number of important new facts. Among other conclusions the author finds that three types of minute structure form the basis of all bones. The first and second types predominate in amphibians, reptiles, and birds, the third in mammals and man. The first type, composed of lamellæ, appears as a uniform structure or in a twofold or threefold division, and characterizes the amphibians, lizards, and bats. The second type (laminar) appears first in the amphibians and in an early or late form of differentiation in birds and lower mammals. The third type (Haversian system) is first outlined in the amphibians and reaches its highest development in the higher mammals and especially in man.

For valuable material, facilities for study and courtesies extended, the writer is especially indebted to the Division of Physical Anthropology of the United States National Museum, to the Divisions of Mammals and Reptiles of the same institution, to the Departments of Reptiles, Birds, and Mammals of the American Museum of Natural History, to the Nebraska State Hospital, and to the Departments of Anatomy of the Northwestern, the Tulane, the Nebraska, and Creighton Universities.

Furthermore, he desires to express his deep sense of obligation to those who have assisted him: to Dr. Aleš Hrdlička for his encouraging interest and most valuable suggestions in the pursuance of the study, without his clearing-house advice the tedious details would have fallen into a useless mass; to Creighton University for apparatus and material assistance in the publication of this report; to Professor William F. Rigge for the calculation of the medullary indices; and to the many students and friends who have rendered assistance in every possible manner.

J. S. Foote.

A CONTRIBUTION TO THE COMPARATIVE HISTOLOGY OF THE FEMUR

By J. S. FOOTE, M. D.

I. INTRODUCTION

The investigations in the Comparative Histology of the Femur were begun by the writer in 1909, and were suggested by a section of the turkey's femur which he had casually prepared and which seemed to show a type of bone structure quite unlike that usually described. Before long, other peculiarities were noticed and it was then decided to extend the study to various animals for the purpose of determining what variations of bone structure may exist, and, if possible, what is their significance. Accordingly, the femora of 46 different animals, including amphibians, reptiles, birds, mammals, and man, were examined as they could be obtained and described, the report being published in the Transactions of the American Miscroscopical Society of April, 1911.[1] The number of femora examined up to that time was small, nevertheless the results of the work were so new and interesting as to warrant further study.

Following the report and upon the suggestion of Dr. Aleš Hrdlička, curator of the Division of Physical Anthropology in the United States National Museum, the writer extended his investigations to a much greater number of orders, genera, and species of the lower animals, and finally also to the three main races of man—black, yellow-brown, and white—the latter including the ancient Egyptian. An abstract of the results of the advanced investigations was published in 1913 by the Smithsonian Institution.[2] The studies, however, were still continued as long as material was available and finally have been combined in this memoir which presents a comprehensive view of the whole work thus far accomplished. In all, 600 sections have been examined; of these 440 are described.

The present report includes, besides the text, 467 drawings. They were made, for the most part, directly from the slides with the help of the Edinger Drawing Apparatus, and are illustrations of the structural bone units, of the types and combinations of bone types in their various stages of differentiation,

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[1] Foote, J. S. The comparative histology of femoral bones. Trans. Amer. Micros. Soc., 30, 1911, pp. 87-140, 9 plates.

[2] Foote, J. S. The comparative histology of the femur. Smithsonian Miscellaneous Collections, Vol. 61, No. 8 (Publication 2232), Washington, 1913, pp. 1-9, 3 plates.

and of the arrangements of types as they would appear in reconstructed femora. The exact number of histologic bone units of any section does not, and obviously could not, appear in the drawings. The writer's endeavor has been to represent, in a comprehensive way, the development, proportions, and arrangements of these units, rather than their exact number.

It was also found impracticable to make the drawings of the various bone sections to a definite, uniform scale, the femora ranging from 0.5 mm. to 13 cm. in diameter. Microphotographs were essayed, but were found unsatisfactory.

The various diameters of the examined femora, their medullary canals, and medullary indices are given in the synoptic tables and also in the text at the beginning of each detailed description. The sections and measurements were made invariably at the middle of the shaft of the bone.

The femur was selected for these studies rather than any other bone of the body, because it is of good size, because it is in fairly constant use, and on account of its being the sole bone of an important segment of the body. It is, in other words, a good representative bone and perhaps the best adapted to the investigations of this nature.

The illustrations have, generally, been grouped according to the structural relations of the bones.

The type or combination of types of structure which any bone was observed to present will be found noted in the tables, so that by a glance at these there may be readily obtained a comprehensive view of the grouping of the femora of the various animals.

The femora examined and included in this report are those of amphibians, reptiles, birds, mammals, and man. Fetal, young, adolescent, adult, and senile femora of the same species were examined whenever possible, and, when circumstances allowed, observations were also made on other bones of the body. All sections were carefully ground to proper thinness and mounted in hard balsam.

II. SUMMARY OF RESULTS

As the mass of detailed observations which follow will be consulted in special instances only, it may be convenient to the reader to have a general summary of the principal results of the study presented at this place instead of at the end of the work.

The microscopic structure of a long bone described by the early histologists happened to be that of a third or Haversian system type, and it has been assumed, perhaps without a more definite reason, that all long bones have the same structure. From an examination of a large number of femora it is evident that they have not.

If there is any one distinctive characteristic of bone structure shown by the present investigation, it is that of extensive variation, variation due to heredity, to age, size and strength of the bone, and possibly to other conditions. It is certainly safe to say that few long bones, and particularly femora, have precisely the same structure, and yet, through all their diversity, there can be perceived certain definite, readily recognizable strains, which are found not only peculiar to separate groups of animals, but also to definite stages of differentiation.

The summary which follows will be treated under the following headings:

General shape.

Relation of structure to shape.

Density of bone.

Measurements.

Medullary index.

Medullary canal.

Medullary contents.

Medullary surface.

Cancellous bone and trabeculæ.

Variety of minute structure of the wall of the femur.

Units of bone structure.

Bone cells—lacunæ.

Dendrites and canaliculi.

Differentiated bone units—Lamellæ.
  Uniformly lamellated bone.
  Twofold division.
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Laminæ.

Haversian system.

Types of bone structure.

Frequency of the occurrence of types.

Type combinations.

Type of bone structure according to classes of animals.

The factors influencing types of bone structure as could be determined from the grade of the animal.

Geographic position.

Sex, age, function, individuality, health and disease, heredity.

Senility.

GENERAL SHAPE OF THE FEMORA OF THE LOWER ANIMALS

By the shape of the femur is understood the shape of the cross-section of the bone at its middle. That this shape of the shaft of the femur varied considerably in man was long since shown by Hrdlička.[1] The present studies demonstrate that it differs also in animals. In general it is represented by the same geometrical types as in man, being triangular, elliptical, round, quadrangular, and plano-convex. Also, as in man, besides the femora which are fairly true to a type, there are others which are irregular or indeterminate in shape and do not admit of any definite classification.

Generally speaking, however, there was one particular shape which was more prominent than any other, and that was the elliptical. This was found to be true of the majority of adults among amphibians, reptiles, birds, bats, and other mammals, and, therefore, was the most common shape of femur below man as far as these examinations were concerned. The differences in the lengths of the two main diameters were usually small, the lateral diameter being generally the longest; in only a few specimens—as in the femur of the seal—were the lateral diameters greatly in excess of the antero-posterior. The femora of the *Hyla cinerea, Erinaceus europeus, Tatu novemcinctus, Castor canadensis,* and *Rhinoceros bicornis* had very long posterior, lateral, curved or straight ridges and differed very materially from other femora. The variations from the circular and elliptical shapes were in a measure dependent upon the development of the linea aspera. In some femora this was absent; in others it was fairly well developed; and in still others its development was extreme. In the table which follows will be found the various shapes of the femora of the lower animals expressed in percentages:

SHAPE OF THE SHAFT OF THE LOWER ANIMAL FEMUR AT THE MIDDLE

	No. of femora examined	I Triangular	II Elliptical	III Round	IV Quadrangular	V Indeterminate	VI Plano-Convex
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Amphibians	39	26	41	28	0	5	0
Reptiles	34	29	53	9	3	0	6
Birds	40	12	52	18	3	0	15
Bats	55	0	72	25	0	0	3
Other Mammals	133	21	53	15	0	5	6
Totals	301	17	50	25	0.7	3	5

RELATION OF STRUCTURE TO SHAPE

As far as present investigations are concerned, no special relation of the histologic structure of the femur to the shape of its shaft has been determined. The prolonged posterior ridge of the triangular sections is due to the linea aspera, and wherever the latter is well developed macroscopically it is composed of Haversian systems regardless of the type of the rest of the bone.

As will be seen later, the linea aspera seems to have a development quite distinct from the rest of the femur.

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[1] See in this connection, Hrdlička, A.—Typical forms of shaft of long bones. Proc. Amer. Assoc. Anatomists, 14th Sess., 1900 (Washington, 1901), pp. 55-69.

DENSITY OF BONE

This quality of bone was estimated by its weight and the subjective feeling experienced during the process of grinding, and was found to be far from uniform. Hardly any two bones were the same in this respect. Some were heavy and others were light; some were hard and others were soft. In some, one portion of the wall was hard and another was soft, and in still others there were soft and hard spots. The femur of the hippopotamus was extremely heavy and exhibited a stone-like quality in grinding, while that of the peahen, turkey-buzzard, or eagle was light and had a flint-like character. Many mammalian and human femora were found to vary greatly in the densities of the different portions of their wall. The outer was soft and the inner hard, or vice versa. This was noticed more especially in human femora. Many human bones also had small areas of unequal hardness which were sometimes accounted for by senile changes. Finally, sections of some femora—as those of the elk—seemed to show an extremely brittle character.

In some cases these inequalities could be explained by histological variations; while in others the chemical character of the inorganic compound seemed to govern the hardness. As a rule, first and second type bones (lamellar and laminar) ground more easily than third (Haversian system), as might be expected. But the femur of the peahen had flinty hardness and yet showed an incomplete second type of structure. This could only be explained by some peculiarity of its inorganic composition.

MEASUREMENTS

The following measurements of each cross-section were taken: the antero-posterior and lateral diameters of the bone and the same diameters of the medullary canal. All measurements were recorded in millimeters. The results will be found in the synoptic tables and also at the beginning of each detailed description. The measurements will give a correct impression of the relative diameters of the shafts of the various femora, and upon them are based the calculated ratios of the medullary canals to their respective bones.

MEDULLARY INDEX

The ratio of the square of the mean diameter of the medullary canal to that of the surrounding bone, as determined from cross-sections of the middle portions of the various femora, is referred to as the medullary index. It has been calculated from the formula below.[1] The individual indices will be found

---

[1] $$\left(\frac{\left(\frac{a+b}{2}\right)^2 \times 100}{\left(\frac{A+B}{2}\right)^2 - \left(\frac{a+b}{2}\right)^2} \right) = R.$$

a and *b* are the long and short diameters of the medullary canal respectively. *A* and *B* are the long and short diameters of the bone respectively. *R* is the ratio of the medullary canal to the bone.

The calculations were made by William F. Rigge, S. J., Professor of Astronomy, Creighton University, Omaha, Nebraska.

in percentages in the synoptic tables and text. By an examination of these indices it will be seen that the medullary canals of the various femora do not bear a constant relation to the bones, but present very important variations. In some bones the canals are relatively large and in others they are relatively small. The larger the canal in a given species the thinner the wall of bone, and vice versa. There are also some individual variations within each species, and quite noticeable differences in this respect between the young, adult, and senile bones.

The averages given below show that the medullary indices of the different classes of animals and even in man vary considerably:

		Per cent
Amphibians		36.6
Reptiles (including turtles)		26.1
Reptiles (excluding turtles)		33.0
Birds		159.0
Bats		48.6
Other mammals		63.3
Man	Black race	41.9
	Yellow-brown race	43.8
	Ancient Egyptian	39.5
	Modern white race	35.8
Human race as a whole		38.6

Looking over the above averages it will be noticed:

First.—That the lowest index is found in the reptiles where it is 26.1%. The average index of the class of reptiles is lowered by the turtles, in most of which the index is zero. In the turtle femora the medullary canals are occupied by heavy cancellous bone with very small meshes filled with marrow. Observed with the naked eye these bones appear to be solid. If the turtles are excluded the average reptile index is 33% instead of 26.1%. As far as the medullary canals are concerned, both in regard to their contents and indices, those of the turtles do not resemble those of other reptilian genera in any respect. Comparing the indices of the amphibians with those of the reptiles, it will be seen that the index falls quite sharply or that the medullary canal diminishes and the mass of bone increases markedly from amphibian to reptile.

The highest average index is found in birds, where it is 159%. From this it will be seen that the medullary canal increases relatively in size and the bone decreases in mass enormously from reptile to bird. In proportion to their weight, the birds have less bone than amphibians or reptiles. The index is higher in those birds which have empty medullary canals (226.4%) than in those which have full canals (149.7%). That is, the femora with empty canals have thinner walls in relation to the size of the bone than those with full canals.

Second.—The mean index falls, to a marked degree, from birds to mammals, or from 159% to 63.3%. The index in bats is 48.6%, and in mammals without the bats 63.3%. That is, the canal is smaller and the walls of the bone are thicker in mammals than in birds, and the canal is smaller and the walls are thicker in bats than in other mammals.

Third.—The medullary index in the human race, as a whole, is 38.6% and, therefore, much lower than in other mammals, in which it averages 63.3%; that is, the medullary canal is relatively smaller and the wall of the bone thicker in bipeds which carry the weight of the body on two legs than in quadrupeds which carry the weight on four. The three races, however, show slight variations. In all, 139 human femora were examined—34 black, 23 Indian (pre-Columbian), 9 ancient Egyptian, and 73 modern white. Their respective indices were 41.9%, 43.8%, 39.5%, and 35.8%. From these it will be seen that the index is higher in the ancient than in the modern white femora (counting the Egyptian as of white race), and lower in the modern white (35.8%) than in the modern black (41.9%) or the pre-Columbian Indian (43.8%). That is, the canal is larger and the mass of bone smaller in ancient (Egyptian) than in the modern white femur, and the canal is relatively smaller and the bone larger in the modern white than in the modern black race or the pre-Columbian Indian. The smallest canal and thickest wall were found in the modern white, and the relatively largest canal and thinnest wall in the Indian. Some of these detailed differences may, of course, be purely accidental, due to the insufficient number of specimens, or other conditions; but they are of sufficient interest to warrant further observations.

Medullary Canal

The canal presents many peculiarities in position, shape, size, surface, and contents.

In some femora it is situated eccentrically. This is more especially true of human fetal bones, where the canal occupies the anterior half of the cross-section. It is also true in many adult femora of the triangular shape and third (or Haversian) type. In femora of the first type of structure (the lamellar), the canal is situated almost centrally, as such femora do not often have a well-defined linea aspera. In still other cases it is situated obliquely, as in some human femora.

The shape of the canal seldom corresponds with the peripheral outline of the bone, and the wall of the femur, therefore, is not of uniform thickness excepting in round bones with central canals, and these are generally limited to small femora, to those of the young, and to simple types. In adult bones, the canal varies considerably in shape. In some bones it is nearly circular with fairly regular outlines, as may be seen in the small first type (lamellar) femora like those of the bats. In others it is elliptical or irregular, regardless of the shape of the bone, as in some human specimens.

In size the canal presents several peculiarities. Some femora have relatively very small, and others very large canals. In some cases it is reduced to extremely small dimensions, as in the amblystoma, turtles, yellow-hammer, and some embryonic mammals. It reaches its greatest relative size in birds and its smallest in amphibians and reptiles.

Medullary Contents

The contents vary. Some medullary canals are full of marrow, as those of amphibians, of reptiles, and of bats; some contain cancellous bone and marrow, as those of man; some have trabeculæ, as those of the peahen, eagle, and turkey-buzzard. In birds an important variation is found. About one-half of their femora have canals full of marrow, while the remaining half are either empty or contain trabeculæ only. The full or empty condition of the canal seems to bear no relation to the flight of the bird. The peahen is a poor flier and has an empty canal, and the eagle is a good flier and has an empty canal. The wild goose is a good flier and has a full canal, and the domestic turkey[1] is a poor flier and has a full canal. The peahen and domestic turkey may be thought to exhibit the flying habits of domestication; but these birds show two opposite conditions of medullary contents—the peahen has an empty canal and the turkey a full canal. Similar results are also observed in the wild and domestic turkeys. Both have full canals although they differ greatly in their abilities to fly. Again, in some birds, as the yellow-hammer, pigeon, and white pelican, the medullary canals are occupied by a heavy cancellous bone with small meshes and present the appearances of nearly solid bones, and yet these birds are good fliers. Generally speaking, the medullary canals of amphibians, reptiles, mammals, and man are full, while those of the birds examined are about equally divided. In most cases the canals were filled with yellow marrow. A few, however, were full of red marrow.

Medullary Surface

The medullary canals present a variety of surface. In some instances, as in the peacock and eagle, there is seen extending inward from the wall of the femur an intricate network of trabeculæ, which increases in complexity toward the epiphyses. The surfaces in the larger mammals and in man are generally irregular, from the presence of ridge-like projections.

In many instances the medullary surface is smooth, as in the whole class of amphibians, in lizards, and in bats; while in other cases it is rough, uneven, or irregularly corrugated. This is especially true of the larger mammalian femora.

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[1] The humerus has an empty canal crossed by trabeculæ.

Cancellous Bone and Trabeculæ

Cancellous bone is a special form of first type bone characterized by an arrangement of lamellæ enclosing more or less irregularly shaped meshes filled with marrow. The character of the framework varies in the different femora. In some, as in the turtle, it forms a thick, heavy framework with very small meshes (pl. 4, fig. 67). In others, as in some birds, mammals, and in man, it is found as a delicate interwoven lacework with large meshes. In fetal human femora and in the bone of repair there is a channeled bone substance in which irregularly shaped meshes are present.

Cancellous bone, filling the medullary canal, has a wide distribution in the femora of animals. It is found in all classes from amphibian to man, but does not occur in the majority of the species. It was present in only one amphibian, absent in the lizards, present in the turtles, present in a few birds—yellow-hammer, pelican, and domestic pigeon—in many mammals, and in nearly all human femora. It was not found in the order of bats.

Trabeculæ.—Bone trabeculæ are composed of a few lamellæ with long narrow lacunæ and branching canaliculi, with or without Haversian systems.

In those bones which have marrowless medullary canals, trabeculæ form an interlacing network, as in the peahen and turkey-buzzard. The trabeculæ extend transversely from wall to wall, or more or less up and down toward the epiphyses of the bone. Near the extremities they generally form a labyrinth, as in man. The femora having trabeculæ are generally thin-walled.

The medullary canals which do not contain marrow have networks of trabeculæ, while those with marrow have cancellous bone or not, according to the animal.

Trabeculæ are very infrequent in amphibians, reptiles, mammals, or man, and reach their greatest degree of frequency in birds.

Variety of Minute Structure of the Wall of the Femur

We may now approach the minute structure of the wall of the femur. There is no one type of structure which characterizes all the femora of any single species of animal. Some individuals in each species will show single, pure-type bones, while others, and these are generally in the majority, present combinations of types. A great variety of combinations occurs. All bones consist of the same fundamental structural units, but these are combined and arranged in many ways and in different proportions. Three pure types and several combinations of types, in some stage of differentiation, are more clearly distinguishable and will be defined below.

The Units of Bone Structure

The units of bone structure are divisible into the basic and the differentiated. The basic units are the bone substance proper and in a measure also the individual bone cell with its dendrites or the lacuna with its canaliculi. The differentiated units are the lamella, the lamina, and the Haversian system.

But little needs to be said in this place about the basic units. The bone substance behaves passively and is wholly subject to the activity of the cells. While the cells with their processes are the all-important, living, constructive, and destructive parts of the bone, they change and act in ways that are, as yet, largely obscure. Certain modifications in their characteristics have, however, been observed in the course of the present work and will be mentioned in the proper place.

Bone Cells—Lacunæ

Bone cells or osteocytes have formed, and in fresh bone occupy the small spaces called lacunæ. The latter vary in shape from round and oval to long and narrow. Many femora have both. The round lacunæ characterize especially the young bone, while the long prevail in bone which is fully formed. The denser the bone, the more probability there is that it will present the long, narrow lacunæ, while in the rarer, but not senile bone substance, the round and oval forms are more abundant (pl. A, figs. A, B, C).

Dendrites and Canaliculi

The dendrites are processes which extend outwardly from the bone cells, the canaliculi being minute canals in the bone substance for the accommodation of the dendrites. In a cross-section of the femur, the exposed canaliculi are seen to vary considerably. In some cases they are short, branching, and bushy in appearance, while in others they are long and but slightly branched. The former belong to the round or oval, the latter to the long and narrow lacunæ (pl. A, figs. A, B, C).

Differentiated Bone Units—Lamellæ

Although bone first appears as a basic or undifferentiated substance in very young embryos and possibly in the more primitive forms of the lower classes of animals, in the course of time it manifests a tendency towards differentiation. Perhaps the earliest sign of such tendency is indicated by the concentricity of the lacunæ and next by the formation of what are known to the histologist as lamellæ (pl. A, fig. F).

A lamella can, at present, only be defined as a simple, separate layer of bone. The exact mode of its formation is not as yet known, but it must, of course, be the product of the progressive activity of the bone-forming elements. The lamellæ themselves follow several lines of differentiation. Three distinct forms may be distinguished. They are as follows:

UNIFORMLY LAMELLATED BONE

Bones of this character, after their development has reached its limits, are composed entirely of concentric lamellæ. The structure is uniform in all parts of the section. The lacunæ are oval or long and narrow (pl. A, fig. E; pl. 2, fig. 7).

TWOFOLD DIVISION

A further stage of differentiation is found in many femora in which a twofold division has occurred; that is, the section is composed of wide external and very narrow internal lamellar rings in contact with each other (pl. 2, fig. 9).

THREEFOLD DIVISION

In some femora the lamellæ are separated into three concentric rings. The external ring is narrow, the central wide, and the internal again narrow (pl. 2, fig. 27).

Lamellæ appear as the most prominent structures in amphibians, reptiles, bats, and in early fetal human femora.

LAMINÆ

The lamina, as used in this memoir, is a larger and more complex bone layer than the lamella. It is composed of a variable number of concentric sheaths of lamellæ surrounding the bone or its medullary canal, but the characteristic feature is that it is separated from adjacent structures by systems or plexuses of vascular canals extending in a direction parallel with the medullary and external surfaces of the bones. It occurs in birds, mammals, late fetal, and early childhood, and is often, though not invariably, a stage in the differentiation of bone from the first to the third. It reaches its highest degree of development in mammals (pl. A, fig. J; pl. B, figs. 2, 5).

HAVERSIAN SYSTEMS

The Haversian systems are more or less cylindrical shaped complexes of varying diameters composed of concentric lamellæ enclosing a central or Haversian canal. They extend in a direction parallel with the long axis of the bone, and in sections cut at right angles are circular in outline. In many cases, however, and perhaps in the majority, their directions are considerably modified and instead of extending in directions parallel with the long axis they run tortuous courses (pl. A, fig. F; pl. B, figs. 3, 6).

Haversian systems, foreshadowed in a few amphibians, somewhat advanced in some reptiles and birds, much more completely differentiated in the lower mammals, become fully developed in man.

Types of Bone Structure

The most interesting and unexpected fact which has been brought out by the investigations herein reported is the existence, in the femur as well as in other bones of the body, of three distinct, easily separable types of minute bone structure, corresponding, respectively, to the lamellar, laminar, and Haversian system stages of differentiation. These may occur alone, but are very frequently found in various though in general readily analyzable combinations.

The types may be called the primary, intermediate, and advanced; or simply the lamellar, laminar, and Haversian system types. More conveniently than either, perhaps, they may be designated as the first, second, and third types respectively. They are shown in plate A, figures 1, 2, 3; plate B, figures 1, 2, 3; microscopically and grossly in plate B, figures 4, 5, 6.

These types of bone structure are, in the main, nothing but various stages of osseous development. They do not represent radically distinct varieties of bone, but rather consecutive stages of differentiation of one and the same fundamental variety which underlies bone structure in all the terrestrial vertebrates. The bone structure advances from simple to more complex in conformity with definite laws which affect all the organisms possessing a skeleton, and the process is never reversed. The main types of bone structure that were determined may be defined briefly, as follows:

THE FIRST TYPE

This is composed of basic, or but moderately differentiated, bone substance, enclosing more or less numerous lacunæ, from which radiate scant to numerous minute canaliculi. The lacunæ are generally round or oval in shape, and their canaliculi are mostly short and bushy. The lacunæ may or may not occupy a definitely concentric position (pl. A, fig. D). In the more advanced stage the lacunæ assume a concentric arrangement, change in shape to a longer and narrower form, their canaliculi become longer and straighter, and the basic bone substance becomes separable into parallel layers, which are the lamellæ. Here development in many species stops (pl. A, figs. E, F). The first type of bone, therefore, is one varying from wholly basic, unorganized bone substance with no perceivable systematic arrangement of the cells, to that showing distinct lamellation with varying lacunæ and canaliculi. The most advanced and characteristic bone unit is the lamella (pl. A, fig. F; pl. B, figs. 1, 4).

The arrangement of the lamellæ is mostly concentric about a larger or smaller canal (pl. A, fig. E), but in some localities in a bone—as in the areas among the Haversian systems—the lamellæ are fragmentary-like and short, and may be straight or curved. On cross-section the individual lamellæ are seen to be, generally, of uniform thickness. Their ventral and dorsal surfaces, on the whole, are regularly shaped, and the edges of the cross-sections are finely serrated. The separate lamellæ are joined by cement. They may constitute the whole bone structure in a given specimen (pl. A, fig. E), or only a part of it; they may surround the Haversian canal and form the basis of the Haversian system, being then known as Haversian lamellæ (pl. A, fig. F); they may enclose the whole medullary canal, in which case they are known as internal circumferential lamellæ; or, finally, they may form the external boundary of the bone, where they are known as external circumferential lamellæ. The lamella, therefore, may be considered as the primary differentiated unit of bone structure—the first to appear in progressive development. Bone cells, represented by lacunæ, may occur within the lamellæ or between them (pl. A, fig. F; pl. B, figs. 1, 4).

It is interesting to notice that the first type bone unit (lamella) is found, in some form, in all femora from amphibians to man, and, as already pointed out, it may vary in its degree of differentiation. According to such differentiation, the lamellæ may become the foundation of the second and third type bones. The differentiation gives rise to three subtypes of lamellated bone: *The uniformly lamellated,* found in many of the amphibians, reptiles, birds, and bats, but not in the higher mammals or man[1] (pl. 2, fig. 7); *the twofold,* which was seen in amphibians, reptiles, birds, bats, and in a few mammals, but not in adult man (pl. 2, fig. 9); and *the threefold,* which occurs in amphibians, reptiles, birds, and bats, but not in the higher mammals or man (pl. 2, fig. 27).

The principal interest in these secondary differentiations of a first type bone lies in the fact that they indicate the manner of origin of divisions which are so frequently present in the higher and later third type or Haversian system bones. In these the outer and inner lamellar rings are known as the external circumferential and internal circumferential lamellæ, while the central broad ring has differentiated into Haversian systems. In some stage of differentiation, the first type bone is found in all femora as an important structure, and, therefore, may be considered as universal.

THE SECOND TYPE

This is composed of laminæ in some stage of differentiation, arranged concentrically around the medullary canal. While Haversian systems may be present here and there, the laminæ dominate and characterize the bone structure. The degree of differentiation present varies. In some cases it is only a

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[1] Of the total 440 femora examined, 19 per cent were composed entirely of uniformly lamellated bone and were limited to amphibians, reptiles, and bats. (See table, p. 17.)

little in advance of the lamellar type; in others the advancement is more pronounced; while in still others the type appears to have reached its limits of development (pl. A, figs. H, I, J; pl. B, figs. 2, 5).

The exact mode of development of the lamina, as in the case of the lamella, has not yet been traced. Laminæ show incomplete and complete stages of differentiation.

Incomplete: In some cases, as in birds, basic bone substance is partially separated into indistinct laminæ by a few, short, vascular canals having general concentric positions. The lacunæ are round or oval and the canaliculi are short and bushy and rather infrequent (pl. A, fig. H). In other cases the concentric canals are lengthened and arranged in the form of a more or less complete plexus, in the elongated meshes of which laminæ are more clearly seen. The lacunæ are oval and the canaliculi are very numerous and reticular in arrangement (pl. A, figs. I or 2).

Complete: In still other cases the vascular canals form more or less complete circuits, and the laminæ are well defined in clearly differentiated sheaths, with completely developed lamellæ and long lacunæ with straight canaliculi, and are pierced quite regularly by vascular canals extending transversely (pl. A, fig. J; pl. B, figs. 2, 5).

The laminæ have more individuality than the lamellæ, and in a dried femur of the second type they can be scaled off one after another. They are fairly uniform in thickness, but in the incomplete stage vary considerably in the length of their segments. The laminæ were first observed in two amphibians, occurring singly in the femora of the *Bufo americana* and *Hyla gratiosa* (pl. 2, fig. 14; pl. 3, fig. 36). In both of these bones they were only fairly well developed and occupied irregular positions in reference to the medullary and external surfaces. In the alligator and some turtles they alternated with concentric rings of crude Haversian systems. But it is in birds that laminæ first become prominent as units of bone structure. In these animals the structure of the femora examined presented stages of differentiation varying from a very incomplete to an advanced, but not complete, character. It is not until the laminæ reach the class of mammals that they show their highest development, so that in birds they appear to occupy a transitional position. In fact it is not difficult to distinguish between these units of the bird and the mammal by the incomplete character of the concentric canals and the early differentiations of the lacunæ which are present in birds, and the complete concentric canals and higher grade lacunar differentiations which are present in mammals.

THE THIRD TYPE

This type is composed of Haversian systems as the main units of structure. These systems form the whole bone or a larger proportion of the same. Narrow external and internal sheaths of circumferential lamellæ often surround the bone and its medullary cavity, but the characteristic structural units are the Haversian systems. The type presents two stages of differentiation—the incomplete (I) (pl. A, figs. K, L, M), and the complete (C) (pl. A, figs. N or 3; pl. B, figs. 3, 6). The incomplete differentiation is further divisible into three sub-stages which are indicated in the synoptic tables and text as the Ia, Ib, and Ic stages (pl. A, figs. K, L, M). These stages can be readily distinguished microscopically, and may all occur in a single bone. As a matter of fact, it is often impossible to include all Haversian systems of a bone under any one stage of differentiation. Term (Ia) signifies early, (Ib) intermediate, and (Ic) the late stage of incomplete differentiation. When the process of differentiation is completed, the Haversian system is referred to as (C) (pl. A, fig. N).

III, Ia.—This was first observed in a few of the amphibians. In the femora of these animals the system was merely a minute, more or less irregularly shaped, canal, extending in a direction parallel with the long axis of the bone. In cross-section the canal was round, oval, or irregular in shape and surrounded by a small, clear, more or less circular area of bone substance, across which were seen a few canaliculi on their way from neighboring lacunæ. That is, they were *not* concentrically arranged and appeared to be independent of the canal with the exception of a slight connection by means of the canaliculi. The figure presented merely a suggestion of an Haversian system. This stage of development was found in all classes of animals from amphibians to man. Its characteristic structure may be seen by referring to plate A, figure K.

As one studies the many sections in which this stage is found it is clearly evident that it is associated with the earlier periods of development both phylo- and ontogenetically, since the Haversian canal alone is present, and this occurs in the lamellar areas of the bone. There seems to be no particular relation of the canal to adjacent lacunæ.

III, Ib.—This stage represents a morphological advancement characterized by a more definite relation of neighboring lacunæ to the Haversian canal, and by more extensive communication of the bone cells of the lacunæ with the Haversian circulation. The result is that the Haversian system is fairly well outlined. As this stage is but a step in advance of (Ia) it might be expected to appear in any femur in which (Ia) is present, and to a certain extent this is true. It was observed in all classes of animals excepting amphibians and birds (pl. A, fig. L). It was first seen in some of the reptiles, such as the turtles. In these femora the canal was surrounded by a clear, circular area of bone substance, and the lacunæ were arranged concentrically around the circumference of the area. There was a noticeable increase of the canaliculi passing from the lacunæ to the canal. The whole figure presented a circular form and the Haversian system could be clearly distinguished.

III, Ic.—This stage of Haversian development may possibly occupy a transitional position between the early and late differentiations, although it does not resemble either one very closely. It differs from both in the intricate character of the canaliculi, and in some respects suggests as early a development as that seen in (Ia) or (Ib). The Haversian canal is regular in shape and small in size. The lacunæ have assumed a definite concentric arrangement around the canal, and, with their bushy, branching canaliculi forming a delicate network, occupy the clear area of bone substance referred to under (Ia) and (Ib). The structure has taken on the definite form of an Haversian system and presents a peculiar dull character by which it may be identified anywhere (pl. A, fig. M). This stage was observed in birds only and is easily recognized.

III, C.—This is the completely differentiated Haversian system and belongs to the higher mammals and man. In this stage the dim characters of the incompletely differentiated systems have disappeared. The outlines and structural units of the Haversian systems are clearly distinct. The canaliculi are slightly wavy and parallel (pl. A, fig. N).

Such systems were not found below the mammals nor in the lower mammals, such as the monotremes, marsupials, and some of the edentates and Chiroptera, but were always present in the higher mammals and adult man. Therefore it seems safe to regard this form as the Haversian system of the latest differentiation.

The Haversian system in early or late stages of differentiation, appears also in all classes of animals; but there are wide and often characteristic differences in the variety and extent of such bone. In the amphibians it is merely an outline, but in its extension through the reptiles, birds, and mammals to man, it presents phases of an advancing differentiation. The lower the class the earlier the stage, and the higher the class of animals the more complete the stage of development of the Haversian systems. The development seems to be one of a transformation of the first bone type into a third by some plan of arrangement, since a complete Haversian system is composed of concentric lamellæ enclosing an Haversian canal. The earlier stages are generally found in all classes of animals in which the first type bone is present as a characteristic structure, and the later stages are found more especially in those classes in which the first type is disappearing or has disappeared.[1]

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[1] In addition to the ordinary method of Haversian system development one or two other peculiar forms were observed. In a fractured femur of a frog the upper and lower fragments were united by new bone formed around them. The new bone was cancellous or channeled in character and in some of the meshes lamellæ were concentrically deposited until the meshes were filled with the exception of small canals in their centers. The results, at least in appearance, were Haversian systems (pl. A, fig. O; pl. 1, figs. 5, C, E, F). Such results were rather unexpected since there was no structure in the original femur which in the least resembled an Haversian system or even cancellous bone.

Another peculiarity was observed in some second type (laminar) femora, as those of the domestic pig and wild boar. In these bones small, circular enlargements of the concentric canals between the

FREQUENCY OF OCCURRENCE

The distribution of the three types of bone, their stages of development, and divisions may be seen in the following table:

DISTRIBUTION OF THE THREE BONE TYPES AND THEIR DIFFERENTIATIONS

Type		Amphibians	Reptiles	Birds	Bats	Other mam'ls	Adult man	Fetal man	Total
	Number of femora examined...	39	34	40	55	133	139	7	440
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
I.	Lamellæ, uniform throughout..	26	60	30	73	0	0	0	19
	Lamellæ, twofold division.....	51	17	7.5	16	2	0	0	14
	Lamellæ, threefold division....	20	6	5	9	0	0	0	4
	Lamellæ as cancellous bone....	3	17	5	0	46	92	100	46
	Lamellæ as important bone structure..................	100	100	47	100	48	92	100	79
II.	Laminæ, incomplete differentiation.....................	5	9	25	0	10	0	100	18
	Laminæ, complete differentiation.......................	0	0	0	0	40	8	0	1.4
	Laminæ as important bone structures.................	5	9	25	0	50	8	100	21
III.	Haversian system, Ia..........	21	21	5	5	39	32	14	27
	Haversian system, Ib..........	0	23	7	7	28	6	71	15
	Haversian system, Ic..........	0	0	82	0	0	0	0	7
	Haversian system, C...........	0	0	0	0	82	100	0	54
	Haversian system, incomplete differentiation..............	21	52	89	12	67	38	18	46
	Haversian system, complete differentiation..............	0	0	0	0	82	100	0	54

Looking over the above table it will be noticed that lamellæ, in some stage of differentiation, form an important part of the majority of all femora, and, therefore, may be considered as the simplest, oldest, and most universal bone units; that the first type of bone, without concentric divisions, has a wider range than it has *with* concentric divisions, and that cancellous bone—which is first type with a special arrangement of lamellæ—is found in *all* classes of animals; that laminæ—incomplete or complete—are found in the smallest number of femora, and that Haversian systems, in some stages of differentiation, are found in the largest number of femora and to the greatest extent in man. The early differentiations of the Haversian systems are found in 46% and the late in 54% of all femora examined. There are more early differentiations in the lower animals and more late differentiations in man than in the lower animals. Early and late differentiations may occur in the same bone and more especially in mammals and man, as may be seen in such femora as represented in plate 31, figure 399.

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two laminæ occurred at intervals. Around these enlargements two to four concentric lamellæ were arranged, the whole figure presenting the appearance of a small Haversian system (pl. A, fig. P).

These are referred to in the detailed description as aberrant forms of the Haversian system.

TYPE COMBINATIONS[1]

In a large number of femora the three structural types—first, second, and third—are seen represented simultaneously in various proportions and form what may be called type combinations. As a rule, in these combinations, the various types occupy similar positions in all the adult femora that present such combinations. Usually first and second type constituents surround the femur peripherally and encircle also the medullary canal, while the third type bone forms the central portion of the sections. The bone units in these cases show varying stages of development.

While the single types occur as the sole structures in the femora of some amphibians, reptiles, birds, mammals, and man, a large number, perhaps the majority, are composed of various combinations of these types. There may be a marked difference in the degrees of differentiation present in the several structural units in the same bone.

About 60% of the whole number of femora examined presented combinations of bone types. The first and third were found in association in the largest number.

TYPE OF BONE STRUCTURE ACCORDING TO CLASSES OF ANIMALS

AMPHIBIANS

In these animals the type of bone present in the various species showed generally evidences of a progressive character in the structural units. There was observed a change in the shape of the lacunæ from round to long and narrow, in the canaliculi from short and bushy to long and straight, and in the arrangement of the lacunæ from diffuse to concentric. There was also noticed

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[1] The most common type combinations are as follows:

I-II. This combination is composed of lamellæ and laminæ. It is seen more especially in fetal femora. In young bones the lamellæ generally occupy the peripheral portion of the bone, and become separated into laminæ nearer the medullary canal. As differentiation advances, much of the first type (lamellar) structure changes gradually into that of the second type (laminar) (pl. C, fig. 1).

I-III. This is a combination of lamellæ and Haversian systems. The lamellæ form a sheath of varying thickness around the bone and enclose either wholly or partly a ring of Haversian systems, also of varying thickness. The Haversian systems may be of any grade of differentiation (pl. B, fig. 7; pl. C, fig. 2).

II-III. This is a combination of laminæ and Haversian systems. The laminæ, generally, form thin, concentric sheaths around a stout ring of Haversian systems (pl. B, fig. 8; pl. C, fig. 3). Here again the Haversian system may be of various grades of differentiation. If the laminar structure is of advanced type, the Haversian system is also; but if it is not, the Haversian system appears in some of its earlier forms.

I-II-III. This is a combination of lamellæ, laminæ, and Haversian systems. The simple lamellæ are generally located externally, the laminæ more internally, and the Haversian systems form the central portions of the bone. The Haversian systems may be of any grade of development. As a rule, the lamellæ and laminæ are well developed or fairly well developed in these forms of bone, while the Haversian systems vary considerably in their degree of differentiation (pl. B, fig. 9; pl. C, fig. 4).

the separation of the uniformly lamellar wall into two and three concentric divisions, the presence of laminæ in *Bufo americana* and *Hyla gratiosa,* and the appearance of Haversian canals of the (Ia) differentiation in the Surinam and other toads (pls. 2-3, figs. 6-39).

REPTILES

The reptiles seem to be divided in the matter of bone differentiation into two groups—the division occurring between the lizards and the turtles. The first group, which includes the lizards, is characterized by the first type bone structure and the second, including the turtles, by the first and third. Belonging to the lizard group in their type of bone were the femora of the *Python regius,* which were composed of crude first type structure with a twofold division. The femur of the alligator represents a later differentiation than that of the lizards and snakes, inasmuch as the second and third types have appeared. Both of these units have reached a later degree of development than they have in any femur preceding them in the zoological scale, while they are not as far advanced as they are in the turtles which follow them. Comparing the class of reptiles with that of amphibians the chief evidences of type advancement are seen in the more complete differentiations of the third type units (pls. 3, 4, figs. 40-73).

BIRDS

The study of the femora of birds is, to some extent, unsatisfactory. While the three types of bone structure are present, either alone or in combination, they generally bear more or less of a transitional character. The several units —lamellæ, laminæ, and Haversian systems—show, usually, incompleteness of development. In some instances, it is difficult to recognize any distinct type. On the whole, however, evidences of advancing differentiation are prominent in birds, since all three units have appeared and generally in a more complete form than in the femora of reptiles or amphibians.

The first type of bone (lamellar) is present in some species, as in the robin, and is of a very simple form. The second (laminar) appears in a larger number of species, as in the turkey, grouse, and ostrich, and is, perhaps, the most representative type among birds. The laminæ, generally, show an incomplete differentiation. The third type (Haversian systems) is found in several species, and presents distinct characters by which they can be distinguished from the Haversian systems of other animals.

In some cases Haversian systems are present in the posterior ridges, in others, of larger size, in the posterior ridges and anterior walls, and in still others they form the entire central ring (pls. 5, 6, 7, figs. 74-112).

MAMMALS

The femora of mammals, not including man, present the first, second, and third type units and most of their combinations. As far as can be determined microscopically, these units are the same as were present in the amphibians, reptiles, and birds; but on the whole, they show a more advanced differentiation.

Since the complete Haversian system does not appear in amphibians nor in reptiles nor clearly in birds, and does appear in mammals as a predominating structure and often in a high degree of differentiation, its general presence to such an extent and to such a degree of advancement points to the age of mammals as the most important period in the history of bone development.

For convenience in description the bats are treated separately since they do not resemble other mammals as closely as they do some of the lizards.

Bats.—Practically the whole order has been covered, and from the drawings, descriptions, and tables it will be seen that the bat femora are generally true to the first type bone. The sections are composed of lamellæ with round, oval, or long and narrow lacunæ, arranged concentrically around the medullary canal.

The sections are uniform in structure with the exception of a small number in which we find the twofold or threefold lamellar division. Very few structural variations have occurred in the whole order. In the genus Pteropus, which included the largest bats, Haversian canals of the early differentiation are present, and, generally speaking, the femora of the larger species have more of these canals than those of the smaller (pl. 8, figs. 113-166).

Other mammals.—The femora of the fetal sheep, calf, and pig of half-time development and also those of many adult mammals were examined.

In the fetal sheep the type of bone was an incomplete second with short, wide, irregular communicating canals. In the femur of the adult sheep the type was also second; but the laminæ had become regular and concentric and the canals between them much narrower and more regular. In the fetal calf the type of bone was very indistinctly second, with numerous bizarre-shaped canals. In the adult ox the type had become a well developed second and third.

In the fetal pig the type was second and, with the addition of a few Haversian systems in the posterior wall, remained second in the adult (pl. 11, figs. 199, 200, 201).

The most pronounced developmental change was observed in the femur of the calf.

The whole range of differentiation in minute bone structure reaches, generally speaking, the greatest advance in the mammals exclusive of bats.

The often more or less vague character of the structure in lower animals clears up to a marked degree, and the bone units stand out as finished products. Types and type combinations are now distinct. Pure types are found in many instances, though combinations of types are the most numerous and characteristic of mammalian bone. The Haversian systems have differentiated into their later stages, to reach their highest degree of perfection and prominence in man (pls. 9-20, figs. 168-298).

Man.—In human femora the bone structure, as already mentioned in part, reaches, in many respects, the climax of its differentiation. The human femora examined were the fetal and adult. The fetal bones belonged to the black and white races, the adult to the black, yellow-brown, and white including the ancient Egyptian. The number of fetal femora examined is small, but the results indicate that the study of the comparative histology of a larger number of fetal bones, not only of man but also of other animals, would clear up many interesting points in the differentiations which are found in the adult (pls. 21-35, figs. 306-453).

Fetal human femora.—These femora, representing the whole period of intra-uterine life, showed basic bone substance in the early, and differentiated lamellæ and laminæ in the later months; also there was observed the horseshoe-shaped band forming the anterior and lateral wall and the separate formation of the posterior ridge (pl. 21, figs. 299-305). (For details see section III.)

Adult femora.—Generally speaking, the adult human femur is characterized by the predominance of completely differentiated third type units. An exclusive first type was not found in the adult bone. The most primitive form was a first and third combination. The proportions of the structural units (lamellæ, laminæ, and Haversian systems) vary greatly. In some femora first type bone amounted to more than half of the sections; in others it was reduced to a small fraction; in still others there was a second and third instead of a first and third; and, finally, some femora showed the first, second, and third type bone in various combinations.

When first type bone is present in the human femur it is found in the form of a horseshoe-shaped band situated underneath the periosteum. The inter-Haversian lamellæ, frequently present in sections of human femora, are apparently the remains of the disappearing horseshoe band just described. In a fully differentiated human bone, Haversian systems form the whole structure.

The three races, black, yellow-brown, Egyptian, and white, exhibit similar types and combinations of types of bone structure. In each there is a first and third, second and third, and complete third type, with or without senile changes. As a race the white presents more third type femora than the black or yellow-brown race. Early (primitive) and late (advanced) differentiations have been found in the different femora of the negro, Pueblo, and Peruvian Indians, the ancient Egyptian, and modern white. The linea aspera in the adult human femur is always composed of Haversian systems. Senile changes, absent or rare in other animals, are unexpectedly frequent in human femora.

The best type of human femur is composed wholly of Haversian systems of the complete differentiation. The systems have long, narrow lacunæ, with long, straight canaliculi situated between or within concentric lamellæ which enclose the Haversian canal. External and internal circumferential lamellæ form in some instances very narrow rings around the bone and medullary canal, or they may be fragmentary. Such femora are not very common.

Black race.—The femora of the black race exhibit types and combinations of types ranging from a first and third to a complete third. The majority of bones examined are type combinations. In some femora a wide horseshoe-shaped band of lamellæ, enclosing Haversian canals of the early incomplete differentiation and a few, scattered, small Haversian systems, is found partly surrounding a narrow, central ring of completely developed Haversian systems. In others the horseshoe is narrower, and the central ring of Haversian systems is wider; that is, the proportion of the horseshoe band to the Haversian ring is a variable quantity. In still other femora the horseshoe forms a fragmentary background which can be distinguished, but which has been mostly displaced by fully developed Haversian systems (pls. 21-23, figs. 306-324; pl. 25, figs. 335-340).

The negro femur has a higher medullary index than the white or Egyptian race.

During the examination of the right femur of negro No. 248674, U. S. Nat. Mus., it was observed that considerably more than half of the section was first type bone, in which were many Haversian canals of the primitive and incomplete differentiation. It was then decided to examine all of the long bones of that negro in order to ascertain, if possible, whether or not the structure was basic in character. Accordingly, the left femur, tibia, fibula, radius, ulna, humerus, clavicle, and metatarsal bone of the great toe were examined. The result was they were all found to conform closely to what was found in the right femur. It was therefore concluded that the type combination found in the femur was a representative type of the whole long bone formation of that particular negro, and that one type or type combination would probably not be found in one bone of an individual and a different one in another (pl. 24, figs. 325-333).

The yellow-brown race.—With one exception these femora were pre-Columbian. They were a little smaller than those of the blacks. The majority were composed of second and third, and first, second, and third type combinations. Only three or four were pure third type. In the femora, composed of type combinations, there was a greater average proportion of first type bone than was present in the other races examined.

The medullary canals were relatively larger than in the other races, as may be seen from their medullary indices—yellow-brown 43.8%, blacks 41.9%, Egyptians 39.5%, and whites 38.5%. Therefore the yellow-brown femur has proportionately a smaller percentage of bone substance than the femora of other races (pls. 25-27, figs. 341-361).

Egyptian femora of the twelfth dynasty.—This series includes the femora of children, youth, and adults. The bones are interesting on account of their antiquity. They show the structure of the femur of four thousand years ago. By comparing them with modern femora it will be seen that the bone types which were prominent then are still prominent now.

One of the most interesting femora examined was that of a young child, figures 363 and 363-a. It showed the formation of an Haversian system from the circulation, an account of which will be found elsewhere (p. 177). Two or three femora from adolescents showed gradually diminishing first and second and increasing third type units. The adult bones showed two main types of differentiation. One was composed of lamellæ enclosing Haversian systems, and the other of Haversian systems alone, figures 369 and 370. Femur 369 bears the stamp of a much lower degree of development than femur 370. Femur 369 was much more than half lamellæ, while 370 was composed entirely of Haversian systems (pls. 27-28, figs. 363-371).

The white race.—The femora of the modern white race showed a variety of type combinations as well as single types. On the whole, the complete Haversian system type predominated. A larger percentage of the bones examined than in any other race showed the third type structure and senile changes. Individual differences in structure were quite extensive.

The average medullary index, as already seen, was 35.8%. That is, the femur of the white race had a smaller medullary canal and thicker wall of bone than the femur of the other races. In the III, C type of femora the Haversian systems varied considerably in size. Some were small with a few, while others were large with many, concentric lamellæ. The communicating canals between the systems also varied greatly. In some femora they were very numerous and provided a rich blood supply for the whole bone; in other femora they were few in number, comparatively, and the Haversian circulation was very much diminished. Differences in the extent of the circulation in different parts of the bone were observed. The inner wall generally had more inter-Haversian canals than the outer, while the posterior ridge (linea aspera) had a much richer blood supply than the anterior wall (pls. 28-35, figs. 372-453).

In those femora which showed combinations of types, the proportions of the units were found to vary greatly. In some the proportion of lamellæ was considerably over 50% of the whole bone, and in others varying percentages of lamellæ and laminæ from 50% to 0% were observed. In only a few cases the femora composed of Haversian systems alone were without senile evidences. From an examination of two entire human femora of the white race at intervals of 2.5 cm., it was further determined that sections through the middle of the shaft represented the entire structure of the bone with the exception of the extremities.

Factors Influencing Types of Bone Structure

1. Grade of the animal in biological classification.
2. Geographical location.
3. Sex.
4. Age.
5. Function.
6. Individuality.
7. Health and disease.
8. Heredity.

The results of the investigations in these directions are here briefly summarized.

1. THE GRADE OF THE ANIMAL IN BIOLOGICAL CLASSIFICATION

It is, perhaps, impossible to decide just how much *is* evidence in regard to the relation of grade to structure. In the specimens of the different femora examined there were found many variations which, doubtless, have some significance. On the one hand, there are evidences which tend to show that the grade of an animal has an influence in limiting the structural bone type present; but on the other, there are counter evidences which indicate that the whole matter is not so simple. In support of the first view is the fact that the position which the animal occupies in the scale of life is generally in harmony with the type of bone present in its femur. That is, the lowest class of femoral vertebrates, the lowest order of any class, the lowest genus of any order, and the lowest species of any genus, all show the simplest and most primitive types of bone structure. The converse is also equally true—that the highest class, order, genus, and species shows the most advanced or highly developed type of bone. This may be seen from the specimens, tables, and drawings. While each class, order, genus, and species seems to have a bone cycle of its own, the various cycles are bound together by some factor of an advancing differentiation and the high[1] bone units in one class, order, genus, or species become higher in the next in succession.

But there are exceptional features which remain to be explained. Each class of animal—amphibian, reptile, bird, mammal—has some first type bone species. Each class, order, genus, and species shows an early and late differentiation of bone units. While each class of animal seems to be complete in itself,

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[1] The terms high and low do not refer to exact states, but to relative distinctions in differentiation

there is apparently some underlying determinant which gives to the higher group a more complete differentiation than is found in a preceding or lower class. That is, the late differentiation in mammals is more complete than it is in birds, in birds than it is in reptiles, and in reptiles than in amphibians; while the early differentiation in each class seems to remain practically the same. As the animal rises in the scale of differentiation, the grade of the adult bone type also rises. As far as the microscopic appearances are concerned it is difficult, if not impossible, to tell when bone units of structure have become complete, but it is not difficult to observe that they have advanced as we go from one class to another.

2. GEOGRAPHICAL POSITION

The effect of geographical position upon bone variation is not yet reducible to exact deductions. The majority of the femora of amphibians have the first type of bone structure and this, too, regardless of their geographical location. The same is true of the lizards and bats. Perhaps the bats furnish the most important example. As said already, practically the whole order was examined. The individuals came from all parts of the world where bats abound, and they all showed the same type of structure with very little variation. Some mammals of different locations are alike in structure and some are unlike.

In respect to man, the femora of the ancient Egyptians differed from one another greatly, although they were taken from the same cemetery. The same is true of the pre-Columbian Chicama and Pachacamac Indians. In the modern races variations in type are very common and they cannot, in the writer's experience, in any way be associated with geographical position.

As far as the present observations are concerned, therefore, there is no reason to suppose that geography has had any marked influence upon bone type.

3. SEX

In reference to sex, it may be briefly stated that the femora examined showed no conclusive evidence that sex was an important factor in the minute structural variation of bone.

4. AGE

Unlike the previous factors, age influences the type of bone very considerably. In the higher mammals and man the femora invariably change in structure with the advancing age of each individual. Some femora arrive at completion earlier than others. In the formation of the human bone from early fetal types there were to be seen distinct evidences of progressive changes from the first through the second to the third type. In some cases this course of development was completed much earlier than it was in others, and senility appeared to a greater or less degree in the Haversian systems of such femora; in one instance senile changes were manifest although the individual was not over 35 years of age.

5. FUNCTION

The effect of function upon variation in bone structure can scarcely be doubted in some instances, while in others there seems to be little or no evidence of it. In amphibians the largest bones have the most Haversian canals. This, however, is only true as a general rule. For example, the frog has no Haversian canals or laminæ, while the toad, which may be smaller than the frog, shows both laminæ and Haversian canals. In reptiles, the small lizards do not have the Haversian canals, while the larger ones have many. On the other hand, a large alligator has very incomplete Haversian systems, while a small turtle has more advanced third type units. Again, small turtles have few, while the large ones have many, Haversian systems. In birds, some of the larger varieties, as the ostrich, have predominating second types and not the third, while many small birds have predominating third type units.

A turkey of 16 pounds weight has the second type of structure with a few Haversian systems, while a turkey of 32 pounds has the same type with a noticeable increase in the number of Haversian systems. That is, size or weight seems to have a decided influence upon third type bone development in some cases, and little, if any, in others.

In mammals of the same species, provided the species has Haversian systems, there will be more of these systems in the larger than in the smaller varieties. But in animals of different classes the larger species may have, on the average, no more Haversian systems than those of the smaller species. For example, a domestic pig, weighing 500 pounds, has a second type bone with some Haversian systems, while a domestic turkey, weighing 32 pounds, has also a second type bone and nearly as many Haversian systems. The two bones of different classes differ from one another very materially in differentiation of both types, but not in the types themselves. In bipedal mammals of considerable weight like man, in which the weight of the animal is borne by two legs instead of four, there is a greater tendency towards the third type bone, and yet there are many exceptions. Furthermore, the os penis of the raccoon is an Haversian system bone, and conforms, generally, to the femoral type of that animal. In this case it is evident that function has had no effect on bone structure (pl. 20, fig. 288).

A cessation of function in an adult bone favors the appearance of marks of senility. There is a difference between a rudimentary femur without function and a normal bone which has lost its function by accident. The rudimentary femora of the python are first type bones like those of the lizards.

and although the femora are useless, their bone units are apparently sound; while in human femora amputated several years before examination the structure is well differentiated, but shows premature senile changes.

6. INDIVIDUAL VARIATIONS

Individual variations are by no means as common in the lower femoral vertebrates as they are in the higher forms. They are found to increase in the frequency of occurrence from birds to man. As far as the higher vertebrates are concerned, hardly any two individuals are exactly alike. They conform to a general type of structure which is fundamental, and exhibit special variations which are peculiar to the individual. This was found to be the case even with cats of the same litter. The individuals varied in structure.

7. HEALTH AND DISEASE

Variations due to health and disease remain very largely for studies in the future. However, the right femur of an adult white male who had congenital epilepsy shows an extremely thin wall (1 mm. to 2 mm. in thickness), and an index of 277%. See plate 35, figure 453, for drawing and text for description.

8. HEREDITY

The influence of heredity on bone variation requires a greater amount of selected material of known genetic relationship than the writer has been able to gather. Most of the femora utilized are those of individuals with no obtainable family history. However, the femur of the mule resembles structurally the jackass more than the horse, and the femora of a litter of kittens showed quite marked differences. Excluding other causative factors which do not sufficiently account for the variations observed, heredity offers a most attractive field. The further study of bones of the descendants of known ancestors, and of selected crossings, is especially desirable.

CONCLUSIONS

If we survey the whole field of bone histology, as it was observed during the present investigation, the following salient points stand out with sufficient clearness:

1. The predominant shape of cross-sections of the femora of the animals below man is elliptical.

2. Generally speaking, first and second type femora are circular or elliptical and third types are triangular or related shapes.

3. Medullary canals are situated centrally, eccentrically, or obliquely, and may be circular, elliptical, or irregular in shape.

4. The medullary surfaces may be smooth, roughened by depressions, or corrugated.

5. Medullary contents are composed of marrow and its blood vessels, of marrow and cancellous bone, of trabeculæ alone, or the contents may be entirely absent. About half of the bird femora have full medullary canals, while the remaining half have no contents.

6. The medullary index (relative thickness of bone compared with the medullary canal) is lowest in reptiles and highest in birds. It falls from amphibian to reptile, rises from reptile to bird, falls rapidly from bird to mammal, and is about the same in man as in the lower mammals. The reptiles have the highest percentage of bone, the amphibians next, the mammals next, the modern white race of man next, and the bird the lowest percentage. Of the human race the modern white has the most bone, the Egyptian next, the negro next, and the American Indian the least.

7. The femora of the different animals and in man, even those of different individuals, vary in density, and the single femur varies in the density of the different parts of its wall.

8. Lacunæ and canaliculi present various stages of differentiation, the character of the differentiation being harmonious with, and indicative of, the degree of bone development.

9. Lamellæ, laminæ, and Haversian systems appear in bone in the order given, and become the basis of the types and type combinations of bone structure which enter into the formation of the different femora.

10. Basic bone substance is differentiated into lamellæ when the diffuse arrangement of lacunæ becomes concentric.

11. Cancellous bone is present in all classes of animals, and is more frequently observed in large than in small bones.

12. Three types of structure form the basis of all femora. They may occur singly or in combination. The first and second predominate in amphibians, reptiles, and birds, the third in mammals and man.

13. The first type, composed of lamellæ, appears as a uniform structure, or in a twofold or threefold division, and characterizes the amphibians, lizards, and bats.

14. The second type (lamina) appears first in the amphibian, and in an early or late form of differentiation in birds and lower mammals.

15. The third type (Haversian system) is first outlined in the amphibians. It is the result, primarily, of a series of differentiations beginning with the amphibians and ending in man.

16. Combinations of types are of frequent occurrence.

17. In fetal and young femora the differentiation of first into second and second into third types of bone structure was observable.

18. The presence of the early differentiations of type in some black, yellow-brown, white, and Egyptian femora, and of the late or complete differentiations in other femora of the same races was observed.

The following evidences of type advancement appear in the different classes of animals:

Amphibians.—A change of round to oval and long lacunæ, and from their diffuse to their concentric arrangements, a transformation of basic to lamellated bone, the separation of the uniformly lamellated bone structure into a twofold or threefold division, and the formation of distinct laminæ and Haversian canals in the walls of the femora, were all observed in the amphibians.

Reptiles.—The extension of lamellæ and the further development of laminæ and Haversian systems were seen in the femora of reptiles.

Birds.—The extension of lamellæ, prominent development of laminæ, and advancement of Haversian systems were observed in these animals.

Mammals.—Extension of lamellæ, completion of laminæ, and a much better development of Haversian systems were observed in mammals.

Man.—Extension of lamellæ, laminæ, and the completion of the Haversian systems were seen in human femora.

III. FETAL HUMAN FEMORA AND THEIR FURTHER DEVELOPMENT

Type differentiations, changes in the medullary index, and position of the medullary canal, development of the linea aspera, and changes in the shape of the shaft of the femur, are shown very interestingly in these bones, as may be seen from the following descriptive observations.

The fetal bones examined, mostly of the white race, varied in age from two and one-half to nine months. The young bones of two and a half months were composed of a crude, undifferentiated bone substance, with round lacunæ and short, bushy canaliculi, enclosing large irregularly shaped meshes. The medullary canal was very small and irregular in shape, and together with the meshes was filled with marrow. It was situated in the center of the section, and immediately surrounded by a narrow ring of lamellæ, thus showing the twofold division observed in some of the lower animals. The diameters of the bone were, the antero-posterior 1.8 mm., the lateral 1.5 mm., and of the canal 0.5 mm. × 0.4 mm. (pl. 21, fig. 299). The antero-posterior diameter at this stage of life was longer than the lateral. A little later (three to three and one-half months) the same diameters were respectively 2.5 mm. × 2 mm., while those of the medullary canal were 0.5 mm. × 0.5 mm. The canal was situated eccentrically in the anterior half of the section, was only a trifle larger than the canal of the younger bone, and was surrounded by a narrow ring of lamellæ, also showing the twofold division (pl. 21, fig. 300). Comparing this section with the preceding it was noticed that a structural variation had already appeared in the latter bone. The irregular meshes seen in the former were considerably elongated. They had assumed canal shapes and were arranged concentrically. Basic bone substance, with round lacunæ and bushy canaliculi, formed the reticulum between the elongated meshes or canals. Furthermore, a difference in structure was noticed between the posterior and remaining wall. In the posterior wall the concentric arrangement of the canals, described above, was absent, and a general direction of the canals from the medullary canal toward the external surface of the posterior wall was assumed. Here and there in the bone substance between the canals an Haversian canal of the (Ia) differentiation appeared. This whole posterior structure was the beginning of the linea aspera, and seemed to be a distinct bone formation.

In still later femora (four or five months) the diameters of the shaft were 3.5 mm. × 2.5 mm., and those of the medullary canal were 0.6 mm. × 0.5 mm. The medullary canal was situated eccentrically. The section was composed of basic bone substance, enclosing wide, branching, concentric canals, giving the appearance of a very primitive second type formation. The posterior wall was more prominent, and composed of bone substance with round and oval lacunæ, enclosing long, wide, branching canals, directed toward the external surface and at right angles to the structures of the lateral wall. The distinction between the posterior and lateral walls was more pronounced than in the specimens of earlier femora (pl. 21, fig. 301).

In still older femora (five to seven months) a distinct difference between the posterior wall, which now appears as a ridge, and the remaining walls was observed. The diameters of the bone were 3.5 mm. × 3 mm., and those of the medullary canal 0.5 mm. × 0.5 mm. The canal was situated eccentrically. The bone was composed of concentric laminæ arranged in the shape of a horseshoe, enclosing, in part, the medullary canal. The toe of the shoe formed the anterior wall and the heel embraced the posterior ridge. The posterior ridge was composed of elongated Haversian systems, as they appeared in cross-section, with large, wide Haversian canals extending outward toward the external posterior surface and at right angles to the laminæ of the remaining wall. In cross-section the posterior ridge was wedge-shaped and clearly distinct. The laminæ of the remaining wall were incompletely differentiated. They were wide, and composed of bone substance with round and oval lacunæ and bushy canaliculi (pl. 21, fig. 302).

In the femora of the final stages of fetal development (eight to nine months) the diameters of the bone were 4.5 mm. × 5 mm., of the canal 1 mm. × 1 mm. In these bones the lateral diameter was longest. The medullary canal was irregular in shape, larger, and situated eccentrically. The bone was composed of elongated, concentric Haversian systems (in cross-section) arranged in horseshoe shape around the medullary canal. The systems were composed of bone substance with oval and long lacunæ and with bushy and straight canaliculi. They gave one the impression of Haversian systems very much flattened by pressure. The posterior ridge or linea aspera, clearly distinct and wider than in the foregoing sections, was composed of elongated Haversian systems, and was divided into two lateral halves by a narrow radiating space, which is the last part of the linea aspera to become bone (pl. 21, fig. 303).

In a series of five Pueblo Indian femora of different ages, from one year to adult age, various further developmental stages were shown (pl. 9, figs. 341-344). The child's femur was composed of incompletely developed laminæ and Haversian systems, the systems ranging from the (Ia) to the (C) differentiation. The posterior ridge, only partly formed in the femur of one year, was much further advanced in the femur of six years. In the femur of early youth the laminæ were, to a considerable degree, displaced by incompletely developed Haversian systems, and the posterior ridge could not be distinguished from the lateral wall. In the femur of later youth the Haversian systems have increased in proportion and advanced markedly in development, and in the adult bone the lamellæ and laminæ were almost entirely displaced by fully developed Haversian systems. While these femora were from different individuals and probably from individuals of unlike types; yet they showed, in a general way, the differentiating changes in bone development. The Chicama and Pachacamac Indians showed similar changes.

Reviewing the above differentiations chronologically, evidences of advancement were strikingly apparent with increase in age. The femur of the human fetus begins its osseous history as a bone of crude first type, and then gradually advances through the second to the pure third type, or to some combination of the first and third, second and third, or first, second, and third types. Haversian systems begin with the most primitive, incomplete, and advance to the fully developed stage, gradually increasing at the same time in number. An early twofold division of the femoral wall increases to a threefold division.

It may also be seen that the linea aspera of the human femur is the product of a distinct bone formation which occurs in the posterior wall. It was noticed at the early age of three and one-half months, and was observed in the different femora until birth. Therefore, in the formation of the shaft of the human femur, two distinct bone forming processes seem to be evident, one the formation of the horseshoe-shaped band of the anterior and lateral walls, and the other of the posterior ridge or linea aspera. They appear to go on independently of each other for a while, and fuse together some time after birth.

The development of the linea aspera—the last part of the shaft to be completed—is especially interesting from the viewpoint of its function and the growth of bone.

IV. HISTOLOGICAL EXAMINATION OF TWO ENTIRE HUMAN FEMORA—GENERAL DESCRIPTION

As all of the sections were made through the middle of the shaft, and the descriptions given applied only to the structure of one location, it was desirable to examine sections of entire femora of different types in order to determine to what extent the structure of the middle of the shaft represented the whole femur. With this object in view, two entire femora have been examined. In each bone the first section was made transversely through the middle of the head, and the remaining sections at intervals of 2.5 cm. The two femora represented two types of differentiation—one, I-III, C, senile, and the other, III, C, senile.

The first femur (length 41 cm., No. 300, Cr. Med. Coll.).—This was composed of a predominating proportion of lamellæ interrupted by Haversian systems of the (Ia) and (C) differentiation, enclosing a narrow ring of Haversian systems of the (C) differentiation, many of which were senile. This femur, therefore, represented a human bone with incomplete development.

The structural type remained the same throughout the entire femur, but the different sections showed variations in medullary indices, proportions of lamellæ, cancellous bone, and senile changes. The medullary indices diminished from the extremities of the medullary canal toward the middle of the shaft, and were lowest 15 to 20 cm. below the section of the head.

The proportion of the lamellæ to the enclosed Haversian systems increased gradually from the head to the lower extremity. The cancellous bone diminished from the extremities toward the middle of the shaft. The senile changes were most numerous in the middle of the shaft and in the anterior wall.

On the whole, the bone was composed of an external, thick sheath of lamellæ enclosing a thin, shorter sheath of Haversian systems, and a section through the middle of the shaft gave a fair representation of the whole bone structure, excepting that of the two extremities.

It was noticed during the grinding of the middle sections that the lamellar and Haversian system rings were easily separated from one another, and that they were readily fractured in the anterior wall in which senility was most marked.

Second femur (length 38 cm., No. 301, Cr. Med. Coll.).—The upper portion of this femur was composed almost entirely of well developed Haversian systems and the lower portion of lamellæ and Haversian systems. The lamellæ formed a wide external band situated in the anterior wall, and were frequently interrupted by Haversian systems, some of which were senile.

The bone represented a human femur of a much later differentiation than No. 300, although it was not entirely a pure third type bone. The principal variation from the third type was limited to the lower portion.

The medullary indices diminished from the extremities toward the middle of the shaft, and were lowest 15 to 17 cm. below the section of the head. The band of lamellæ began 20 to 22 cm. below the head, and was most pronounced in the anterior wall. It extended downward toward the lower extremity, and, gradually diminishing in thickness, finally merged into the thin envelope of lamellæ surrounding the condyles. Cancellous bone diminished from the extremities toward the middle of the shaft, and was entirely absent from the middle third of the bone. Senile changes, not very marked, were most frequent in the middle portion and the anterior wall.

A section through the middle of this femur, compared with the remaining sections, did not give as fair a representation of the whole bone structure as the corresponding section of femur No. 300 gave to that bone. However, it did show plainly the type of bone to which this femur belonged. Notwithstanding, the lamellar band in the anterior wall of the lower portion, the characteristic unit of the whole bone was the Haversian system.

The heads and condyles of both femora were composed almost entirely of lamellæ.

V. SENILITY

After reaching its highest degree of development, as indicated by the character of its lacunæ and canaliculi, the Haversian system may remain in this condition for a time, but sooner or later the dissociation of the organic and inorganic constituents begins to appear, and the system gradually becomes granular, opaque, and black. The sum total of the processes by which these results are obtained is age or senility.

An examination of the various sections shows that this condition is more common than would be expected, and that, too, regardless of age in years. A human femur may be more or less senile at 35 or any subsequent age.

Adult human femora in general show a much larger percentage of senility than the femora of the lower animals. From a review of the various sections it may be seen that senility does not seem to appear at all in the amphibians, reptiles, birds, or bats, and was seen in only five or six of all the remaining mammalian femora; while it is found in the majority of femora of the white human race. Just when the amphibian, reptile, bird, or mammal becomes adult, just how long this period of life lasts, or when old age sets in, are not known.

The fact that senile changes are so prominent in the lamellæ of Haversian systems and so infrequent in the lamellæ of other situations suggests a difference either in the variations of the blood supply or in the chemical stability of the bone substance, or in both. The circulation is more complicated in a third type bone than it is in a first or second, and therefore more subject to structural deviations.

In a senile Haversian system, at the beginning of the process, the lamella around the Haversian canal becomes dark from a deposit of inorganic granules. This deposit intensifies the clearness of the serrated edges and cement. The granules increase as the process goes on, involving lamella after lamella, until the whole system is opaque and black. After the lamellæ have reached this stage they are gradually broken down into amorphous particles which drop into the Haversian canal and are removed by the blood vessels. The lamellæ of adjoining systems pass through similar processes. The inter-Haversian lamellæ follow and a cavity is formed, which in the section appears as a space. This process continues with a greater or lesser rapidity until the bone, reduced in dimensions and weight, remains as a mere shell of its normal condition (pl. 34, figs. 423-426).

In plate 29, figure 381, these changes may be observed. Haversian systems in different stages of senility are most numerous in the anterior and outer walls and in the middle portion of the shaft of the bone. The systems may be in pretty good condition elsewhere or, in extreme cases, granular deposits of different degrees of intensity may be present in most of them. The internal circumferential lamellæ remain in a fragmentary form. The essential change, therefore, is primarily in the Haversian system.

The changes which occur in senility may be summarized, as follows:

1. Dissociation of the organic and inorganic constituents of the lamellæ around the Haversian canals.

2. Deposit of inorganic granules in the lamellæ around the Haversian canals.

3. Gradual extension of the inorganic deposit toward the periphery of the Haversian systems and opacity of the lamellæ.

4. Absorption and disappearance of the granular lamellæ from the Haversian canal outward.

5. Widening of the Haversian canals and thinning of the walls of the Haversian system.

6. Disappearance of the Haversian systems and formation of irregular spaces. (Deposit of salts in the walls of degenerating vessels.)

7. Decrease in the weight of the bone.

VI. AMPHIBIANS

The study begins with the amphibians. Thirty-nine femora were examined.

General Character of the Femur

The femora of these animals are generally small. They vary to a considerable degree in shape. Some sections are triangular, some elliptical, some round, and a few are indeterminate. In the elliptical sections the lateral diameters are longest. The medullary canals are full of marrow, and in one femur, *Amblystoma tigrinum,* the canal is occupied by cancellous bone. The medullary index varies from zero to 129%, with an average of 36.6%. The type of structure is principally first; the basic or undifferentiated bone substance is found in *Amblystoma tigrinum,* the most primitive of amphibians, the lamellated or differentiated bone in the majority of the remaining species; while the II and III, Ia differentiations occur in the toads. The lacunæ are round, oval, or long, and the canaliculi are short and bushy or long and straight. The structure may be uniform throughout the whole section, or it may present a twofold division, as seen in *Hyla arenicolor;* or a threefold division, as seen in Necturus.

On the whole, then, the amphibian femora show the first type bone, and also mark the beginning of the second and third types.

Detailed Examination

FEMORA OF RANA CATESBIANA. BULL FROG

The femora of four bull frogs were examined, the first unusually large, the second of medium size, the third and fourth small.

They showed different developments of the same type of bone (pl. 1, figs. 1-4).

RIGHT FEMUR OF RANA CATESBIANA (LARGE). FIRST BULL FROG.
CREIGHTON MEDICAL COLLEGE

Pl. 1, Fig. 1. Synoptic Table I

Antero-posterior diameter of bone, 3.5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 16%.

The section is surrounded by a narrow ring of external circumferential lamellæ. Their lacunæ are round and oval, their canaliculi are short and bushy, and all are poorly developed. The central ring, situated between the external and internal lamellæ, is interrupted by many large, bush-like, radiating canals. The lamellæ are indistinct, their lacunæ are round and oval, and the canaliculi communicate with the radiating canals.

The canals are just visible to the naked eye. Some of them extend from the internal to the external circumferential lamellæ, some about two-thirds of that distance, and some are interrupted at various points along the way. The central ring forms about four-fifths of the thickness of the bone, is thicker in the posterior half than in the anterior, and presents a low development.

The internal circumferential lamellæ surround the medullary canal. They are clearer than those of the external lamellæ, their lacunæ are oval, their canaliculi are short and partly in the central ring, and there is a large vascular canal on its way to the medullary canal. The internal lamellæ are poorly developed. The section shows a threefold division.

Type I.

RIGHT FEMUR OF RANA CATESBIANA (MEDIUM SIZED). SECOND BULL FROG. CR. MED. COLL.

Pl. 1, Fig. 2. Syn. Tab. I

Antero-posterior diameter of bone, 2.5 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 1.4 mm.; lateral, 1.6 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—Around the bone is a very narrow ring of dense lamellæ containing a few, long, narrow lacunæ and long canaliculi.

In the center of the anterior wall is a notch, which is part of the nutrient canal. Beginning a little to the outer side of the posterior mid-line and extending around the outer wall, anterior, and about one-fourth of the inner wall, the entire thickness of the bone is composed of concentric lamellæ with oval lacunæ and bushy canaliculi. The remaining portion of the bone is composed of concentric lamellæ, which are crossed by short canals, arranged radially in twos and threes. The canals are surrounded by clear areas of bone substance, and extending from them in all directions are very fine canaliculi. The internal circumferential lamellæ are not distinct from the remaining structure. Its peculiar feature is the gradual disappearance of the radiating canals.

Type I.

RIGHT FEMUR OF RANA CATESBIANA (SMALL). THIRD BULL FROG. CR. MED. COLL.

Pl. 1. Fig. 3. Syn. Tab. I

Antero-posterior diameter of the bone, 1 mm.; lateral, 1.3 mm.

Antero-posterior diameter of the medullary canal, 0.5 mm.; lateral, 0.6 mm.

The medullary canal is full. Medullary index, 29%.

Structure.—The section is composed of lamellæ, concentrically arranged around the medullary canal. There are no radiating canals. The lamellæ are clear, their lacunæ oval, long and narrow, and their canaliculi are long and numerous. The section has a uniform structure.

The peculiar feature is the complete disappearance of the radiating canals.

These figures show drawings of femora taken from the same species of frogs, but of different sizes and weights. The largest (fig. 1) is lowest in development; the second in size (fig. 2) is next, and the third (fig. 3) is last and most complete. They are all of the first type, though of different developments. In figure 1 the radiating canals with poorly developed intervening lamellæ indicate an early stage of development. In figure 2 more than half of the canals have disappeared and better developed lamellæ are formed. In figure 3 all of the canals have disappeared and the whole bone is composed of concentric lamellæ.

Type I.

RIGHT FEMUR OF RANA CATESBIANA (SMALL). FOURTH BULL FROG. CR. MED. COLL.

PL. 1, FIG. 4. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.6 mm.

Medullary index, 24%.

Structure.—The section is composed of concentric lamellæ with long lacunæ and long, straight canaliculi surrounding the medullary canal. The section has a uniform structure.

Type I.

FRACTURED AND REPAIRED FEMUR OF A FROG. CR. MED. COLL.

PL. 1, FIG. 5. SYN. TAB. I

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.7 mm.

Antero-posterior diameter of medullary canal, 0.6 mm.; lateral, 0.7 mm.

The medullary canal is full. Medullary index, 20%.

Structure.—One of the femora had been fractured about the middle of the shaft. The ends of the bone had slipped by each other, and new bone had formed around the fragments. In section (fig. 5) which was taken from the middle of the new bone, two cuts of the femur appear situated eccentrically. The sections are composed of concentric lamellæ with oval and straight lacunæ surrounding the medullary canals.

The upper fragment, H, proximal, shows cell growths bursting through the wall of the bone (pl. 1, fig. 5, A, B). In the lower fragment, D, distal, no cell outbursts appear.

Around the two fragments and extending between them is a formation of cancellous or channeled bone which is the new bone of repair. Some of the meshes of this bone are occupied by newly deposited lamellæ, and resemble Haversian systems, although there are no Haversian systems or cancellous bone in the femur of the frog (pl. 1, fig. 5 (C, E). This fact suggests a genetic relationship between cancellous bone and Haversian systems.

Type I.

RIGHT FEMUR OF AMBLYSTOMA TIGRINUM. AMER. MUS. NAT. HIS.

PL. 2, FIG. 6. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, cancellous meshes.

Medullary index, 0.

Structure.—The section has no distinct medullary canal. It is composed of a narrow external ring of bone substance, with a few oval lacunæ and bushy canaliculi, from the under portion of which a cancellous center is derived. The meshes are filled with structureless material, and their walls have the same structure as the walls of the bone.

Type I.

RIGHT FEMUR OF HYLA VERSICOLOR. TREE FROG. AMER. MUS. NAT. HIST.

PL. 2, FIG. 7. SYN. TAB. I

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.2 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 7%.

Structure.—The entire section is composed of lamellæ with round and oval lacunæ and bushy canaliculi enclosing the medullary canal. The section has a uniform structure.

Type I.

RIGHT FEMUR OF HYLA ARENICOLOR. NO. E 50 30, U. S. NAT. MUS.

PL. 2, FIG. 8. SYN. TAB. I

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.5 mm.

Antero-posterior diameter of medullary canal, 0.2 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 19%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and long, straight canaliculi, divided into wide external and narrow internal rings which surround its medullary canal, thus showing a twofold division.

Type I.

RIGHT FEMUR OF HYLA FEMORALIS. NO. E 60 23, U. S. NAT. MUS.

PL. 2. FIG. 9. SYN. TAB. I

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.4 mm.

Antero-posterior diameter of medullary canal, 0.2 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and long canaliculi, divided into wide external and narrow internal rings which surround the medullary canal, a twofold division.

Type I.

RIGHT FEMUR OF HYLA EVITTATA. NO. E 55 17, U. S. NAT. MUS.

PL. 2, FIG. 10. SYN. TAB. I

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.2 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.1 mm.

The medullary canal is full. Medullary index, 104%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and long canaliculi, divided into wide external and narrow internal concentric rings which surround the medullary canal, a twofold division.

Type I.

RIGHT FEMUR OF HYLA CINEREA. NO. 13095, U. S. NAT. MUS.

PL. 2, FIG. 11. SYN. TAB. I

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 14%.

Structure.—The section has a long posterior process, the central position of which, from the medullary canal to the tip, is occupied by bone substance with a few oval lacunæ and branching canaliculi. The body of the section is composed of lamellæ with oval lacunæ and straight canaliculi. A narrow ring of internal circumferential lamellæ surrounds the medullary canal. The section shows a twofold division.

Type I.

RIGHT FEMUR OF HYLA REGILLA. NO. E 62 39, U. S. NAT. MUS.

PL. 2, FIG. 12. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 0.9 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—The section is composed of lamellæ with oval lacunæ and long canaliculi, divided into wide external and narrow internal rings. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF HYLA SQUIRELLA. NO. E 51 2, U. S. NAT. MUS.

PL. 2, FIG. 13. SYN. TAB. I

Antero-posterior diameter of bone, 0.8 mm,; lateral, 0.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 92%.

Structure.—The section is triangular in shape and composed of lamellæ with round and oval lacunæ and long canaliculi, divided into wide external and narrow internal rings. A vascular canal is seen in the posterior wall. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF HYLA GRATIOSA. NO. E 40 14, U. S. NAT. MUS.

PL. 2. FIG. 14. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 44%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. A narrow lamina, not parallel with the external or medullary surfaces, forms a complete ring around the section. It approaches the medullary surface in the lateral wall and departs from it in the anterior and posterior wall.

Type I-II

RIGHT FEMUR OF DENDROBATES TINCTORIUS. NO. E 14 36, U. S. NAT. MUS.

PL. 2. FIG. 15. SYN. TAB. I

Antero-posterior diameter of bone, 0.6 mm.; lateral, 0.5 mm.

Antero-posterior diameter of medullary canal, 0.2 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 15%.

Structure.—The section is composed of lamellæ with long, narrow lacunæ and long, straight canaliculi, divided into wide external and narrow internal rings. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF LEPTODACTYLUS ALBILABRIS. G 13 11, U. S. NAT. MUS.

PL. 2. FIG. 16. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.8 mm.; lateral, 0.3 mm.

The medullary canal is full. Medullary index, 59%.

Structure.—The section is composed of lamellæ with oval lacunæ and straight canaliculi, divided into wide external and narrow internal rings. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF CHOROPHILUS FERIARUM. NO. E 52 47, U. S. NAT. MUS.

PL. 2. FIG. 17. SYN. TAB. I

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.4 mm.

Antero-posterior diameter of medullary canal, 0.2 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The section is composed of lamellæ with oval lacunæ and straight canaliculi, divided into wide external and narrow internal rings. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF ACRIS GRYLLUS. U. S. NAT. MUS.

PL. 2, FIG. 18. SYN. TAB. I

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.3 mm.

Antero-posterior diameter of medullary canal, 0.2 mm.; lateral, 0.1 mm.

The medullary canal is full. Medullary index, 16%.

Structure.—The section is composed of lamellæ with oval lacunæ and straight canaliculi, divided into wide external and narrow internal rings. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF RANA CATESBIANA. BULL FROG. AMER. MUS. NAT. HIST.

PL. 2, FIG. 19. SYN. TAB. I

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm,; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of lamellæ with round, oval, and long lacunæ and straight, long, thickly set canaliculi, arranged concentrically around the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF RANA PALUSTRIS. NO. F 52 22, U. S. NAT. MUS.

PL. 2, FIG. 20. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm,; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 44%.

Structure.—The section is composed of concentric lamellæ with round and oval lacunæ and bushy canaliculi, separated into two concentric rings. The positions of the lacunæ and canaliculi give a radiating effect. The internal ring forms the internal circumferential lamellæ. Twofold division.

Type I.

RIGHT FEMUR OF RANA AREOLATA CIRCULOSA. NO. F 72 3, U. S. NAT. MUS.

PL. 2, FIG. 21. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.4 mm.

The medullary canal is full. Medullary index, 110%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform in structure. A portion of the nutrient canal is seen.

Type I.

RIGHT FEMUR OF RANA AGILIS AURORA. NO. F 50 10, U. S. NAT. MUS.

PL. 2, FIG. 22. SYN. TAB. I

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 19%.

Structure.—The section is composed of lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal, and divided into dim, wide external and narrow internal rings. Twofold division.

Type I.

RIGHT FEMUR OF RANA PRETIOSA. NO. F 75 11, U. S. NAT. MUS.

PL. 2, FIG. 23. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 41%.

Structure.—The section is composed of lamellæ with round and oval lacunæ and bushy canaliculi, dimly separated into four or five concentric divisions. In some portions of the section a few radiating canals are seen.

Type I.

RIGHT FEMUR OF RANA DRAYTONII. NO. F 70 14, U. S. NAT. MUS.

PL. 2. FIG. 24. SYN. TAB. I

Antero-posterior diameter of bone, 3 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The medullary canal is full and eccentrically situated. Medullary index, 33%.

Structure.—The section is composed of lamellæ with round and oval lacunæ and bushy canaliculi surrounding the medullary canal. The lacunæ are generally arranged in concentric rows and their bushy canaliculi extend outward from them. The canaliculi frequently unite and form a fine network. In some parts of the section there are large radiating canals extending the whole width of the walls of the bone. These canals communicate with adjacent lacunæ by fine canaliculi. The section as a whole has a bushy appearance. The large radiating canals seem to be found only in the frogs of large size.

Type I.

RIGHT FEMUR OF SPELERPES RUBER. RED SALAMANDER. AMER. MUS. NAT. HIST.

PL. 2. FIG. 25. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.3 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 4%.

Structure.—The entire section is composed of lamellæ with elongated lacunæ and bushy canaliculi enclosing the medullary canal. The bone has a uniform structure.

Type I.

RIGHT FEMUR OF CRYPTOBRANCHUS ALLEGHENIENSIS. HELLBENDER. AMER. MUS. NAT. HIST.

PL. 2, FIG. 26. SYN. TAB. I

Antero-posterior diameter of bone, 2.5 mm.; lateral. 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 7%.

Structure.—With the exception of a few lamellæ around the medullary canal the entire section is composed of round and oval lacunæ with bushy canaliculi embedded in bone substance and arranged concentrically around the medullary canal. The medullary canal is relatively small. A slight structural differentiation appears in the lamellæ around the medullary canal. Twofold division.

Type I.

RIGHT FEMUR OF NECTURUS MACULATUS. AMER. MUS. NAT. HIST.

PL. 2. FIG. 27. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 9%.

Structure.—Around the section are a few enclosing lamellæ with rather long lacunæ. Nearly the entire section is composed of large, oval, round, and elongated lacunæ with bushy canaliculi arranged radially between enclosing lamellæ. The arrangement of the lacunæ is such as to give a radiating appearance. Around the medullary canal are a few lamellæ with long lacunæ and long and straight canaliculi. Threefold division.

Type I.

RIGHT FEMUR OF SCAPHIOPUS HOLBROOKII. SPADEFOOT TOAD. AMER. MUS. NAT. HIST.

PL. 2, FIG. 28. SYN. TAB. 1

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 11%.

Structure.—The section is composed of two divisions, one, external, composed of concentric lamellæ with round and oval lacunæ and long, straight canaliculi, and the other, internal, composed of circumferential lamellæ with long, narrow lacunæ and long, straight canaliculi. Twofold division.

Type I.

RIGHT FEMUR OF SCAPHIOPUS COUCHII. NO. F 50 20, U. S. NAT. MUS.

PL. 2, FIG. 29. SYN. TAB. 1

Antero-posterior diameter of bone, 1 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.6 mm.

Medullary canal is full. Medullary index, 24%.

Structure.—The section is composed of lamellæ with long lacunæ and bushy canaliculi, indistinctly divided into concentric rings which surround the medullary canal.

Type I.

RIGHT FEMUR OF SCAPHIOPUS HAMMONDII. NO. F 20 6, U. S. NAT. MUS.

PL. 2, FIG. 30. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric rings of lamellæ surrounding a central medullary canal. The lacunæ are oval and the canaliculi are long.

Type I.

RIGHT FEMUR OF PIPA AMERICANA. SURINAM TOAD. AMER. MUS. NAT. HIST.

PL. 3, FIG. 31. SYN. TAB. 1

Antero-posterior diameter of bone, 3.5 mm.; lateral, 5.5 mm.

Antero-posterior diameter of medullary canal, 0.8 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 3%.

Structure.—The section is surrounded by a wide ring of lamellæ with long lacunæ and rather infrequent bushy canaliculi, interrupted by Haversian canals of the (Ia) differentiation. The ring is widest in the lateral walls. The canals appear in cross and oblique sections. Underneath this ring is a wide, central ring composed of crude lamellæ with oval lacunæ and relatively few canaliculi, enclosing large, irregularly shaped canals with surrounding, clear areas and presenting a general concentric arrangement. A few internal circumferential lamellæ with long lacunæ surround the medullary canal. Two large, open, round spaces appear, one in the inner posterior wall and the other in the outer lateral wall. The femur shows the three usual divisions—external circumferential lamellæ, central ring, internal circumferential lamellæ and primitive Haversian canals—all of which indicate slight advancement. Structural differentiation is shown by the three divisions and primitive Haversian canals.

Type I-III, Ia.

RIGHT FEMUR OF BUFO AGUA. BERMUDA TOAD. NO. 1113, AMER. MUS. NAT. HIST.

PL. 3, FIG. 32. SYN. TAB. 1

Antero-posterior diameter of bone, 5 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 39%.

Structure.—The section is surrounded by a wide band of bone substance with long, obliquely arranged lacunæ and straight canaliculi, interrupted by round, oval, and elongated filled canals around which are clear areas (Ia, differentiation). Underneath this band is a wide central ring of lamellæ with oval lacunæ and bushy canaliculi, interrupted by elongated and oval-filled canals surrounded by clear areas of bone substance (Ia, differentiation). Fine canaliculi pass from these canals to adjacent lacunæ. The canals mark the beginning of Haversian systems. Around the medullary canal is a narrow ring of lamellæ with oval lacunæ and bushy canaliculi. Threefold division.

Type I-III, Ia.

RIGHT FEMUR OF BUFO HALOPHILUS. NO. E 35 8, U. S. NAT. MUS.

PL. 3, FIG. 33. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 129%.

Structure.—The structure shows the three divisions. The external circumferential lamellæ form a narrow boundary ring. The central ring constitutes most all of the section, and is composed of lamellæ with oval lacunæ and bushy canaliculi. In the anterior and posterior walls the ring is traversed by

Haversian canals of the (Ia) differentiation. Internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia.

RIGHT FEMUR OF BUFO COLUMBIENSIS. NO. E 40, U. S. NAT. MUS.

Pl. 3, Fig. 34. Syn. Tab. I

Antero-posterior diameter of bone, 2 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.4 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 111%.

Structure.—The section shows the three divisions, external circumferential lamellæ very thin, central ring of lamellæ, and internal circumferential lamellæ. The external lamellæ are little more than a condensation of the external portion of the central ring. The central ring consists of concentric lamellæ with oval lacunæ. In the posterior and part of the lateral walls, oval lacunæ with bushy canaliculi are crowded together between the central ring and internal lamellæ. A few canals appear in the inner wall. The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia.

RIGHT FEMUR OF BUFO LENTIGINOSUS WOODHOUSII. NO. E 45 9, U. S. NAT. MUS.

Pl. 3, Fig. 35. Syn. Tab. I

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The section is composed of a thick ring of concentric lamellæ with oval lacunæ, crossed by numerous radiating canals and perforated by a few Haversian canals (Ia). Internal circumferential lamellæ form a narrow ring around the medullary canal. Twofold division.

Type I-III, Ia.

RIGHT FEMUR OF BUFO AMERICANUS. AMERICAN TOAD. AMER. MUS. NAT. HIST.

Pl. 3, Fig. 36. Syn. Tab. I

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 0.6 mm.

The medullary canal is full. Medullary index, 15%.

Structure.—The section is surrounded by a wide band of lamellæ with oval lacunæ and bushy canaliculi, interrupted by frequent Haversian canals of the (Ia) differentiation. The band is widest in the anterior and inner walls.

Underneath this band is a single lamina with long, well-developed lacunæ and straight canaliculi, parallel with neither surface of the bone, but occupying an irregular position.

Underneath the lamina is a wide central ring of lamellæ with oval lacunæ and bushy canaliculi, interrupted by frequent Haversian canals of the (Ia) differentiation. A narrow ring of internal circumferential lamellæ surrounds the medullary canal. Threefold division.

Type I-II-III, Ia.

RIGHT FEMUR OF BUFO LENTIGINOSUS COGNATUS. NO. 13 11, U. S. NAT. MUS.

PL. 3. FIG. 37. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 0.9 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—The three divisions are evident. The external circumferential lamellæ, with long lacunæ and straight canaliculi, surround the section. The central ring is composed of lamellæ with oval lacunæ perforated by Haversian canals of the (Ia) differentiation. The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia.

RIGHT FEMUR OF BUFO VALLICEPS. NO. E 21 5, U. S. NAT. MUS.

PL. 3. FIG. 38. SYN. TAB. I

Antero-posterior diameter of bone, 2 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.9 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 31%.

Structure.—The section is surrounded by a thick band of lamellæ with oval lacunæ and bushy canaliculi. It is perforated by numerous Haversian canals of the (Ia) differentiation. In the inner wall many radiating canals appear. The canaliculi from adjacent lacunæ extend into both the circular and radiating canals. A narrow ring of internal circumferential lamellæ encloses the medullary canal. Twofold division.

Type I-III, Ia.

RIGHT FEMUR OF RANA BOYLII. NO. F 61 20, U. S. NAT. MUS.

PL. 3, FIG. 39. SYN. TAB. I

Antero-posterior diameter of bone, 1 mm.; lateral, 0.6 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 47%.

Structure.—The section is composed of two parts, viz.: A wide ring of external lamellæ with oval lacunæ and bushy canaliculi, and a narrow ring of internal lamellæ with long, narrow lacunæ and straight canaliculi around the medullary canal. Twofold division.

Type I.

VII. REPTILES

Thirty-four femora were examined.

General Character of the Femur

The general shape of the reptilian femur varies considerably. The triangular, elliptical, round, and indeterminate forms are present. The majority are elliptical. In some sections the antero-posterior diameters are longest, as in many of the lizards, and in others the lateral diameters are longest, as in the turtles.

The contents of the medullary canals are variable in character. In the lizards they are filled with marrow and in the turtle with cancellous bone, the meshes of which are filled with marrow.

The medullary surfaces are smooth in the small, and rough in the large, femora.

The medullary index varies from 0 to 88% with an average of 26.1%. Excluding the turtles, in most of which the index is zero, the average is 33%.

The reptilian femora follow about the same kind of development as was seen in the amphibians, but the development is carried further.

The first type of bone predominates in both amphibians and reptiles. Haversian canals, (Ia) stage, appear in the amphibians, while a better developed form of Haversian system, (Ib) stage, is found in some of the reptiles. In the amphibians the external, internal circumferential lamellæ, and central ring appear, while in the reptiles these divisions are not prominent. Cancellous bone was found in one amphibian, the Amblystoma. It does not appear in the lizards, and is a characteristic structure of turtles.

Detailed Examination

RIGHT FEMUR OF SPHENODON PUNCTATA (MOST PRIMITIVE OF REPTILES). AMER. MUS. NAT. HIST.

Pl. 3, Fig. 40. Syn. Tab. 11

Antero-posterior diameter of bone, 3 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 26%.

Structure.—The section is composed entirely of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. A large vascular canal appears in the inner and posterior wall. There is very little differentiation of structure. The bone is uniform.

Type I.

RIGHT FEMUR OF PHRYNOSOMA CORNUTUM. TEXAS HORNED TOAD. NO. 1200, AMER. MUS. NAT. HIST.

PL. 3, FIG. 41. SYN. TAB. II

Antero-posterior diameter of bone, 2.8 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.8 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 10%.

Structure.—The section is composed of concentric lamellæ with long and oval lacunæ and straight and bushy canaliculi surrounding the medullary canal. The lacunæ of the external portion are long and narrow with straight canaliculi, and those of the medullary portion are oval with bushy canaliculi. There is very little differentiation of structure. The section shows an indistinct twofold division.

Type I.

LEFT FEMUR OF CHAMÆLEO VULGARIS. CHAMELEON. NO. 135, AMER. MUS. NAT. HIST.

PL. 3, FIG. 42. SYN. TAB. II

Antero-posterior diameter of bone, 1.8 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—The section is composed of an external ring of lamellæ with oval lacunæ and bushy canaliculi. The lacunæ tend to flatten as they reach the external surface. In the posterior wall the lacunæ are large and nearly round. Underneath this ring is another of lamellæ with oval lacunæ and bushy canaliculi. The two rings are separated by concentric, central lacunæ closely packed together. The bone shows an indistinct twofold division.

Type I.

RIGHT FEMUR OF PHRYNOSOMA DOUGLASSII. NO. L 50 12, U. S. NAT. MUS.

PL. 3, FIG. 43. SYN. TAB. II

Antero-posterior diameter of bone, 2 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and long canaliculi surrounding the medullary canal. Little or no differentiation has occurred. The section has a uniform structure.

Type I.

RIGHT FEMUR OF PTYCHOZOON HOMALOCEPHALUM—GECKO. NO. 684 AMER. MUS. NAT. HIST.

Pl. 3, Fig. 44. Syn. Tab. II

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with long lacunæ and long, straight canaliculi surrounding the medullary canal. Very little differentiation appears. The section is uniform.

Type I.

RIGHT FEMUR OF IGUANA TUBERCULATA. AMER. MUS. NAT. HIST.

Pl. 3. Fig. 45. Syn. Tab. II

Antero-posterior diameter of bone, 3.5 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 2 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 61%.

Structure.—The section is composed of concentric lamellæ with long lacunæ and long, straight canaliculi surrounding the medullary canal. The posterior wall is thickest and shows a column of oval lacunæ and their lamellæ extending from the medullary canal toward the external posterior surface. Very little differentiation of structure appears. The section is uniform.

Type I.

LEFT FEMUR OF VARANUS SALVATOR. AMER. MUS. NAT. HIST.

Pl. 3, Fig. 46. Syn. Tab. II

Antero-posterior diameter of bone, 11 mm.; lateral, 10 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 51%.

Structure.—The section is composed of concentric lamellæ with long and oval lacunæ and bushy canaliculi surrounding the bone, with the exception of the posterior wall. The lamellæ are partially separated into laminæ by concentric rows of long lacunæ placed end to end. Numerous short canals, parallel to each other and radiating from the medullary canal, cross the lamellæ. Around the canals are clear areas of bone substance crossed in many instances by fine canaliculi. In the posterior and inner wall the concentric lamellæ are displaced by canals and oval lacunæ with bushy canaliculi extending from the external surface to the medullary canal. The canals mark the locations of future Haversian systems. Fragments of lamellæ surround the medullary canal. In the posterior wall a little cancellous bone appears. The bone shows an early differentiation by its traces of laminæ and Haversian canals.

Type I-III, Ia.

RIGHT FEMUR OF AMPHIBOLURUS BARBATUS. (AUSTRALIA.)

AMER. MUS. NAT. HIST.

PL. 3, FIG. 47. SYN. TAB. II

Antero-posterior diameter of bone, 3 mm.; lateral, 4 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 49%.

Structure.—The section is composed of concentric lamellæ with long and oval lacunæ and long, straight canaliculi surrounding the medullary canal. No differentiation of structure is present. A large, vascular canal appears in the inner wall. The section is uniform.

Type I.

LEFT FEMUR OF VARANUS ARENARIUS. AMER. MUS. NAT. HIST.

PL. 3, FIG. 48. SYN. TAB. II

Antero-posterior diameter of bone, 4.5 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi arranged around the medullary canal. Many small canals traverse the walls of the bone radially from the medullary canal outward and from the external surface inward. There is very little differentiation of structure. The section is uniform.

Type I.

RIGHT FEMUR OF VARANUS NUCHALIS. MONITOR. AMER. MUS. NAT. HIST.

PL. 3, FIG. 49. SYN. TAB. II

Antero-posterior diameter of bone, 4.5 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 88%.

Structure.—With the exception of a small area of lamellæ along the medullary surface of the posterior wall, the section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi, interrupted by a large number of short, radiating canals around which are clear areas of bone substance. In the posterior wall the canals are circular in cross-section, elsewhere they are long. The bone shows a little differentiation of structure.

Type I-III, Ia.

RIGHT FEMUR OF HELODERMA SUSPECTUM. GILA MONSTER. NO. 583, AMER. MUS. NAT. HIST.

PL. 4, FIG. 50. SYN. TAB. 11

Antero-posterior diameter of bone, 3 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 0.7 mm.; lateral, 0.7 mm.

The medullary canal is full. Medullary index, 5%.

Structure.—The section is composed of concentric lamellæ having oval and long lacunæ with bushy and straight canaliculi indistinctly outlined in laminæ. The external lamellæ show long lacunæ and rather straight canaliculi, the remaining lamellæ, oval lacunæ and bushy canaliculi. Around the medullary canal is an enclosing ring of lamellæ with lacunæ and long, straight canaliculi. The bone shows traces of differentiation into the three main divisions—external, a central ring, and internal circumferential lamellæ. There is no trace of an Haversian system.

Type I.

RIGHT FEMUR OF SCELOPORUS CLARKII. NO. 16117, U. S. NAT. MUS.

PL. 4, FIG. 51. SYN. TAB. 11

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. There is no differentiation of structure. The section is uniform.

Type I.

RIGHT FEMUR OF SCELOPORUS SPINOSUS FLORIDANUS. NO. 17312, U. S. NAT. MUS.

PL. 4, FIG. 52. SYN. TAB. 11

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—The section is composed of concentric lamellæ with long lacunæ and straight canaliculi surrounding the medullary canal. There is no differentiation of structure. The section is uniform.

Type I.

RIGHT FEMUR OF SCELOPORUS OCCIDENTALIS. NO. 1 74 3, U. S. NAT. MUS.

PL. 1, FIG. 53. SYN. TAB. II

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.6 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The section is composed of lamellæ with oval and long lacunæ and straight canaliculi surrounding the medullary canal. There is no differentiation of structure.

Type I.

RIGHT FEMUR OF SCELOPORUS MAGISTER. NO. J 71 2, U. S. NAT. MUS.

PL. 4, FIG. 54. SYN. TAB. II

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 19%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. There is no differentiation of structure.

Type I.

RIGHT FEMUR OF CYCLURA CARINATA. U. S. NAT. MUS.

PL. 4, FIG. 55. SYN. TAB. II

Antero-posterior diameter of bone, 5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 3 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. There is very little differentiation of structure. The section is uniform.

Type I.

RIGHT FEMUR OF ANOLIS CRISTATELLUS. NO. L 15 13, U. S. NAT. MUS.

PL. 4, FIG. 56. SYN. TAB. II

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of two rings of lamellæ, external and internal. The external has long lacunæ with straight canaliculi and the internal, oval and round lacunæ with bushy canaliculi. They are of nearly equal width. There is very little differentiation of structure. The section shows the twofold division.

Type I.

RIGHT FEMUR OF CROTAPHYTUS COLLARIS. NO. J 21 12, U. S. NAT. MUS.

PL. 4. FIG. 57. SYN. TAB. II

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—The section is composed of two concentric rings of lamellæ surrounding the medullary canal. The external ring has long lacunæ and straight canaliculi, the internal, oval lacunæ and bushy canaliculi. The section shows the twofold division.

Type I.

LEFT FEMUR OF CROTAPHYTUS COLLARIS. NO. J 32 9, U. S. NAT. MUS.

PL. 4. FIG. 58. SYN. TAB. II

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.8 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 40%.

Structure.—The section is composed of two concentric rings of lamellæ surrounding the medullary canal. The external has long lacunæ and straight canaliculi, the internal, oval lacunæ and bushy canaliculi. The section shows the twofold division.

Type I.

RIGHT FEMUR OF AMEIVA EXUL. (CAYA DE SANTIAGO, PORTO RICO.) NO. L 21 11, U. S. NAT. MUS.

PL. 4, FIG. 59. SYN. TAB. II

Antero-posterior diameter of bone, 2 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index. 33%.

Structure.—The section is composed of concentric lamellæ with oval and long lacunæ and straight canaliculi surrounding the medullary canal. There is very little differentiation of structure. The section is uniform.

Type I.

RIGHT FEMUR OF EUMECES FASCIATUS. NO. H 31 4, U. S. NAT. MUS.

PL. 4, FIG. 60. SYN. TAB. II

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.6 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The section is composed of lamellæ with oval lacunæ and bushy canaliculi dimly outlined in laminæ. There is little differentiation of structure.

Type I.

RIGHT FEMUR OF SAUROMALUS. NO. J 40 6, U. S. NAT. MUS.

PL. 4, FIG. 61. SYN. TAB. II

Antero-posterior diameter of bone, 3 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.2 mm.

The medullary canal is full. Medullary index, 32%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi partially divided into concentric rings. A vascular canal is seen in the posterior inner wall. A narrow ring of lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal.

Type I.

RIGHT FEMUR OF GERRHONOTUS GRANDIS. NO. 1 22 4, U. S. NAT. MUS.

PL. 4, FIG. 62. SYN. TAB. II

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 11%.

Structure.—The section is composed of concentric lamellæ with oval and long lacunæ and straight and bushy canaliculi. Around the posterior and lateral medullary surface is a crescent of basic bone substance with round lacunæ and bushy canaliculi.

Type I.

RIGHT FEMUR OF PYTHON REGIUS. PYTHON. (11½ FEET IN LENGTH—DIED AT WASHINGTON ZOO)

PL. 4, FIG. 63. SYN. TAB. II

Antero-posterior diameter of bone, 1 mm.; lateral, 0.6 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.3 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The femur is rudimentary. The section is composed of lamellæ arranged in a peculiar manner. In the anterior wall they are arranged concentrically around a semicircle with a short radius. In the lateral and posterior wall the lamellæ take a long curve from the medullary surface of the anterior wall. The lacunæ are round and the canaliculi are bushy. The anterior wall is best developed. A narrow ring of internal lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal.

Type I.

LEFT FEMUR OF THE SAME PYTHON REGIUS. U. S. NAT. MUS.

Pl. 4, Fig. 64. Syn. Tab. II

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—The section is composed of two rings of lamellæ, viz.: external and internal. The external is thickest and is composed of lamellæ with a few round and oval lacunæ and bushy canaliculi. The canaliculi of the posterior wall are long and straight and, in the anterior wall, infrequent and bushy. A narrow ring of internal lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal.

Type I.

LEFT FEMUR OF ALLIGATOR MISSISSIPPIENSIS. ALLIGATOR. CR. MED. COLL.

Pl. 4, Fig. 65. Syn. Tab. II

Antero-posterior diameter of bone, 17 mm.; lateral, 15 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 20%.

Structure.—A thin cross-section of this femur held up to the light presents a ringed appearance like that of a cross-section of the trunk of a tree.

The section is composed of three concentric rings of laminæ with long, narrow lacunæ and straight canaliculi, alternating with four concentric rings of bone substance enclosing crude Haversian canals. The Haversian canals are round, oval, or irregular in shape, are large and small in size, and very numerous. They are surrounded by clear areas of bone substance and many fine canaliculi from concentric adjacent oval lacunæ pass radially across the areas of bone substance into the canals. The (Ib) stage of the Haversian system is represented. The laminæ are fairly well developed.

Type I-II-III, Ia, Ib.

FEMUR OF CHELYDRA SERPENTINA. SNAPPING TURTLE. CR. MED. COLL.

Pl. 4, Fig. 66. Syn. Tab. II

Antero-posterior diameter of bone, 8 mm.; lateral, 8.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 1.5%.

Structure.—The wall of the shaft is very thick, proportionately, and the medullary canal is very small. The femur is nearly solid. The section has four concentric rings of laminæ alternating with three concentric rings of bone substance in which are many Haversian canals. The canals are much more regular in shape than they were in the alligator and are surrounded by smaller, clear areas of bone substance. Oval lacunæ are arranged concentrically around the boundaries of these areas and bushy canaliculi pass from the lacunæ to the canals. The laminæ are much better developed than the Haversian systems which have reached the (Ib) differentiation. The posterior wall is composed of bone substance with round lacunæ and bushy canaliculi arranged as a crude cancellous bone and merges into the cancellous bone of the medullary canal.

Type I-II-III, Ia, Ib.

RIGHT FEMUR OF TRIONYX SPINIFER. SOFT-SHELLED TURTLE. NO. 2325, AMER. MUS. NAT. HIST.

PL. 4, FIG. 67. SYN. TAB. II

Antero-posterior diameter of bone, 3.5 mm.; lateral, 5.5 mm.

Antero-posterior diameter of medullary canal—cancellous bone.

The medullary canal is full. Medullary index, 0.

Structure.—The section is surrounded by a ring of lamellæ with oval lacunæ and bushy canaliculi. It is interrupted by Haversian canals of the (Ia) differentiation. In the posterior wall here and there an Haversian system appears in the (Ib) stage of advancement. Cancellous bone occupies the central canal of the bone and is derived, by extension, from the enclosing lamellar ring. The walls of the cancellous meshes are composed of lamellæ with oval and long lacunæ and straight canaliculi. There is no individual medullary canal.

Type I-III, Ia, Ib.

RIGHT FEMUR OF CINOSTERNUM PENNSYLVANICUM. MUD TURTLE. AMER. MUS. NAT. HIST.

PL. 4, FIG. 68. SYN. TAB. II

Antero-posterior diameter of bone, 3 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal—cancellous bone.

The medullary canal is full. Medullary index, 0.

Structure.—The section is surrounded by a narrow ring of lamellæ with oval lacunæ and bushy canaliculi, from which is derived the cancellous bone which fills the medullary canal. A few Haversian systems of the (Ib) differentiation are found in the posterior wall.

Type I-III, Ib.

RIGHT FEMUR OF CHELOPUS GUTTATUS. SPOTTED TURTLE. AMER. MUS. NAT. HIST.

PL. 4, FIG. 69. SYN. TAB. II

Antero-posterior diameter of bone, 2.5 mm.; lateral, 4 mm.

Antero-posterior diameter of medullary canal—cancellous bone.

The medullary canal is full. Medullary index, 0.

Structure.—The section is surrounded by a narrow ring of lamellæ with oval lacunæ and bushy canaliculi, interrupted by a few Haversian canals of the (Ia) differentiation. From the under surface of this ring is derived a cancellous bone which entirely fills the medullary canal. The walls of the meshes are composed of lamellæ with oval lacunæ and bushy canaliculi. In the posterior wall are a few Haversian systems of the (Ib) stage of development.

Type I-III, Ia, Ib.

LEFT FEMUR OF CHRYSEMYS PICTA. PAINTED TURTLE. AMER. MUS. NAT. HIST.

Pl. 4, Fig. 70. Syn. Tab. II

Antero-posterior diameter of bone, 2.5 mm.; lateral, 4 mm.

Antero-posterior diameter of medullary canal—cancellous bone.

The medullary canal is full. Medullary index, 0.

Structure.—The section is surrounded by a ring of lamellæ with oval lacunæ and bushy canaliculi, interrupted by a few Haversian canals of the (Ia) differentiation. Haversian systems of the (Ib) stage of development are found in the posterior wall. From the lamellar ring is derived the cancellous bone which occupies the whole medullary canal.

Type I-III, Ia, Ib.

RIGHT FEMUR OF AROMOCHELYS ODORATUS. MUSK TURTLE. AMER. MUS. NAT. HIST.

Pl. 4, Fig. 71. Syn. Tab. II

Antero-posterior diameter of bone, 1.8 mm.; lateral, 1.4 mm.

Antero-posterior diameter of medullary canal, 0.3 mm.; lateral, 0.3 mm.

The medullary canal is full. Medullary index, 4%.

Structure.—The section is surrounded by a band of lamellæ of various widths. The lacunæ are long and their canaliculi are long and straight. Underneath this is a central ring of lamellæ with oval lacunæ and bushy canaliculi. In this ring are several Haversian systems of the (Ib) differentiation forming a circular row around the medullary canal.

Around the medullary canal is a ring of internal circumferential lamellæ with long lacunæ and straight canaliculi. The bone shows the outlines of the three divisions—external and internal circumferential lamellæ and the central ring of lamellæ with Haversian systems.

Type I-III, Ib.

RIGHT FEMUR OF PSEUDEMYS FLORIDANA. NO. 28417, U. S. NAT. MUS.

Pl. 4, Fig. 72. Syn. Tab. II

Antero-posterior diameter of bone, 4 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal—cancellous bone.

Medullary index, 0.

Structure.—The section is composed of lamellæ with oval lacunæ and bushy canaliculi, incompletely separated into laminæ which surround the medullary canal. In the posterior wall the crude laminæ are frequently interrupted by Haversian canals of the (Ib) differentiation. In the internal laminæ of the anterior wall are several crude undeveloped and a few fairly well developed Haversian systems. The medullary canal is occupied by cancellous bone.

Type I-II-III, Ib.

RIGHT FEMUR OF TESTUDO (GOPHERUS) POLYPHEMUS. NO. 7555, U. S. NAT. MUS.

Pl. 4, Fig. 73. Syn. Tab. II

Antero-posterior diameter of bone, 8.5 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal—cancellous bone.

The medullary canal is full. Medullary index, 0.

Structure.—The section is composed of incompletely formed, concentric laminæ which constitute the anterior, outer, and posterior wall. The laminæ are crossed by short, radiating canals and interrupted by Haversian systems of the (Ia) differentiation. Beneath the laminæ of the anterior and outer wall are Haversian systems of the (Ib) stage of development and the posterior ridge is made up almost entirely of Haversian systems of the same development. The inner wall is composed of lamellæ.

Type I-III, Ia, Ib.

VIII. BIRDS

Forty femora were examined.

General Character of the Femur

The femora of birds vary considerably in shape. A few are triangular, many are elliptical, and some are circular. The majority of them are elliptical and their antero-posterior diameters are longest. The medullary contents present a variable character. In some femora the medullary canals are full of marrow; in some, of cancellous bone, the meshes of which are filled with marrow; while in others, the canals are empty or occupied by trabeculæ only. About half of the femora examined have no contents.

The medullary surfaces also vary somewhat in character. In those canals filled with marrow and blood vessels the surface is uneven, while in those which have no contents the surface is smooth. In these bones the walls are thin, the canals large, and the trabeculæ are numerous. The medullary index varies from 0 to 327%, with an average of 159%.

The bone structures show considerable variation. The three single types and many combinations of types, in an incomplete or complete differentiation, are found. None of these, with the possible exception of the first, have reached their full development. The second is found in a very incomplete and an advanced stage and forms the structure of a large number of femora; while the third has assumed a more complex form than that found in reptiles. The Haversian systems are comparatively large, the Haversian canals are small and around them are concentrically arranged round or oval lacunæ with intricate networks of canaliculi. This is the (1c) stage of Haversian differentiation and is characteristic of birds.

Detailed Examination

RIGHT FEMUR OF CYANOCITTA STELLERI AZTECA. AZTEC JAY. NO. 2874, AMER. MUS. NAT. HIST.

Pl. 5, Fig. 74. Syn. Tab. III

Antero-posterior diameter of bone, 3 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 2 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 68%.

Structure.—The section is composed of bone substance with oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone substance is partially separated into laminæ by short canals. The bone shows but little differentiation of structure.

Type I-II.

LEFT FEMUR OF MERGUS SERRATOR. RED-BREASTED MERGANSER. NO. 3117, AMER. MUS. NAT. HIST.

Pl. 5. Fig. 75. Syn. Tab. III

Antero-posterior diameter of bone, 6.5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 68%.

Structure.—The section is composed of bone substance with oval lacunæ and bushy canaliculi, separated into incomplete laminæ by short, concentric, branching canals. A few vascular canals running longitudinally appear in the posterior inner and anterior wall. In the bone substance are a few Haversian systems of the (Ic) stage of development, and a single better differentiated system occurs in the tip of the posterior ridge. The lacunæ are oval. A narrow ring of internal circumferential lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal.

Type I-II-III, Ic.

RIGHT FEMUR OF AJAIA AJAJA. ROSEATE SPOONBILL. NO. 2858, AMER. MUS. NAT. HIST.

PL. 5, FIG. 76. SYN. TAB. III

Antero-posterior diameter of bone, 7 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 4.5 mm.

Medullary index, 114%.

Structure.—With the exception of two rather crude Haversian systems in the posterior ridge the section is composed of lamellæ with oval lacunæ and bushy canaliculi, separated by canals of a branching character into crude laminæ. The general direction of the canals is concentric. The bone shows very little differentiation of structure.

Type I-II.

RIGHT FEMUR OF TYMPANUCHUS AMERICANUS. PRAIRIE CHICKEN. CR. MED. COLL.

PL. 5, FIG. 77. SYN. TAB. III

Antero-posterior diameter of bone, 5 mm.; lateral 6 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 4.5 mm.

The medullary canal is empty. Medullary index, 148%.

Structure.—The bone is composed of lamellæ, crossed at all angles by short canals, some of which extend inward from the external surface. In the posterior and outer wall they unite and form a coarse network, while in the anterior and inner wall they do not. Their lacunæ are oval or narrow and their canaliculi are bushy or long and branching.

A very few Haversian systems of the (Ic) stage are found interrupting the lamellæ of the anterior and inner wall. In the posterior wall are two ridges separated by a concave intermediate wall of bone. Two or three undeveloped Haversian systems are found in each ridge.

The internal circumferential lamellæ surround the medullary canal. They are well developed. Their lacunæ are long and narrow and their canaliculi are long and branching.

Type I.

RIGHT FEMUR OF NUMIDA MELEAGRIS. GUINEA FOWL. CR. MED. COLL.

PL. 5. FIG. 77½. SYN. TAB. III

Antero-posterior diameter of bone, 7 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 116%.

Structure.—The section is composed of crude laminæ with oval lacunæ and bushy canaliculi, interrupted by Haversian systems of the (Ic) differentiation. In the anterior and posterior wall the laminæ have a radial direction. The internal circumferential lamellæ with long lacunæ and straight canaliculi form a narrow ring around the medullary canal.

Type II-III, Ic.

RIGHT FEMUR OF CYANOCITTA CRISTATA. BLUE JAY. CR. MED. COLL.

PL. 5. FIG. 78. SYN. TAB. III

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The bone is nearly round. The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of bone substance separated into crude laminæ by short, branching, more or less concentric canals. A few Haversian systems of the (Ic) stage of differentiation appear here and there. The lacunæ are oval and the canaliculi are short and bushy.

Type II-III, Ic.

LEFT FEMUR OF PTEROGLOSSUS TORQUATUS. BANDED TOUCAN. NO. 2854, AMER. MUS. NAT. HIST.

PL. 5. FIG. 79. SYN. TAB. III

Antero-posterior diameter of bone, 3 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 2 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi, crossed by a few short canals surrounding the medullary canal.

Type I.

LEFT FEMUR OF CHARADRIUS PLUVIALIS. GOLDEN PLOVER. NO. 3356, AMER. MUS. NAT. HIST.

PL. 5. FIG. 80. SYN. TAB. III

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi, interrupted by a few crude Haversian systems. The lamellæ are partially separated into laminæ by short concentric canals. The bone shows little differentiation.

Type II.

LEFT FEMUR OF AMAZONA ORATRIX. MEXICAN YELLOW-HEADED PARROT. NO. 3025, AMER. MUS. NAT. HIST.

PL. 5, FIG. 81. SYN. TAB. III

Antero-posterior diameter of bone, 4 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 3 mm.

The medullary canal is full. Medullary index, 177%.

Structure.—The section is composed of lamellæ with oval lacunæ and bushy canaliculi, incompletely separated into dim laminæ by short, concentric canals and interrupted by Haversian canals of the (Ia) differentiation. In the central portion of the section, and extending nearly around it, is a concentric row of Haversian systems of the (Ic) differentiation. In the posterior wall, oval lacunæ are crowded together along the medullary surface.

Type II-III, Ia, Ic.

RIGHT FEMUR OF TURDUS MIGRATORIUS. ROBIN. CR. MED. COLL.

PL. 5, FIG. 82. SYN. TAB. III

Antero-posterior diameter of bone, 2 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 129%.

Structure.—The section is composed of concentric lamellæ with oval and long lacunæ and straight and bushy canaliculi surrounding the medullary canal. A concentric row of small Haversian systems of the (Ic) stage is found in the central portion of the wall of the bone. A few canals cross the bone in different directions.

Type I-III, Ic.

FEMUR OF PELECANUS ERYTHRORHYNCHUS. WHITE PELICAN. CR. MED. COLL.

PL. 5, FIG. 83. SYN. TAB. III

Antero-posterior diameter of bone, 12 mm.; lateral, 10 mm.

Antero-posterior diameter of medullary canal, 0; lateral, 0.

The central portion of the bone is cancellous. Medullary index, 0.

Structure.—The external circumferential lamellæ form a narrow enclosing ring. Underneath this is a central ring of Haversian systems of the (Ic) differentiation with canals running at all angles. Beneath this is a narrow ring of internal circumferential lamellæ from the inside of which is derived a cancellous structure occupying the whole medullary region of the bone. The meshes are filled with insoluble matter. A very small medullary canal is situated in the posterior half of the section.

Type I-III, Ic.

RIGHT FEMUR OF ARA MACAO. MACAW. CR. MED. COLL.

PL. 5, FIG. 84. SYN. TAB. III

Antero-posterior diameter of bone, 5.5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 3.5 mm.

The medullary canal is full. Medullary index, 178%.

Structure.—The bone is composed of rather crude laminæ, separated and crossed at various angles by numerous canals and interrupted here and there by a few Haversian systems of the (Ic) differentiation. In the posterior ridge the systems form a considerable portion of the thickness of the wall. The laminæ are composed of a few lamellæ with oval and round lacunæ and short, bushy canaliculi.

Type II-III, Ic.

RIGHT FEMUR OF NYCTHERODIUS VIOLACEUS. NIGHT HERON. CR. MED. COLL.

PL. 5, FIG. 85. SYN. TAB. III

Antero-posterior diameter of bone, 5 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 148%.

Structure.—The external circumferential lamellæ are not distinct. The bone is composed, for the most part, of short, irregular, and incomplete laminæ, marked off by short, concentric canals. The laminæ are interrupted by small Haversian systems of the (Ic) differentiation which form nearly the whole of the posterior ridge. Each lamina consists of a few lamellæ with oval lacunæ and bushy canaliculi. The canals separating the laminæ are wide and short, and not often uniting. Internal circumferential lamellæ with long lacunæ and straight canaliculi surround the medullary canal.

Type II-III, Ic.

FEMUR OF PAVO CRISTATUS. PEAFOWL. CR. MED. COLL.

PL. 5, FIG. 86. SYN. TAB. III

Antero-posterior diameter of bone, 10 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 10 mm.

The walls of the bone are thin. The medullary canal is large, empty, and has a network of trabeculæ which extends from one wall in a downward direction to the opposite wall.

Medullary index, 277%.

Structure.—The section is composed of a concentric network of canals enclosing short laminæ. The canals intersect at all angles. The laminæ, composed of bone substance with oval lacunæ and relatively few rather short, bushy canaliculi, are interrupted by a few Haversian systems of the (Ic) differentiation.

Type II-III, Ic.

FEMUR OF HALIÆTUS LEUCOCEPHALUS. EAGLE. CR. MED. COLL.

PL. 5, FIG. 87. SYN. TAB. III

Antero-posterior diameter of the bone, 13 mm.; lateral, 14 mm.

Antero-posterior diameter of the medullary canal, 11 mm.; lateral, 11.5 mm.

The medullary canal is empty. Medullary index, 227%.

Structure.—External circumferential lamellæ surround the bone, excepting the posterior ridge where they are interrupted by tendon attachments. Their lacunæ are long, narrow, and concentrically arranged and their canaliculi are rather short and branching.

The central ring of bone is composed of concentric laminæ, interrupted by Haversian systems of the (Ic) differentiation. The canals which separate the laminæ are relatively wide and, on account of their frequent communications with neighboring canals, they present the appearance of a coarse network.

Internal circumferential lamellæ surround the medullary canal. They are fairly well developed and are frequently crossed by canals extending inward from the medullary canal. Their lacunæ are long and narrow and their canaliculi are long and branching.

On the posterior surface are two ridges, one central and one on the posterior inner lateral border. The bone at these points consist of Haversian systems of the (Ic) stage, separated by frequent wide canals which pass to an apex at the outer surface of the ridges. The external circumferential laminæ are absent at these points and tendon insertions, interspersed with many canals, occupy the posterior ridges.

Type II-III, Ic.

LEFT FEMUR OF ARAMUS VOCIFERUS. COURLAN. NO. 2859, AMER. MUS. NAT. HIST.

PL. 5, FIG. 88. SYN. TAB. III

Antero-posterior diameter of bone, 6.5 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 5 mm.

The medullary canal is empty. Medullary index, 239%.

Structure.—The section is composed of concentric laminæ with oval lacunæ and bushy canaliculi. In the anterior and posterior walls a single Haversian system of the (Ic) stage is seen. Around the medullary canal is a narrow ring of lamellæ with long lacunæ and straight canaliculi. The bone shows very little variation of structure.

Type II.

LEFT FEMUR OF CENTROCERCUS UROPHASIANUS. SAGE GROUSE OR SAGE HEN. CR. MED. COLL.

Pl. 5. Fig. 89. Syn. Tab. III

Antero-posterior diameter of bone, 7 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 5 mm.

The medullary canal is empty. Medullary index, 252%.

Structure.—The bone is composed of short, concentric laminæ, with the exception of a short, narrow crescent of poorly developed Haversian systems in the posterior inner wall. The laminæ are frequently crossed by canals. Each lamina is composed of a few lamellæ with long, narrow lacunæ and long canaliculi. In the posterior wall on both sides of the mid-line are two tendon insertions which mark the attachment of muscles.

Type II.

FEMORA OF MELEAGRIS GALLIPAVO. WILD AND DOMESTIC TURKEYS. CR. MED. COLL.

Pl. 6, Figs. 90, 91, 91½. Syn. Tab. III

Left Wild Turkey	Antero-posterior diameter of bone, 15 mm.; lateral, 17.5 mm. Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 13 mm. Medullary, index, 109%.
Left Domestic Turkey, 18 lbs. weight	Antero-posterior diameter of bone, 9 mm.; lateral, 11 mm. Antero-posterior diameter of medullary canal, 7 mm.; lateral, 8 mm. Medullary index, 129%.
Left Domestic Turkey, 32 lbs. weight	Antero-posterior diameter of bone, 15 mm.; lateral, 17 mm. Antero-posterior diameter of medullary canal, 13 mm.; lateral, 13 mm. Medullary, index, 194%.

Since the three bones resemble each other closely, one description will answer for all. The medullary canals are full and relatively large. The walls of the bone are thin. The index is higher in the domestic than in the wild turkey.

Structure.—External circumferential lamellæ, with long, narrow lacunæ and many bushy canaliculi, surround the sections. Along the posterior ridges of the femora are small areas of Haversian systems of the (Ic) differentiation which occupy nearly the entire thickness of the posterior walls of the bones. In the anterior walls are small areas of similar Haversian systems. The Haversian canals are large, the lacunæ are oval, and their canaliculi are numerous and bushy.

The lateral walls of the bones are composed of rather crude concentric laminæ, interrupted by a few Haversian systems of the (Ia, Ic) differentiations, separated by prominent concentric canals and crossed at frequent intervals by smaller canals extending from both surfaces of the bone. The laminæ are composed of lamellæ, between which are oval lacunæ with short, bushy canaliculi. Around the medullary canal the internal circumferential lamellæ are not distinct from the adjoining laminæ.

As the femur of the domestic turkey was the first bone to suggest variation in bone type, a number of turkey femora were examined. It was found that they were all second type with Haversian systems of the (Ia) and (Ic) stages of development. The turkeys of greatest weight had the most Haversian systems. A turkey of 32 pounds weight (pl. 6, fig. 91½) had more systems than one of 14, 16, or 18 pounds, and the systems were distributed over a greater area in the different walls of the bone.

Type II-III, Ia, Ic.

LEFT FEMUR OF DENDRAGAPUS OBSCURUS. GROUSE. CR. MED. COLL.

Pl. 6, Fig. 92. Syn. Tab. III

Antero-posterior diameter of bone, 5 mm.; lateral, 5.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5 mm.

The medullary canal is empty. Medullary index, 277%.

Structure.—The bone, with the exception of a narrow ring of internal circumferential lamellæ, is composed of short, concentric laminæ, separated by wide canals. Each lamina is composed of lamellæ, with long, narrow or oval lacunæ and long, branching or bushy canaliculi. The canals freely communicate with each other across the laminæ. In the anterior wall (middle portion) is a slight prominence or ridge, consisting of poorly developed Haversian systems, situated close to the external surface. In the posterior wall are two ridges separated by a concave intermediate wall of bone. A single, poorly developed Haversian system is found at the apex of each ridge, around which are collections of oval lacunæ, with short, bushy canaliculi. Close to the internal circumferential lamellæ are a few Haversian systems of a crude type.

Internal circumferential lamellæ surround the medullary canal. Their lacunæ are long and narrow.

Type II.

LEFT FEMUR OF RHEA AMERICANA. RHEA. NO. 2875, AMER. MUS. NAT. HIST.

Pl. 6. Fig. 93. Syn. Tab. III

Antero-posterior diameter of bone, 25.5 mm.; lateral, 20.5 mm.

Antero-posterior diameter of medullary canal, 19 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 120%.

Structure.—The section is composed of concentric laminæ, separated and crossed by numerous canals, and, here and there, interrupted by small Haversian systems of the (Ic) differentiation.

Type II-III, Ic.

LEFT FEMUR OF STRUTHIO. OSTRICH. AMER. MUS. NAT. HIST.

PL. 6, FIG. 94. SYN. TAB. III

Antero-posterior diameter of bone, 54 mm.; lateral, 40 mm.

Antero-posterior diameter of medullary canal, 47 mm.; lateral, 32 mm.

The medullary canal is empty. Medullary index, 240%.

Structure.—The bone is large, thin-walled, and light. The section is composed of incomplete, concentric, short and long laminæ, crossed by numerous canals, and interrupted by many Haversian systems of the (Ic) stage of differentiation. The posterior ridges are composed mostly of similar Haversian systems. The central zones of these systems are composed of lamellæ with round lacunæ and short, bushy canaliculi, while their external zones, much narrower, consist of lamellæ with long, narrow lacunæ and straight canaliculi.

Type II-III, Ic.

HAVERSIAN SYSTEM OF THE OSTRICH

PL. 6, FIG. 95. SYN. TAB. III

An Haversian system from the posterior wall of the femur of an ostrich (fig. 94) is enlarged in order to show developmental stages.

The system consists of a central and peripheral portion. The central portion is composed of bone substance with round lacunæ and branching canaliculi forming a delicate canalicular network around the Haversian canal. The peripheral portion is composed of long, narrow lacunæ with straight canaliculi situated in and between lamellæ and arranged concentrically around the central portion. The central portion suggests an early development by its round lacunæ and close proximity to the circulation of the Haversian canal, while the peripheral portion suggests a later and more complete development by its long, narrow lacunæ and removal from the Haversian canal.

LEFT FEMUR OF PHASIANUS TORQUATUS. CHINESE PHEASANT. CR. MED. COLL.

PL. 6, FIG. 95½. SYN. TAB. III

Antero-posterior diameter of bone, 6 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 4.5 mm.

The medullary canal is empty. Medullary index, 129%.

Structure.—The section is composed of crude, short laminæ interrupted by a few Haversian systems of the (Ic) differentiation. The lacunæ are oval and the canaliculi are short and bushy. Internal circumferential lamellæ partly surround the medullary canal.

Type II, Ic.

RIGHT FEMUR OF DROMÆUS NOVÆ HOLLANDIÆ. EMU. NO. 2916, AMER. MUS. NAT. HIST.

PL. 6, FIG. 96. SYN. TAB. III

Antero-posterior diameter of bone, 30 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 22 mm.; lateral, 19.5 mm.

Medullary index, 122%.

Structure.—The section is composed, for the most part, of a background of short laminæ separated by short concentric canals in which are scattering Haversian systems of the (Ic) differentiation. In the outer wall a threefold division is present—external circumferential laminæ, central ring, and internal circumferential lamellæ.

The central ring is composed of Haversian systems, many of which are arranged in a peculiar manner. They occur in groups of two to eight, enclosed within an envelope of laminæ resembling cross-sections of cables. The systems are of the (Ic) differentiation. This is the only bone in which this arrangement has been seen.

Type II-III, Ic.

FEMUR OF ANAS BOSCAS. MALLARD DUCK. CR. MED. COLL.

PL. 6, FIG. 97. SYN. TAB. III

Antero-posterior diameter of bone, 4.5 mm.; lateral, 6.5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 5 mm.

The medullary canal is empty. Medullary index, 141%.

Structure.—The section is composed of crude laminæ arranged concentrically and interrupted by rather small and poorly developed Haversian systems. The two posterior ridges have groups of the (Ic) differentiation.

Type II-III, Ic.

FEMUR OF EMBERIZA CITRINELLA. YELLOW-HAMMER. CR. MED. COLL.

PL. 6, FIG. 98. SYN. TAB. III

Antero-posterior diameter of bone, 2.5 mm.; lateral, 3 mm.

Antero-posterior and lateral diameters of medullary canals, 0.

The medullary canal is full and situated close to the posterior wall. Medullary index, 0.

Structure.—The section is surrounded by external circumferential lamellæ, within which are a few Haversian systems of the (Ic) differentiation. Large canals extend transversely across the walls of the bone, communicating with the meshes of the central bone structure.

The central portion of the bone, usually occupied by the medullary canal, is composed of a fine cancellous bone with the exception of a small medullary canal, about the size of a fine sewing needle, situated near the posterior wall. The femur is therefore nearly solid bone. The cancellous center is composed of fine lamellæ forming a meshwork extended from the internal circumferential lamellæ. The meshes are filled with granular material, insoluble in ether or chloroform. The lacunæ are small, round, or oval and their canaliculi are short, bushy, and infrequent. Although the bird is a good flier its femur is practically a solid bone.

Type I-III, Ic.

RIGHT FEMUR OF CHAUNA CRISTATA. CRESTED SCREAMER. NO. 2861, AMER. MUS. NAT. HIST.

PL. 6, FIG. 99. SYN. TAB. III

Antero-posterior diameter of bone, 12.5 mm.; lateral, 12 mm.

Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 10.5 mm.

The medullary canal is empty. Medullary index, 277%.

Structure.—The section has the three divisions well marked. The external circumferential lamellæ form a narrow, distinct ring around the section. Their lacunæ are long and the canaliculi are straight. The central ring is composed of Haversian systems of the (Ic) stage and of canals and fragments of lamellæ. The internal circumferential lamellæ form a distinct ring around the medullary canal. Their lacunæ are long.

Type III, Ic.

LEFT FEMUR OF PANDION CAROLINENSIS. AMERICAN OSPREY. NO. 55, CR. MED. COLL.

PL. 6, FIG. 100. SYN. TAB. III

Antero-posterior diameter of bone, 7.5 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 6.5 mm.

The medullary canal is full. Medullary index, 188%.

Structure.—The external circumferential lamellæ are not distinct from the underlying structure. The bone is composed of crude laminæ which are frequently interrupted by Haversian systems of the (Ic) differentiation, and crossed at differing angles by vascular canals. In the posterior wall near the mid-line is a cluster of small Haversian systems with which tendon intersections are blended. The lacunæ of the laminæ are round and oval.

Concentric laminæ surround the medullary canal. They are frequently crossed by short canals from the medullary canal.

Type II-III, Ic.

RIGHT FEMUR OF SARCORHAMPHUS GRYPHUS. ANDEAN CONDOR. NO. 1276, AMER. MUS. NAT. HIST.

PL. 7. FIG. 101. SYN. TAB. III

Antero-posterior diameter of bone, 18.5 mm.; lateral, 17.5 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 14.5 mm.

The medullary canal is full. Medullary index, 204%.

Structure.—The bone has three divisions. The external circumferential lamellæ form a narrow enclosing ring. Their lacunæ are long and their canaliculi are straight. The central ring is composed of round and elongated Haversian systems of the (Ic) differentiation. Internal circumferential lamellæ form an uneven ring around the medullary canal. Their lacunæ are long.

Type I-III, Ic.

RIGHT FEMUR OF OLOR SP. SWAN. NO. 1681, AMER. MUS. NAT. HIST.

PL. 7. FIG. 102. SYN. TAB. III

Antero-posterior diameter of bone, 11.5 mm.; lateral, 10.5 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 8 mm.

Medullary index, 87%.

Structure.—The bone has the three divisions. The external circumferential lamellæ form a narrow enclosing ring. Their lacunæ are long and their canaliculi are straight. The central ring is composed of crude laminæ with oval lacunæ, partly displaced by Haversian systems of the (Ic) differentiation. In the anterior inner wall indistinct laminæ appear. A wide ring of lamellæ, partly separated into laminæ, surrounds the medullary canal. The lamellæ have long lacunæ and are crossed by numerous canals.

Type II-III, Ic.

LEFT FEMUR OF GAVIA STELLATA. RED-THROATED LOON. NO. 2801, AMER. MUS. NAT. HIST.

PL. 7. FIG. 103. SYN. TAB. III

Antero-posterior diameter of bone, 8.5 mm.; lateral, 6.5 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 4 mm.

The medullary canal is divided into two equal parts, antero-posteriorly by a partition of bone. Medullary index, 184%.

Structure.—The section has the three divisions. The external circumferential lamellæ form a narrow enclosing ring. The lacunæ are long and oval and their canaliculi are long and bushy. The central ring is composed of lamellæ and Haversian systems of the (Ic) differentiation. The internal circumferential lamellæ with long lacunæ and straight canaliculi surround the medullary canal and form the dividing partition. Four large vascular canals appear in the anterior wall and two or three in the posterior. Their lacunæ are long and oval with long and straight canaliculi.

Type I-III, Ic.

FEMUR OF GALLUS. DOMESTIC CHICKEN. CR. MED. COLL.

PL. 7, FIG. 104. SYN. TAB. III

Antero-posterior diameter of bone, 9 mm.; lateral, 9 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 153%.

Structure.—Well marked external circumferential lamellæ with long, narrow lacunæ and branching canaliculi surround the section. The central ring is composed of irregularly shaped Haversian systems of the (Ic) differentiation. At the posterior ridge they occupy the entire thickness of the wall of the bone as far as the internal circumferential lamellæ. Interspersed between the systems are short lamellæ.

Internal circumferential lamellæ completely surround the medullary canal. Their lacunæ are long and narrow and their canaliculi are bushy.

Type I-III, Ic.

FEMUR OF CORVUS AMERICANUS. CROW. CR. MED. COLL.

PL. 7, FIG. 105. SYN. TAB. III

Antero-posterior diameter of bone, 4 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 70%.

Structure.—External circumferential lamellæ form a wide ring around the bone. The lacunæ are oval with bushy, connecting canaliculi.

The central ring is composed of lamellæ and irregular Haversian systems of the (Ic) stage of development. There is very little difference in the structure of the various parts of the bone.

Internal circumferential lamellæ form a narrow ring around the medullary canal. Their lacunæ are narrow and long and their canaliculi are long and branching.

Type I-III, Ic.

FEMUR OF ASIO WILSONIANUS. LONG-EARED OWL

PL. 7, FIG. 106. SYN. TAB. III

Antero-posterior diameter of bone, 8 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 178%.

Structure.—The external circumferential lamellæ surround the section. Their lacunæ are long, numerous, and have very fine, long canaliculi. Here and there canals traverse the entire thickness of them all.

The central ring is composed of irregularly shaped Haversian system of the (Ic) stage of development, extending between which are numerous short canals. The lacunæ are oval, numerous, and have bushy canaliculi.

The internal circumferential lamellæ form a thick, heavy ring around the medullary canal. In the outer wall of the bone they tend to separate into laminæ. The whole ring of internal circumferential lamellæ forms about one-third of the thickness of the wall of the bone. It is traversed by many canals extending from the medullary canal into the canals of the Haversian systems. Their lacunæ are long and numerous and their canaliculi are bushy.

Type I-II-III, Ic.

RIGHT FEMUR OF BERNICLA CANADENSIS. WILD GOOSE

PL. 7, FIG. 107. SYN. TAB. III

Antero-posterior diameter of bone, 9 mm.; lateral, 8.5 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 178%.

Structure.—The external circumferential lamellæ surround the section. Their lacunæ are long and narrow and their canaliculi are rather few in number. At the posterior ridge are found many Haversian systems of the (Ic) differentiation. The anterior wall of the bone is composed of similar Haversian systems occupying the whole thickness of the wall between the external and internal circumferential lamellæ. The remainder of the bone shows quite different structures and arrangements in the different portions of the wall. Laminæ occupy the inner half of the wall, while Haversian systems of the (Ic) stage of development occupy the outer half and are situated under the external circumferential lamellæ.

The two halves are well marked and distinct from each other. The lacunæ of the systems and laminæ are oval and their canaliculi are few and short. The canals between the laminæ are irregular and branching. The internal circumferential lamellæ are well developed. In the inner wall of the bone quite large canals extend from the medullary canal through the laminæ to the Haversian canals between the laminæ.

Type II-III, Ic.

LEFT FEMUR OF LEPTOPTILOS SP. STORK. NO. 2827, AMER. MUS. NAT. HIST.

PL. 7, FIG. 108. SYN. TAB. III

Antero-posterior diameter of bone, 17 mm.; lateral, 15 mm.

Antero-posterior diameter of medullary canal, 14.5 mm.; lateral, 13.5 mm.

The medullary canal is empty. Medullary index, 327%.

Structure.—The section has the three divisions; the external circumferential lamellæ form a narrow ring around the section and have long lacunæ and straight canaliculi. The central ring is composed of Haversian systems of the (Ic) differentiation between which are canals and short fragments of lamellæ with oval lacunæ and bushy canaliculi. The internal circumferential lamellæ form a distinct, narrow ring around the medullary canal. Their lacunæ are long and canaliculi are straight.

Type I-III, Ic.

RIGHT FEMUR OF ANTHRACOCEROS MALABARICUS. HORN BILL. NO. 2887, AMER. MUS. NAT. HIST.

Pl. 7, Fig. 109. Syn. Tab. III

Antero-posterior diameter of bone, 6.5 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 5 mm.

The medullary canal is empty. Medullary index, 240%.

Structure.—The section has three divisions. The external circumferential lamellæ with long lacunæ and straight canaliculi form a distinct, narrow ring around the bone. The central ring is composed of lamellæ with round and oval lacunæ, interrupted by many canals and Haversian systems of the (Ic) stage. The internal circumferential lamellæ with long lacunæ form a narrow distinct ring around the medullary canal.

Type I-III, Ic.

FEMUR OF ASTUR ATRICAPILLUS. GOSHAWK. CR. MED. COLL.

Pl. 7, Fig. 110. Syn. Tab. III

Antero-posterior diameter of bone, 4 mm.; lateral, 4.3 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 3.3 mm.

The medullary canal is empty. Medullary index, 139%.

Structure.—The section is surrounded by external circumferential lamellæ, fairly well developed. Their lacunæ are more frequently oval than long. The canaliculi are bushy.

In the inner lateral posterior wall is a slight ridge to which are attached muscle tendons penetrating the external lamellæ. Underneath the external circumferential lamellæ is a thick ring of Haversian systems of the (Ic) stage of development. The ring is crossed at all angles by wide, irregular canals.

The medullary canal is enclosed by internal circumferential lamellæ with long lacunæ and canaliculi.

Type I-III, Ic.

LEFT FEMUR OF INOCOTIS PAPILLOSUS. IBIS. NO. 3178, AMER. MUS. NAT. HIST.

PL. 7, FIG. 111. SYN. TAB. III

Antero-posterior diameter of bone, 7 mm.; lateral, 6.5 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 5.5 mm.

Medullary index, 264%.

Structure.—The section shows the three divisions. External circumferential lamellæ form a narrow ring around the section. Their lacunæ are long and narrow. Underneath this ring is a wide central ring of lamellæ, Haversian systems, and canals. The lamellæ have oval lacunæ and bushy canaliculi. The Haversian systems are of the (Ic) stage of development. Around the medullary canal is a ring of lamellæ with long and narrow lacunæ.

Type I-III, Ic.

RIGHT FEMUR OF CATHARTES AURA. TURKEY-BUZZARD. NO. 70, CR. MED. COLL.

PL. 7, FIG. 112. SYN. TAB. III

Antero-posterior diameter of bone, 9.5 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 7.5 mm.; lateral, 7 mm.

The medullary canal is empty. Medullary index, 219%.

Structure.—The walls are very thin and hard. The usual three structural divisions are present. The external circumferential lamellæ form a narrow ring around the section excepting in the posterior ridge where a few tendon insertions displace them. Their lacunæ are long, narrow, and well developed. The central ring is composed of Haversian systems of the (Ic) differentiation. The lacunæ are some distance apart and their canaliculi are rather infrequent. The ring is crossed at all angles by canals. The internal circumferential lamellæ constitute a narrow ring around the medullary canal. Their lacunæ are well developed.

Type I-III, Ic.

IX. MAMMALS—BATS

Fifty-five femora were examined.

GENERAL CHARACTER OF THE FEMUR

The prevailing shape of the femur is elliptical. Several are round, and a few are plano-convex. The medullary canals are all full of marrow and one, *Desmodus rotundus,* is full of red marrow. No cancellous bone and no trabeculæ are found. The medullary surfaces are smooth or very slightly corrugated.

The medullary index varies from 12% to 178% with an average of 48.6%.

The type of structure is first. The bone substance is lamellated, the lacunæ are round, oval or long, and the canaliculi are bushy, short, or long. In some of the large bats of the Pteropus genus, Haversian canals of the (Ia) differentiation are present.

DETAILED EXAMINATION

RIGHT FEMUR OF MORMOOPS. NO. 102231, U. S. NAT. MUS.

PL. 8, FIG. 113. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.6 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 59%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF RHINOLOPHUS MEHELYI. NO. 84768, U. S. NAT. MUS.

PL. 8, FIG. 114. SYN. TAB. IV

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 64%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF STURNIRA LILIUM. NO. 115053, U. S. NAT. MUS.

PL. 8, FIG. 115. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.9 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 29%.

Structure.—The section is composed of concentric lamellæ with long, narrow lacunæ and long, straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF LONCHORHINA. NO. 173849, U. S. NAT. MUS.

PL. 8, FIG. 116. SYN. TAB. IV

Antero-posterior diameter of bone, 0.9 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF ROUSETTUS AMPLEXICAUDATUS. NO. 175844, U. S. NAT. MUS.

PL. 8, FIG. 117. SYN. TAB. IV

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 44%.

Structure.—The section is dimly separated into three concentric divisions, external, central, and internal. The external and central divisions have lamellæ with long, narrow lacunæ and straight canaliculi, while the internal division has lamellæ with oval lacunæ and bushy canaliculi. The bone shows the threefold division.

Type I.

RIGHT FEMUR OF HIPPOSIDEROS LARVATUS. NO. 152076, U. S. NAT. MUS.

PL. 8, FIG. 118. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi separated into external, central, and internal rings which surround the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF HEMIDERMA. NO. 123744, U. S. NAT. MUS.

PL. 8, FIG. 119. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF DESMODUS ROTUNDUS. NO. 114977, U. S. NAT. MUS.

PL. 8. FIG. 120. SYN. TAB. IV

Antero-posterior diameter of bone, 1.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 2 mm.

The medullary canal is full of red marrow. Medullary index, 129%.

Structure.—The section is flattened antero-posteriorly and is surrounded by external circumferential lamellæ. The central ring is widest and is composed of oval lacunæ with very delicate bushy canaliculi. The posterior wall has two ridges. In the outer ridge is a vascular canal. The bone shows the threefold division.

Type I.

LEFT FEMUR OF LEPTONYCTERIS. NO. 105129, U. S. NAT. MUS.

PL. 8, FIG. 121. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ divided into wide external and narrow internal rings. The external is composed of lamellæ with oval lacunæ and bushy canaliculi, and the internal, of lamellæ with long, narrow lacunæ and straight canaliculi. The bone has the twofold division.

Type I.

RIGHT FEMUR OF RHINOPOMA. (PALESTINE.) NO. 122140, U. S. NAT. MUS.

PL. 8, FIG. 122. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.9 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 29%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF EROPHYLLA BOMBIFRONS. NO. 86262, U. S. NAT. MUS.

PL. 8, FIG. 123. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF PHYLLOSTOMA HASTATUM. NO. 102906, U. S. NAT. MUS.

PL. 8, FIG. 124. SYN. TAB. IV

Antero-posterior diameter of bone, 2.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 64%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The lamellæ are dimly separated into wide external and narrow internal rings by a condensation of the lacunæ around the medullary canal. Twofold division.

Type I.

LEFT FEMUR OF EPOMOPHORUS WAHLBERGII. NO. 113451, U. S. NAT. MUS.

PL. 8, FIG. 125. SYN. TAB. IV

Antero-posterior diameter of bone, 2 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of lamellæ divided into three concentric rings. The external is narrow and composed of lamellæ with long lacunæ and straight canaliculi; the central is wide and consists of lamellæ with oval lacunæ and bushy canaliculi; and the internal is narrow and composed of lamellæ with long lacunæ and straight canaliculi. The bone shows the threefold division.

Type I.

LEFT FEMUR OF GLOSSOPHAGA ELONGATA. NO. 102107, U. S. NAT. MUS.

PL. 8, FIG. 126. SYN. TAB. IV

Antero-posterior diameter of bone, 0.9 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF NYCTALUS AVIATOR. NO. 102098, U. S. NAT. MUS.

PL. 8, FIG. 127. SYN. TAB. IV

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF SCOTOPHILUS HEATHII. NO. 13692, U. S. NAT. MUS.

PL. 8, FIG. 128. SYN. TAB. IV

Antero-posterior diameter of bone, 2 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1.2 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 65%.

Structure.—The section is divided into two rings, an external composed of lamellæ with oval lacunæ and bushy canaliculi, and an internal composed of lamellæ with long lacunæ and straight canaliculi. Twofold division.

Type I.

RIGHT FEMUR OF MINIOPTERUS SCHREIBERSII. NO. 152610, U. S. NAT. MUS.

PL. 8, FIG. 129. SYN. TAB. IV

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.7 mm.

Antero-posterior diameter of medullary canal, 0.3 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 64%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF PROMOPS FOSTERI. NO. 105676, U. S. NAT. MUS.

PL. 8, FIG. 130. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF VESPERTILIO MURINUS. NO. 5333, U. S. NAT. MUS.

PL. 8, FIG. 131. SYN. TAB. IV

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF MOLOSSUS NIGRICANS. NO. 8268, U. S. NAT. MUS.

PL. 8, FIG. 132. SYN. TAB. IV

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.7 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with long lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF DASYPTERUS INTERMEDIUS. NO. 22408, U. S. NAT. MUS.

Pl. 8, Fig. 133. Syn. Tab. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.9 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 29%.

Structure.—The section is composed of lamellæ divided into wide external and narrow internal rings. The external consists of lamellæ with oval lacunæ and straight canaliculi, and the internal, of lamellæ with long lacunæ and straight canaliculi. The bone has the twofold division.

Type I.

LEFT FEMUR OF MOLOSSUS MAJOR. NO. 101893, U. S. NAT. MUS.

Pl. 8, Fig. 134. Syn. Tab. IV

Antero-posterior diameter of bone, 0.6 mm.; lateral, 0.6 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi. Two divisions appear, external and internal. The external is wide and the internal is narrow. The concentric divisions surround the medullary canal. The bone shows a twofold division.

Type I.

LEFT FEMUR OF ANTROZOUS PALLIDUS. NO. 63386, U. S. NAT. MUS.

Pl. 8, Fig. 135. Syn. Tab. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.8 mm.; lateral, 0.8 mm.

The medullary canal is full. Medullary index, 178%.

Structure.—The section is thin-walled and composed of concentric lamellæ with oval and round lacunæ with bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF EUMOPS CALIFORNICUS. NO. 61387, U. S. NAT. MUS.

Pl. 8, Fig. 136. Syn. Tab. IV

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.9 mm.; lateral, 0.9 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi, divided into wide external and narrow internal rings. Twofold division.

Type I.

RIGHT FEMUR OF PLECOTUS AURITUS. NO. 152597, U. S. NAT. MUS.

PL. 8. FIG. 137. SYN. TAB. IV

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.7 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF NYCTICEIUS HUMERALIS. NO. 115141, U. S. NAT. MUS.

PL. 8, FIG. 138. SYN. TAB. IV

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.7 mm.

Antero-posterior diameter of medullary canal, 0.6 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 116%.

Structure.—The section is composed of a few concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF MYOTIS MYOTIS. NO. 86500, U. S. NAT. MUS.

PL. 8, FIG. 139. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF EPTESICUS BAHAMENSIS. NO. 121929, U. S. NAT. MUS.

PL. 8. FIG. 140. SYN. TAB. IV

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.7 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF NYCTERIS BOREALIS. NO. 101945, U. S. NAT. MUS.

PL. 8. FIG. 141. SYN. TAB. IV

Antero-posterior diameter of bone, 0.8 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF GLISCHROPUS TYLOPUS. NO. 142385, U. S. NAT. MUS.

PL. 8. FIG. 142. SYN. TAB. IV

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.4 mm.

Antero-posterior diameter of medullary canal, 0.3 mm.; lateral, 0.2 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The section is composed of lamellæ with round lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF NYCTERIS CINEREA. NO NUMBER, U. S. NAT. MUS.

PL. 8. FIG. 143. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi, divided into wide external and narrow internal rings which surround the medullary canal. The bone shows a twofold division.

Type I.

LEFT FEMUR OF PHYLLONYCTERIS. NO. 103501, U. S. NAT. MUS.

PL. 8. FIG. 144. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF MEGADERMA SPASMA. NO. 114272, U. S. NAT. MUS.

PL. 8, FIG. 145. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi. The lamellæ are divided into wide external and narrow internal rings which partly surround the medullary canal. The internal ring is limited to the lateral walls. The bone shows a partial twofold division.

Type I.

RIGHT FEMUR OF PTERONOTUS. NO. 113570, U. S. NAT. MUS.

PL. 8, FIG. 146. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF BALANTIOPTERYX PLICATA. NO. 142606, U. S. NAT. MUS.

PL. 8, FIG. 147. SYN. TAB. IV

Antero-posterior diameter of bone, 0.5 mm.; lateral, 0.5 mm.

Antero-posterior diameter of medullary canal, 0.3 mm.; lateral, 0.3 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of a few concentric lamellæ with round and oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

RIGHT FEMUR OF SACCOPTERYX. NO. 123800, U. S. NAT. MUS.

PL. 8, FIG. 148. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.4 mm.; lateral, 0.3 mm.

The medullary canal is full. Medullary index, 18%.

The bone is flat on the posterior side.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi surrounding the medullary canal. The bone is uniform.

Type I.

LEFT FEMUR OF PETALIA. NO. 154866, U. S. NAT. MUS.

PL. 8, FIG. 149. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.9 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

LEFT FEMUR OF MONOPHYLLUS. NO. 113677, U. S. NAT. MUS.

PL. 8, FIG. 150. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

LEFT FEMUR OF VAMPYROPS LINEATUS. U. S. NAT. MUS.

PL. 8, FIG. 151. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

RIGHT FEMUR OF CHILONYCTERIS. NO. 173842, U. S. NAT. MUS.

PL. 8, FIG. 152. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

RIGHT FEMUR OF CYNOPTERUS. NO. 141241, U. S. NAT. MUS.

PL. 8, FIG. 153. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

LEFT FEMUR OF ARTIBEUS PALMARUM. NO. 102866, U. S. NAT. MUS.

PL. 8, FIG. 154. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

LEFT FEMUR OF BRACHYPHYLLA. NO. 103251, U. S. NAT. MUS.

PL. 8, FIG. 155. SYN. TAB. IV

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

RIGHT FEMUR OF MACROGLOSSUS MINIMUS. NO. 171695, U. S. NAT. MUS.

PL. 8, FIG. 156. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 0.8 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The bone is uniform. Type I.

LEFT FEMUR OF TAPHOZOUS PHILIPPINENSIS. NO. 144851, U. S. NAT. MUS.

PL. 8, FIG. 157. SYN. TAB. IV

Antero-posterior diameter of bone, 1 mm.; lateral, 1 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi surrounding the medullary canal. The lamellæ are dimly separated into external and internal rings. Incomplete twofold division.

Type I.

RIGHT FEMUR OF CHEIROMELES TORQUATUS. NO. 102462, U. S. NAT. MUS.

PL. 8, FIG. 158. SYN. TAB. IV

Antero-posterior diameter of bone, 3.5 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 27%.

Structure.—The section is composed of concentric lamellæ with narrow lacunæ and long, straight canaliculi, divided into two distinct rings—external wide and internal narrow—which surround the medullary canal. The internal ring has very few lacunæ. Twofold division.

Type I.

RIGHT FEMUR OF NOCTILIO. NO. 49545, U. S. NAT. MUS.

PL. 8, FIG. 159. SYN. TAB. IV

Antero-posterior diameter of bone, 2 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 0.9 mm.

The medullary canal is full. Medullary index, 82%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ. In the outer wall there are a few minute canals surrounded by clear areas of bone substance, around which oval lacunæ with bushy canaliculi are assuming a partial concentric arrangement.

Type I-III, Ia.

LEFT FEMUR OF PTEROPUS MOLOSSINUS (SMALL). NO. 151561, U. S. NAT. MUS.

PL. 8, FIG. 160. SYN. TAB. IV

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.: lateral, 1.5 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—The section is composed of lamellæ with oval lacunæ and straight canaliculi indistinctly separated into three concentric rings. Incomplete threefold division.

Type I.

RIGHT FEMUR OF PTEROPUS MOLOSSINUS (LARGE). U. S. NAT. MUS.

PL. 8, FIG. 161. SYN. TAB. IV

Antero-posterior diameter of bone, 3 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 147%.

Structure.—The section is composed of lamellæ with long, narrow lacunæ and straight canaliculi enclosing the medullary canal. The lamellæ are divided into two rings, a narrow external and wide internal. In the inner wall the lamellæ are interrupted by a few canals of the (Ia) differentiation. The femur shows a little advancement. Twofold division.

Type I-III, Ia.

RIGHT FEMUR OF PTEROPUS ALDABRENSIS. NO. 20989, U. S. NAT. MUS.

PL. 8. FIG. 162. SYN. TAB. IV

Antero-posterior diameter of bone, 2 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 43%.

Structure.—The section is composed of concentric lamellæ with oval and long lacunæ and straight canaliculi interrupted by a few crude, undeveloped Haversian systems of the (Ia) differentiation.

Type I-III, Ia.

RIGHT FEMUR OF PTEROPUS. (CELEBES.) NO. 172460, U. S. NAT. MUS.

PL. 8. FIG. 163. SYN. TAB. IV

Antero-posterior diameter of bone, 4 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—The section is composed of a wide external band of lamellæ divided into two nearly equal concentric rings by longitudinal canals of the (Ia) differentiation. The lacunæ are oval and narrow and the canaliculi are straight. Internal circumferential lamellæ with long lacunæ and straight canaliculi surround the medullary canal.

Type I-III, Ia.

RIGHT FEMUR OF PTEROPUS. (JAVA.) NO. 12616, U. S. NAT. MUS.

PL. 8. FIG. 164. SYN. TAB. IV

Antero-posterior diameter of bone, 3 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 91%.

Structure.—The section is composed of concentric lamellæ with oval and long lacunæ and straight canaliculi, interrupted by many very crude Haversian systems of the (Ia) differentiation.

Type I-III, Ia.

RIGHT FEMUR OF PTEROPUS LEPICOS. NO. 112404, U. S. NAT. MUS.

PL. 8, FIG. 165. SYN. TAB. IV

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The section is composed of concentric lamellæ with oval and long lacunæ and straight canaliculi crossed by numerous radiating canals. Here and there a few very crude Haversian systems of the (Ia) differentiation are seen. The bone is uniform.

Type I-III, Ia.

RIGHT FEMUR OF PTEROPUS. (TONGATABU.) NO. 173884, U. S. NAT. MUS.

PL. 8, FIG. 166. SYN. TAB. IV

Antero-posterior diameter of bone, 3 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and straight canaliculi, partially separated by undeveloped Haversian systems of the (Ia) differentiation into two laminæ. The systems occupy a central concentric position. The bone has a twofold division.

Type I-III, Ia.

RIGHT FEMUR OF PTEROPUS POLIOCEPHALUS. U. S. NAT. MUS.

PL. 9. FIG. 167. SYN. TAB. IV

Antero-posterior diameter of bone, 3.5 mm.; lateral, 3.5 mm.

Antero-posterior diameter of medullary canal, 2 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 49%.

Structure.—The section has the three concentric divisions, external, central, and internal. The lacunæ are oval and the canaliculi are straight. In the central division or ring are found numerous Haversian canals situated nearer to the internal than to the external division. The canals run parallel with the medullary canal. They are surrounded by clear areas of bone substance which are crossed radially by very fine canaliculi from adjacent lacunæ. The canals with their canaliculi and lacunæ are crude outlines of Haversian systems of the (Ia) differentiation. The bone has the threefold division.

Type I-III, Ia.

X. OTHER MAMMALS NOT INCLUDING MAN

One hundred and thirty-three femora were examined.

General Character of the Femur

The general shape of the femur varies very considerably. Some bones are triangular, many elliptical, some round, some indeterminate, and a few are plano-convex. The majority of them are elliptical.

The medullary canals, with one or two exceptions, are full of marrow, and a large number have cancellous bone, the meshes of which are filled with marrow. The medullary surfaces are generally rough or irregularly corrugated. The medullary index varies from 9% to 289% with an average of 63.3%.

The type of structure varies greatly. Nearly all types and type combinations in their various stages of differentiation are found. The bone units of monotremes and marsupials present an earlier differentiation than the higher mammals.

The first type bone is present in many genera and may be associated with the undeveloped third type of the (Ia) differentiation. A number of mammalian femora present a well marked second type structure. The laminæ are much better developed than in birds. In most of these bones Haversian systems are found to the greatest extent in the posterior ridges. The pure third type of the (C) differentiation occurs only in a few mammals. Of these the African elephant is the best example. The majority of mammalian femora exhibit type combinations. These may be first and third, second and third, or first, second, and third in some form of differentiation. The majority are composed of the first and third types.

Detailed Examination

LEFT FEMUR OF TUPAIA. TREE-SHREW. AMER. MUS. NAT. HIST.

Pl. 9, Fig. 168. Syn. Tab. V

Antero-posterior diameter of bone, 3 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 2 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 67%.

Structure.—With the exception of a few small and poorly developed Haversian systems of the (Ib) differentiation in the posterior and inner walls, the section is composed of lamellæ with oval lacunæ and straight canaliculi. The specimen shows very little differentiation of structure. The bone is uniform.

Type I.

RIGHT FEMUR OF ECHIDNA. EGG-LAYING MAMMAL. NO. 17355, AMER. MUS. NAT. HIST.

PL. 9. FIG. 169. SYN. TAB. V

Antero-posterior diameter of bone, 6 mm.; lateral, 11.5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 6.5 mm.

The medullary canal is full. Medullary index, 49%.

Structure.—A few primitive Haversian systems of the (Ib) differentiation are found in the inner and outer walls. The section, for the most part, is composed of basic bone substance with round and oval lacunæ and bushy canaliculi, crossed at various angles by branching canals. Around the medullary canal the lacunæ are longer and the lamellæ denser than elsewhere. In the outer wall of the medullary canal cancellous bone occurs. The bone shows some departure from the first type by its crude Haversian systems.

Type I.

LEFT FEMUR OF ORNITHORHYNCHUS. DUCK BILL. EGG-LAYING MAMMAL. NO. 13354 U. S. NAT. MUS.

PL. 9, FIG. 170. SYN. TAB. V

Antero-posterior diameter of the bone, 4 mm.; lateral, 5 mm.

Antero-posterior diameter of the medullary canal, 2.5 mm.; lateral, 3.5 mm.

The medullary canal is full. Medullary index, 79%.

Structure.—The section is divided about equally into two concentric parts or rings not separated by any well marked boundary. The external half is composed of basic bone substance with a great many oval and round lacunæ and short, bushy canaliculi. In some places, as in the outer and inner ridges, crude Haversian systems appear. Wide canals arranged transversely, obliquely, and concentrically occur at frequent intervals. The internal half consists of lamellæ with long lacunæ and canaliculi, interrupted in the outer wall by Haversian systems of the (Ib) differentiation. The lamellæ are crossed by canals, and in the anterior wall the canals run concentrically.

Type I-III, Ib.

LEFT FEMUR OF CAVIA CUTLERI. GUINEA PIG. AMER. MUS. NAT. HIST.

Pl. 9, Fig. 171. Syn. Tab. V

Antero-posterior diameter of bone, 6 mm.; lateral, 4 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 3 mm.

The medullary canal is full. Medullary index, 100%.

Structure.—The three divisions are plainly marked. The external circumferential lamellæ with long lacunæ and straight canaliculi form a narrow ring around the bone. The central ring consists of basic bone substance with round and oval lacunæ and bushy canaliculi, interrupted by poorly developed Haversian systems of the (Ia) differentiation and crossed by radiating canals. In the posterior wall the ring consists of crude Haversian systems between which is bone substance with oval lacunæ and bushy canaliculi.

The internal circumferential lamellæ form a narrow ring around the medullary canal. The bone shows a threefold division.

Type I-III, Ia.

LEFT FEMUR OF SCALOPUS AQUATICUS. MOLE. AMER. MUS. NAT. HIST.

Pl. 9, Fig. 172. Syn. Tab. V

Antero-posterior diameter of bone, 1.5 mm.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—The section is composed of lamellæ with long and oval lacunæ and straight canaliculi, partially separated into two equal, concentric rings by concentric, branching canals and crossed at various angles by radiating canals. In the posterior wall the lamellæ are crude Haversian systems of the (Ib) differentiation.

Type I-III, Ib.

RIGHT FEMUR OF SOREX. SHREW. AMER. MUS. NAT. HIST.

Pl. 9, Fig. 173. Syn. Tab. V

Antero-posterior diameter of bone, 3 mm.; lateral, 3.3 mm.

Antero-posterior diameter of medullary canal, 1.2 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 22%.

Structure.—The section is composed of bone substance with oval lacunæ and bushy canaliculi, frequently interrupted by primitive Haversian systems of the (Ib) differentiation and crossed by canals. In some places fragments of external circumferential lamellæ appear. In the posterior wall is a group of oval lacunæ with short, bushy canaliculi.

The bone shows but little differentiation of structure. It is uniformly of an early differentiation.

Type I-III, Ib.

RIGHT FEMUR OF MACROPUS. WALLABY. NO. 22810, AMER. MUS. NAT. HIST.

PL. 9, FIG. 174. SYN. TAB. V

Antero-posterior diameter of bone, 14 mm.; lateral, 14 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 10.5 mm.

The medullary canal is full. Medullary index, 115%.

Structure.—The section is composed of lamellæ with oval long lacunæ and straight canaliculi, interrupted in the posterior wall by vascular canals and crude Haversian systems, and elsewhere by frequent radiating canals and Haversian systems of the (Ia) differentiation. It is indistinctly laminated.

Type I-III, Ia.

LEFT FEMUR OF SOLENODON PARADOXUS (YOUNG). AMER. MUS. NAT. HIST.

PL. 9, FIG. 175. SYN. TAB. V

Antero-posterior diameter of bone, 5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 3.5 mm.

The medullary canal is full. Medullary index, 165%.

Structure.—The section is composed of lamellæ with round and oval lacunæ and bushy canaliculi, frequently interrupted by Haversian systems of the (Ia) and (Ib) differentiation and crossed by many oblique and radiating canals which take their origin in the medullary canal. The bone shows a very incomplete differentiation.

Type I-III, Ia, Ib.

RIGHT FEMUR OF SOLENODON PARADOXUS (ADULT). AMER. MUS. NAT. HIST.

PL. 9, FIG. 176. SYN. TAB. V

Antero-posterior diameter of bone, 6.5 mm; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 3.5 mm.

The medullary canal is full. Medullary index, 94%.

Structure.—The section shows the three divisions. The external circumferential lamellæ form a distinct ring around the section. It is widest in the inner wall. The lacunæ are long and the canaliculi are bushy and straight. The central ring is composed of lamellæ with oval lacunæ and bushy canaliculi, interrupted by crude Haversian systems of the (Ia) and (Ib) differentiations. The section is nearly all lamellæ. The internal circumferential lamellæ form a fragmentary ring around the medullary canal. Their lacunæ are oval and straight and the canaliculi are straight.

Type I-III, Ia, Ib.

FEMUR OF LEMUR MONGOZ. NO. 86849, U. S. NAT. MUS.

Pl. 9, Fig. 177. Syn. Tab. V

Antero-posterior diameter of bone, 9 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 100%.

Structure.—The section is composed of lamellæ with long lacunæ and straight canaliculi, divided into wide external and narrow internal rings. The lamellæ of the external ring are interrupted by small and rather crude Haversian systems of the (Ib) differentiation and by vascular canals which occupy a concentric position in the wall of the bone. The internal ring of lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal. The bone has the twofold division.

Type I-III, Ib.

LEFT FEMUR OF COLOBUS ABYSSINICUS CAUDATUS. NO. 27711, AMER. MUS. NAT. HIST.

Pl. 9, Fig. 178. Syn. Tab. V

Antero-posterior diameter of bone, 12.5 mm.; lateral, 13 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 43%.

Structure.—The section is composed of a very wide band of external circumferential lamellæ, interrupted by numerous very crude Haversian systems of the (Ia) and (Ib) differentiations. The band forms nearly the whole width of the wall of the bone. In the posterior wall the lamellæ are displaced by small undeveloped Haversian systems and in the outer wall a narrow crescent of Haversian systems of the (C) stage appears just external to the internal circumferential lamellæ.

Internal circumferential lamellæ surround the medullary canal. Generally the lacunæ are long and narrow and the canaliculi are straight, but in the posterior wall the lacunæ are oval. The bone shows the twofold division.

Type I-III, Ia, Ib, C.

FEMUR OF PUTORIUS VULGARIS. WEASEL. CR. MED. COLL.

Pl. 9, Fig. 179. Syn. Tab. V

Antero-posterior diameter of the bone, 1.5 mm.; lateral, 2 mm.

Antero-posterior diameter of the medullary canal, 1 mm.; lateral, 1.5 mm.

The medullary canal contains a very thin layer of marrow around the walls of the bone. Medullary index, 62%.

Structure.—The section is composed of lamellæ with long and narrow lacunæ and long, straight canaliculi. In the outer wall the lamellæ are interrupted by irregularly shaped whorls of oval and round lacunæ closely packed together in the bone substance. The canaliculi are short and bushy. In one of these whorls a central canal appears and the whole figure resembles slightly a crude Haversian system. A few large canals cross the section radially on their way from the medullary canal to the external surface. The bone is uniform.

Type I.

FEMUR OF MUS RATTUS. RAT. CR. MED. COLL.

PL. 9, FIG. 180. SYN. TAB. V

Antero-posterior diameter of bone, 2.5 mm.; lateral, 3.5 mm.

Antero-posterior diameter of the medullary canal, 1.5 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 75%.

Structure.—The section is composed of two concentric rings of about equal width surrounding the medullary canal. The external ring is composed of lamellæ with long lacunæ and long, branching canaliculi. Here and there cross canals appear. The internal ring is composed of short lamellæ, laminæ, and a few incomplete Haversian systems of the (Ib) differentiation, separated by a network of canals. The lacunæ are oval and round and the canaliculi are bushy. The internal circumferential lamellæ are so blended with the other structures of the internal ring that they are poorly defined.

Type I-III, Ib.

LEFT FEMUR OF HETEROMYS. SPINY POCKET RAT. AMER. MUS. NAT. HIST.

PL. 9, FIG. 181. SYN. TAB. V

Antero-posterior diameter of bone, 4.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 153%.

Structure.—The anterior and inner walls are composed of lamellæ with long and oval lacunæ and straight canaliculi, crossed radially by frequent canals. The posterior wall is composed of rather crude Haversian systems with oval lacunæ and bushy canaliculi, and the outer wall of lamellæ with oval lacunæ and bushy canaliculi, interrupted by crude Haversian systems of the (Ia) and (Ib) differentiations and crossed by canals. The internal circumferential lamellæ are not distinct. The bone shows but little differentiation of structure.

Type I-III, Ia, Ib.

RIGHT FEMUR OF MYOGALE MOSCHATA. DESMAN. CR. MED. COLL.

Pl. 9, Fig. 182. Syn. Tab. V

Antero-posterior diameter of bone, 5 mm.; lateral, 6.5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 3 mm.

Medullary canal has no contents. Medullary index, 30%.

Structure.—The inner wall of the bone is extended in the form of a ridge, which is composed of a network of laminæ and canals running transversely and occupying the outer four-fifths of the ridge. Each lamina is composed of lamellæ with long or oval lacunæ and long branching or bushy canaliculi. The inner one-fifth of the ridge wall is composed of a network of laminæ running from the medullary canal to the outer network. The remainder of the bone (anterior, outer, and posterior wall) is composed of a very irregular, wide internal ring of lamellæ surrounding the medullary canal and having an outer wavy border, in some places distinct and in other places fused with an external network of laminæ. Many canals cross the lamellæ on their way from the medullary canal to the middle of the wall. Within the lamellar ring are several round or elliptical bodies composed of lamellæ running lengthwise of the cross-section. These bodies are such as would result from a transverse section of solid pillars. In the outer wall of the bone lamellæ form the entire thickness. Here and there occur a few incomplete Haversian systems consisting of a central canal and radiating canaliculi. Twofold division.

Type I-II-III, Ib.

FEMUR OF CYNOMYS LUDOVICIANUS. PRAIRIE DOG. CR. MED. COLL.

Pl. 9, Fig. 183. Syn. Tab. V

Antero-posterior diameter of bone, 4.5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 3 mm.

The medullary canal is empty. Medullary index, 50%.

Structure.—The section is composed of external circumferential lamellæ forming an irregular ring which reaches its greatest width in the inner wall. The lacunæ are long and narrow and the canaliculi are long.

The central ring is composed of incomplete Haversian systems of the (Ib) differentiation. Their lamellæ are indistinct, their lacunæ are oval, and their canaliculi are bushy.

A very wide ring of internal circumferential lamellæ surrounds the medullary canal. The ring is widest in the anterior wall. Their lacunæ are long and narrow and their canaliculi are long. Numerous canals pass from the medullary canal across the lamellæ into the interior of the bone.

Type I-III, Ib.

LEFT FEMUR OF TRICHOSURUS VULPECULA. PHALANGER. NO. 22804, AMER. MUS. NAT. HIST.

PL. 9, FIG. 184. SYN. TAB. V

Antero-posterior diameter of bone, 7 mm.; lateral, 7.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 61%.

Structure.—The section is composed of lamellæ with long lacunæ and straight canaliculi, interrupted by a few Haversian systems of the (Ia) and (Ib) differentiations and crossed radially by vascular canals.

The bone shows very little differentiation of structure. The bone is uniform.

Type I-III, Ia, Ib.

LEFT FEMUR OF PHASCOLOMYS URSINUS. WOMBAT. AMER. MUS. NAT. HIST.

PL. 9, FIG. 185. SYN. TAB. V

Antero-posterior diameter of bone, 11.5 mm.; lateral, 13 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 11%.

Structure.—The section is composed of several concentric rings of lamellæ with long lacunæ and straight canaliculi surrounding the medullary canal.

The rings of lamellæ are separated by small, crude Haversian systems of the (Ia) and (Ib) differentiations and crossed radially by many canals. The posterior ridge is double. The two ridges are composed of very crude Haversian systems and inter-Haversian lamellæ. Between them and forming the posterior wall the structure is the same as elsewhere.

The lacunæ are long and oval and the canaliculi are long, straight, or bushy. The bone shows but little differentiation of structure.

Type I-III, Ia, Ib.

RIGHT FEMUR OF LASIOPYGA KOLBI. AFRICAN MONKEY. NO. 27719, AMER. MUS. NAT. HIST.

PL. 9, FIG. 186. SYN. TAB. V

Antero-posterior diameter of bone, 8.5 mm.; lateral, 10 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 98%.

Structure.—The section is composed of concentric lamellæ with oval lacunæ and bushy canaliculi, interrupted by small crude Haversian systems of the (Ia) and (Ib) differentiation enclosing the medullary canal. A few fairly well developed Haversian systems appear in the inner wall and several are found in the posterior wall. The bone is uniform.

Type I-III, Ia, Ib.

RIGHT FEMUR OF TRAGULUS JAVANICUS. JAVA MOUSE-DEER. NO. 14128, AMER. MUS. NAT. HIST.

PL. 10. FIG. 187. SYN. TAB. V

Antero-posterior diameter of bone, 7.5 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 289%.

Structure.—The section is composed of lamellæ with long lacunæ and straight canaliculi incompletely separated into laminæ, interrupted by a few Haversian systems of the (Ia) and (C) differentiations and crossed by canals. In the posterior wall Haversian systems are most numerous. The lacunæ are long and oval. The bone shows but little differentiation of structure.

Type II-III, Ia, C.

RIGHT FEMUR OF MUS SYLVATICUS. WOOD MOUSE. CR. MED. COLL.

PL. 10. FIG. 188. SYN. TAB. V

Antero-posterior diameter of bone, 2 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—The section is composed of lamellæ with round, oval, and long lacunæ and bushy canaliculi, separated into short bands which extend spirally, concentrically, and radially along the walls. Here and there a few crude Haversian systems appear.

Type I-III, Ib.

LEFT FEMUR OF ERINACEUS EUROPÆUS. HEDGEHOG. AMER. MUS. NAT. HIST.

PL. 10. FIG. 189. SYN. TAB. V

Antero-posterior diameter of bone, 3 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 2 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—With the exception of the anterior wall, the section is surrounded by bone substance with oval lacunæ and bushy canaliculi.

The body of the section is composed of bone substance with oval lacunæ and bushy canaliculi in which are Haversian systems of the (Ib) differentiation. In the anterior wall is a narrow concentric lamina. The posterior wall is very much extended and composed of cancellous bone substance with oval lacunæ. The internal circumferential lamellæ are absent.

Type I-III, Ib.

RIGHT FEMUR OF VIVERRA. CIVET. AMER. MUS. NAT. HIST.

PL. 10, FIG. 190. SYN. TAB. V

Antero-posterior diameter of bone, 8 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—The section has three divisions. A wide ring of lamellæ, dimly separated into concentric parts and frequently interrupted by Haversian systems of the (Ia) differentiation, forms the greater part of the bone. The lacunæ are oval and the canaliculi are bushy and straight. Underneath this is a long crescent of Haversian systems of the (Ib) differentiation surrounding the section with the exception of the inner wall. The systems are separated by bone substance with round lacunæ and bushy canaliculi.

A narrow ring of lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal.

Type I-III, Ia, Ib.

RIGHT FEMUR OF RATUFA MAXIMA. GIANT SQUIRREL. NO. 22839, AMER. MUS. NAT. HIST.

PL. 10, FIG. 191. SYN. TAB. V

Antero-posterior diameter of bone, 5.5 mm.; lateral, 6.5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—The section is surrounded by a wide ring of lamellæ with long lacunæ and straight canaliculi, interrupted by Haversian systems of the (Ia) differentiation. In the posterior and outer wall is a narrow ring of small Haversian systems of the (Ib) differentiation. The internal circumferential lamellæ are not distinct.

Type I-III, Ia, Ib.

FEMUR OF GALEOPITHECUS. FLYING LEMUR. NO. 49640, U. S. NAT. MUS.

PL. 10. FIG. 192. SYN. TAB. V

Antero-posterior diameter of bone, 6.5 mm.; lateral, 5.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 3.5 mm.

The medullary canal is full. Medullary index, 64%.

Structure.—The section is composed of a wide ring of external circumferential lamellæ with long lacunæ and straight canaliculi, frequently interrupted by small, crude Haversian systems of the (Ia) differentiation. The lamellæ form the whole thickness of the anterior wall with the exception of the internal circumferential lamellæ.

The internal circumferential lamellæ, with a long, narrow crescent of Haversian systems of the (Ib) differentiation, especially in the posterior and adjacent lateral wall, surround the medullary canal.

Type I-III, Ia, Ib.

LEFT FEMUR OF MANIS. SCALY ANT-EATER. AMER. MUS. NAT. HIST.

PL. 10. FIG. 193. SYN. TAB. V

Antero-posterior diameter of bone, 7.5 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 74%.

Structure.—The three divisions appear indistinctly marked. The external circumferential lamellæ with long lacunæ and straight canaliculi form a wide band around the section. They are interrupted by crude Haversian systems of the (Ia) differentiation and crossed by canals which assume a radial direction. Under this band is a narrow ring of lamellæ with oval lacunæ and bushy canaliculi. Beneath this again is a narrow ring of Haversian systems of the (Ib) differentiation. The lacunæ are oval and long and the canaliculi are bushy.

Internal circumferential lamellæ form a narrow ring around the medullary canal. Their lacunæ are oval. In the outer wall tendon insertions and crude systems are found. Threefold division.

Type I-III, Ia, Ib.

RIGHT FEMUR OF PROCAVIA CAPENSIS. CONEY. NO. 35326, AMER. MUS. NAT. HIST.

PL. 10, FIG. 194. SYN. TAB. V

Antero-posterior diameter of bone, 7.5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 25%.

Structure.—The external circumferential lamellæ form a narrow boundary of the posterior wall and then gradually widen to form the whole of the anterior wall. They are interrupted by Haversian systems of the (Ia) differentiation.

Their lacunæ are long and their canaliculi are straight. In the posterior half of the section the central ring borders the medullary surface of the posterior and inner wall and is discontinued as it reaches the anterior wall. It is composed of well developed Haversian systems. Internal circumferential lamellæ form a broken ring around the medullary canal.

Type I-III Ia, C.

LEFT FEMUR OF HELICTIS ORIENTALIS. ASIATIC BADGER. NO. 31806, AMER. MUS. NAT. HIST.

PL. 10. FIG. 195. SYN. TAB. V

Antero-posterior diameter of bone, 5.5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of medullary canal, 3.2 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 129%.

Structure.—The section is composed of lamellæ frequently interrupted by Haversian systems and crossed by canals. The lamellæ have oval and long lacunæ and straight and bushy canaliculi.

Type I-III, C.

RIGHT FEMUR OF CYNOCEPHALUS. BABOON. NO. 35120, AMER. MUS. NAT. HIST.

PL. 10. FIG. 196. SYN. TAB. V

Antero-posterior diameter of bone, 16 mm.; lateral, 16 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 64%.

Structure.—The section is composed of a wide ring of external lamellæ, interrupted by small, crude Haversian systems of the (Ia) differentiation and by large spaces. The lacunæ are long and oval with long canaliculi. The ring forms nearly the whole width of the wall. Around the medullary canal the internal circumferential lamellæ form an enclosing ring which is partly cancellous. A few Haversian systems occur between the internal and external lamellæ. In the posterior ridge Haversian systems, separated by lamellæ with oval lacunæ, constitute the structure.

Type I-III, Ia, Ib.

RIGHT FEMUR OF CYNOCEPHALUS MAIMON. MANDRILL. NO. 22817, AMER. MUS. NAT. HIST.

PL. 10. FIG. 197. SYN. TAB. V

Antero-posterior diameter of bone, 13 mm.; lateral, 11.5 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 8 mm.

The medullary canal is full. Medullary index, 75%.

Structure.—The section is composed of two parts: a wide external circumferential ring of lamellæ, interrupted by a few crude Haversian systems of the (Ia) and (Ib) differentiations, and a narrower internal ring of cancellous bone. The lacunæ are long and oval and their canaliculi are straight. The bone shows but little differentiation of structure.

Type I-III, Ia, Ib.

RIGHT FEMUR OF HYDROCHŒRUS CAPYBARA. NO. 35325, AMER. MUS. NAT. HIST.

PL. 10, FIG. 198. SYN. TAB. V

Antero-posterior diameter of bone, 22 mm.; lateral, 20 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 48%.

Structure.—The section is surrounded by a narrow ring of Haversian systems and inter-Haversian lamellæ. The central ring, confined to the outer wall, is composed of crude Haversian systems of the (Ib) differentiation, between which are lamellæ with large, oval lacunæ and bushy canaliculi in the outer wall, and lamellæ with oval lacunæ and bushy canaliculi interrupted by canals of the (Ia) differentiation in the inner and anterior wall. The internal circumferential lamellæ form a narrow ring round the medullary canal. The lacunæ are oval.

Type I-III, Ia, Ib.

FEMORA OF FETAL SHEEP, CALF, AND PIG—HALF TIME

RIGHT FEMUR OF FETAL SHEEP, 11 WEEKS. NO. 93, CR. MED. COLL.

PL. 11, FIG. 199. SYN. TAB. V

Antero-posterior diameter of bone, 3.5 mm,; lateral, 4 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 1 mm.

The medullary canal is full. Medullary index, 8%.

Structure.—The section is composed of short, wide, irregular laminæ with oval lacunæ and bushy canaliculi, between which are short, wide, irregular communicating canals. The section is pretty uniform in structure. A few Haversian systems of the (Ib) differentiation are present in the posterior wall. This femur is about one-half of the full fetal term and may be compared with the human femur of 4 to 5 months.

Type II-III, Ib.

RIGHT FEMUR OF FETAL CALF, 18 WEEKS. NO. 94, CR. MED. COLL.

PL. 11, FIG. 200. SYN. TAB. V

Antero-posterior diameter of bone, 12 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 18%.

Structure.—The bone is half fetal development. It is composed of small, very irregular areas of laminæ separated by many canals of bizarre shapes. Around the circumferential fourth of the bone the canals are elongated and the laminæ have assumed a general concentric arrangement. In the medullary three-fourths there is no definite plan of arrangement. The laminæ are composed of oval and long lacunæ with rather infrequent canaliculi. Here and there, and especially in the posterior ridge, some laminæ have widened, shortened, and assumed in part the shape of Haversian systems.

Type II-III, Ib.

RIGHT FEMUR OF A FETAL PIG, HALF FETAL PERIOD—8½ WEEKS.

PL. 11, FIG. 201. SYN. TAB. V

Antero-posterior diameter of bone, 3.5 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1 mm.

The medullary canal is situated eccentrically. The anterior wall is thinnest, the posterior thickest.

The medullary canal is full. Medullary index, 17%.

Structure.—The section is composed of concentric laminæ separated and crossed by wide canals. In the anterior wall the laminæ are short, in the lateral wall, long, and in the posterior wall, irregular. There are no Haversian systems, although in the posterior wall the laminæ are very short and inclined to a circular bend. The lacunæ are oval and the canaliculi are bushy.

Type II.

FEMUR OF CARIACUS MACROTIS. DEER. CR. MED. COLL.

PL. 11, FIG. 202. SYN. TAB. V

Antero-posterior diameter of bone, 25 mm.; lateral, 24 mm.

Antero-posterior diameter of the medullary canal, 17 mm.; lateral, 16.5 mm.

The medullary canal is full. Medullary index, 88%.

Structure.—The bone is composed almost entirely of laminæ. They are well developed, separated, and crossed by wide canals. Their lacunæ are long, narrow, and completely developed and the canaliculi are long and branching. Here and there are found a few aberrant Haversian systems, produced by a circular widening of the concentric canals and the bending of a few lamellæ around the circular openings. The laminæ form the entire section, excepting the posterior ridge and a small area near the anterior wall which are composed of Haversian systems with many oval lacunæ. There are no distinct external circumferential lamellæ. The canals between the laminæ cross them at right angles and communicate freely with each other.

The internal circumferential laminæ form an irregularly shaped boundary of the medullary canal. They are frequently crossed by canals extending outward from the medullary canal. The surface of the posterior ridge shows the tendon attachments of muscles. Extending from this surface to the internal circumferential laminæ, and for a short distance on either side of the posterior mid-line, is an area of Haversian systems. They are irregular in shape, well developed for the most part, separated by bone substance with oval lacunæ and bushy canaliculi, and surrounded by a coarse network of canals. Their lacunæ are long and narrow, generally. A few, however, show round or oval lacunæ with short, bushy canaliculi. The bone is uniform.

Type II-III, C.

FEMUR OF SUS. DOMESTIC PIG. CR. MED. COLL.

PL. 11, FIG. 203. SYN. TAB. V

Antero-posterior diameter of bone, 21.5 mm.; lateral, 18.5 mm.

Antero-posterior diameter of medullary canal, 16.5 mm.; lateral, 12.5 mm.

The medullary canal is full. Medullary index, 108%.

Structure.—The bone, with the exception of the posterior wall, is composed of concentric laminæ. The laminæ are separated and crossed by wide canals which frequently communicate with each other. The separating canals, here and there, widen into circular areas which are surrounded by incompletely developed concentric lamellæ and form aberrant Haversian systems. The laminæ are long or short and strongly developed. They have long, narrow lacunæ and branching canaliculi. In the posterior wall are two areas of well developed Haversian systems separated by an intermediate wall of laminæ. These are the only regular systems of the section.

The femur of the adult pig is second type with two areas of Haversian systems in the posterior wall. This bone, therefore, is essentially second in type as it emerges from the fetal stage, and, for the most part, remains second in the adult.

Type II-III, C.

RIGHT FEMUR OF SUS SCROFA. WILD BOAR. (ARKANSAS.) CR. MED. COLL.

PL. 11, FIG. 201. SYN. TAB. V

Antero-posterior diameter of bone, 23 mm.; lateral, 20 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 13 mm.

The medullary canal is full. Medullary index, 74%.

Structure.—The bone is composed of concentric laminæ crossed and divided into short segments by canals. The laminæ are composed of lamellæ with long narrow lacunæ and straight canaliculi.

In the posterior wall are two ridges separated by the intervening portion of the posterior wall. These ridges are composed of well developed Haversian systems which occupy the whole thickness of the wall from the external laminæ to the internal. Between the ridges the posterior wall is composed of laminæ alternating with Haversian systems in concentric rows. About the middle of the lateral walls on both sides of the two ridges, crude Haversian systems are extended for some distance between the laminæ. The lacunæ of all units are well developed.

Type II-III, C.

FEMUR OF ALCES MACHLIS. ELK. CR. MED. COLL.

PL. 11, FIG. 205. SYN. TAB. V

Antero-posterior diameter of bone, 35 mm.; lateral, 33 mm.

Antero-posterior diameter of medullary canal, 23 mm.; lateral, 20 mm.

The medullary canal is full. Medullary index, 66%.

Structure.—A ring of external circumferential lamellæ surrounds the bone. Their lacunæ are long and narrow and their canaliculi are long and branching. The central ring, constituting the greater part of the bone, is composed of fully developed laminæ separated by concentric canals and interrupted at short intervals by completely developed Haversian systems. The laminæ are frequently transected by the canals, which freely communicate with each other. They are composed of lamellæ with long, narrow lacunæ and branching canaliculi. They have the appearance of a strong development. The canals are wide and in some places have widened into Haversian canals.

The Haversian systems have long, narrow lacunæ and long branching canaliculi. The Haversian canals are large, round or oval in shape, and freely communicate with each other. Beginning in the posterior wall, and extending around the outer wall, nearly to the anterior mid-line, and occupying a position next to the internal circumferential lamellæ, is a narrow zone of Haversian systems. Another group is found near the surface of the anterior wall, and near the medullary canal are several large vascular canals surrounded by lamellæ.

Type II-III, C.

RIGHT FEMUR OF CAMELUS. CAMEL. NO. 35379, AMER. MUS. NAT. HIST.

PL. 11, FIG. 206. SYN. TAB. V

Antero-posterior diameter of bone, 51 mm.; lateral, 50 mm.

Antero-posterior diameter of medullary canal, 35 mm.; lateral, 35 mm.

The medullary canal is full. Medullary index, 93%.

Structure.—The section is composed of concentric laminæ crossed by numerous canals. Their lacunæ are oval and long and their canaliculi are bushy and straight. Near the medullary border the laminæ are interrupted by numerous irregularly shaped spaces. The posterior ridge is composed of Haversian systems of the (Ib) differentiation. Around the medullary surface these are separated by large, irregularly shaped spaces.

Type II-III, Ib.

RIGHT FEMUR OF AUCHENIA GLAMA. LLAMA. NO. 36363, AMER. MUS. NAT. HIST.

PL. 11. FIG. 207. SYN. TAB. V

Antero-posterior diameter of bone, 25 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal. 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index. 69%.

Structure.—The section is composed of short and long concentric laminæ with long lacunæ and straight canaliculi, separated and crossed by canals and frequently interrupted by small Haversian systems of the (Ib) differentiation. The posterior ridge is composed of Haversian systems. Around the medullary canal are many irregularly shaped spaces.

Type II-III, Ib.

RIGHT FEMUR OF RANGIFER. REINDEER. NO. 4176, U. S. NAT. MUS.

PL. 11. FIG. 208. SYN. TAB. V

Antero-posterior diameter of bone, 26 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 60%.

Structure.—Beginning on both sides of the posterior ridge and extending around the section is a horseshoe band of laminæ with long lacunæ and straight canaliculi, frequently interrupted by small, crude Haversian systems of the (Ia) differentiation. The band constitutes the whole width of the wall with the exception of the narrow internal circumferential lamellæ. The posterior ridge is composed of Haversian systems—(Ib differentiation). The medullary canal is surrounded by a ring of lamellæ.

Type II-III, Ia, Ib.

LEFT FEMUR OF URSUS AMERICANUS. BLACK BEAR. CR. MED. COLL.

PL. 12, FIG. 209. SYN. TAB. V

Antero-posterior diameter of bone, 31 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 22 mm.; lateral, 21 mm.

The medullary canal is full. Medullary index, 105%.

Structure.—The bone is nearly round and has thin walls. The anterior wall is thickest. The bone is composed of short and long laminæ having a general concentric arrangement, but presenting a variety of positions in the different portions of the wall. In the anterior and outer wall they are short and long, having the curvature of the bone, or present short angular curves and run transversely. The laminæ are quite uniform in width and are separated by distinctly wide canals. The lacunæ are long and the canaliculi are straight.

In the posterior wall the laminæ are interrupted by a few Haversian systems well developed. In the inner wall the laminæ are more uniformly concentric.

Type II.

RIGHT FEMUR OF TAUROTRAGUS ORYX. ELAND. NO. 27891, AMER. MUS. NAT. HIST.

PL. 12, FIG. 210. SYN. TAB. V

Antero-posterior diameter of bone, 55 mm.; lateral, 44 mm.

Antero-posterior diameter of medullary canal, 35 mm.; lateral, 30 mm.

The medullary canal is full. Medullary index, 73 %.

Structure.—The section is composed entirely of laminæ with the exception of the posterior ridge. They are short in the anterior wall and of varying lengths in the lateral wall. Their lacunæ are generally oval and their canaliculi are straight. The posterior ridge is composed of irregular Haversian systems, separated by bone substance with oval lacunæ and bushy canaliculi.

Type II.

LEFT FEMUR OF CONNOCHÆTES TAURINUS ALBOJUBATUS. GNU. NO. 27824, AMER. MUS. NAT. HIST.

PL. 12, FIG. 211. SYN. TAB. V

Antero-posterior diameter of bone, 33.5 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 17.5 mm.

The medullary canal is full. Medullary index, 53%.

Structure.—With the exception of the posterior ridge the section is composed of short and long laminæ. The laminæ are composed of lamellæ with oval lacunæ and straight canaliculi and are separated and crossed by canals.

The ridge is composed of fairly well developed Haversian systems, separated by short lamellæ with oval lacunæ and bushy canaliculi.

Type II.

RIGHT FEMUR OF OVIBOS MOSCHATUS WARDI. MUSK OX. AMER. MUS. NAT. HIST.

PL. 12, FIG. 212. SYN. TAB. V

Antero-posterior diameter of bone, 36 mm.; lateral, 34 mm.

Antero-posterior diameter of medullary canal, 30 mm.; lateral, 28 mm.

The medullary canal is full. Medullary index, 219%.

Structure.—The section is composed of laminæ with oval lacunæ and straight canaliculi, separated by concentric canals. The laminæ are short and long, and interrupted here and there by small Haversian systems of the (Ib) differentiation: The posterior ridge is composed of small Haversian systems.

In the inner lateral wall is another aggregation of the same type of Haversian systems.

Type II-III, Ib.

RIGHT FEMUR OF MEXICAN BURRO. CR. MED. COLL.

PL. 12, FIG. 213. SYN. TAB. V

Antero-posterior diameter of bone, 30 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 31%.

Structure.—The section is composed of concentric laminæ, separated and crossed by canals, and interrupted by crude and fairly well developed Haversian systems. Several laminæ extend from the anterior to the posterior wall along the medullary surface of the inner wall. The internal circumferential lamellæ with long lacunæ and straight canaliculi form a narrow boundary of the medullary canal. Haversian systems occupy the mid-line of the posterior ridge.

Type II.

RIGHT FEMUR OF TAPIRUS. TAPIR. NO. 35181, AMER. MUS. NAT. HIST.

PL. 12, FIG. 214. SYN. TAB. VI

Antero-posterior diameter of bone, 32 mm.; lateral, 35 mm.

Antero-posterior diameter of medullary canal, 21 mm.; lateral, 25 mm.

The medullary canal is full. Medullary index, 98%.

Structure.—The section is composed of laminæ interrupted by two groups of Haversian systems, one in the posterior outer ridge and the other in the posterior inner ridge. In the anterior wall a few systems also appear. The lacunæ are oval, the canaliculi bushy, and cross canals are infrequent. A little cancellous bone is seen in the anterior wall. The Haversian systems of the posterior wall are separated by considerable inter-Haversian lamellæ.

Type II-III, C.

LEFT FEMUR OF EQUUS HEMIONUS. WILD ASS OF ASIA. NO. 49493, U. S. NAT. MUS.

PL. 12, FIG. 215. SYN. TAB. VI

Antero-posterior diameter of bone, 46 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 26 mm.; lateral, 19 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—Beginning on both sides of the posterior ridge and constituting the entire thickness of the wall of the bone are laminæ which are interrupted by small Haversian systems, and also alternate with Haversian systems. The systems are most numerous in the posterior wall. There is nearly an equal concentric division of the laminæ. In the external portion they follow a regular concentric course; while in the internal they form two wide crescent-shaped bands around the medullary canal. In the mid-line of the anterior wall the systems are arranged in a narrow column from one surface to the other.

The posterior ridge is composed of Haversian systems, large, small, and irregular in shape. Internal circumferential lamellæ in a narrow ring enclose the medullary canal.

Type II-III, C.

RIGHT FEMUR OF ELEPHAS AFRICANUS. AFRICAN ELEPHANT. NO. 35185, AMER. MUS. NAT. HIST.

Pl. 12, Fig. 216. Syn. Tab. VI

Antero-posterior diameter of bone, 108 mm.; lateral, 83 mm.

Antero-posterior diameter of medullary canal, 65 mm.; lateral, 49 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—With the exception of a very narrow fragmentary ring of external circumferential lamellæ with long lacunæ and straight canaliculi, the section is composed almost entirely of Haversian systems of the (C) differentiation. Inter-Haversian lamellæ are present in some portions of the bone. The systems form the external boundary of the inner anterior wall where the lamellæ are deficient. Numerous cross canals unite the systems. The lacunæ of the whole section are long and narrow and their canaliculi are long, straight, and thickly set. The internal circumferential lamellæ are fragmentary.

Type III, C.

FEMUR OF CHOLŒPUS DIDACTYLUS. TWO-TOED SLOTH. NO. 104593, U. S. NAT. MUS.

Pl. 12, Fig. 217. Syn. Tab. VI

Antero-posterior diameter of bone, 16 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 4 mm.

The medullary canal is cancellous. Medullary index, 9%.

Structure.—The section has a long posterior ridge and exhibits the three structural divisions. The external circumferential lamellæ form a narrow ring around the bone excepting at the posterior ridge. The lacunæ are long with straight canaliculi in some places and oval with bushy canaliculi in others.

The central ring is composed of very distinct Haversian systems with little inter-Haversian lamellæ. They are of a high structural type. Their lacunæ are long and their canaliculi are long and straight. Some of the Haversian systems are united by cross canals, but not many. The systems are well developed but many, especially around the medullary canal, show senile changes.

The internal circumferential lamellæ take the form of a thick ring of cancellous bone. The lacunæ are well developed.

Type III, C, senile.

RIGHT FEMUR OF POTOS CAUDIVOLVULUS. KINKAJOU. AMER. MUS. NAT. HIST.

Pl. 12. Fig. 218. Syn. Tab. VI

Antero-posterior diameter of bone, 7 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—The section has three divisions. The external circumferential lamellæ form a narrow band around the anterior and lateral wall. Their lacunæ are oval and their canaliculi are straight. The central ring is composed of Haversian systems and inter-Haversian lamellæ with oval lacunæ and bushy canaliculi. The ring forms the inner wall with the exception of the internal lamellæ. The internal circumferential lamellæ form a ring around the medullary canal.

Type III, C.

RIGHT FEMUR OF LUTRA CANADENSIS. OTTER. NO. 30191, AMER. MUS. NAT. HIST.

Pl. 12, Fig. 219. Syn. Tab. VI

Antero-posterior diameter of bone, 14.5 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—The external circumferential lamellæ appear in fragments. The central ring constitutes nearly the whole section and is composed of well developed Haversian systems. In the posterior wall the systems are separated by lamellæ with oval lacunæ and straight canaliculi. The internal circumferential lamellæ surround the medullary canal and form a wide band in the outer wall.

Type III, C.

RIGHT FEMUR OF SIMIA SATYRUS. ORANG-UTAN. (BORNEO.) NO. 154304, U. S. NAT. MUS.

Pl. 13, Fig. 220. Syn. Tab. VI

Antero-posterior diameter of bone, 20 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 16 mm.

The medullary canal is full. Medullary index, 41%.

Structure.—The external circumferential lamellæ are deficient in a portion of the anterior wall, the Haversian systems of the central ring reaching the surface at this point. The lamellæ begin to increase in thickness as they pass around the inner wall where they form nearly one-third of its width. They then diminish in thickness as they reach the posterior wall, then slightly increase in the outer wall, and finally disappear as they approach the anterior wall. In this manner they form a complete ring with the exception of a small anterior portion of the circumference. They are interrupted by vascular canals and Haversian canals of the (Ia) differentiation.

The central ring is composed of well developed Haversian systems separated here and there by short lamellæ. The systems are small and large, but well developed. Their lacunæ are long and narrow. The systems are frequently united by cross canals. The internal circumferential lamellæ form a complete ring of varying widths around the medullary canal.

The femur of the orang-utan resembles the human femur more closely than those of other apes or monkeys.

Type I-III, Ia, C.

LEFT FEMUR OF FELIS TIGRIS. TIGER. NO. 174981, U. S. NAT. MUS.

Pl. 13, Fig. 221. Syn. Tab. VI

Antero-posterior diameter of bone, 28 mm.; lateral, 22 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 41%.

Structure.—The posterior ridge is composed of well developed Haversian systems. Beginning on both sides of the ridge and extending around the section is a horseshoe band of lamellæ with long lacunæ and straight canaliculi, interrupted by Haversian systems of the (Ia) differentiation. The central ring is composed of well developed Haversian systems. The internal circumferential lamellæ with long lacunæ and straight canaliculi form a wide irregular ring around the medullary canal. The ring is crossed by numerous radiating canals.

Type I-III, Ia, C.

RIGHT FEMUR OF HEMIGALUS HARDWICKI. CIVET CAT. NO. 32358, AMER. MUS. NAT. HIST.

Pl. 13, Fig. 222. Syn. Tab. VI

Antero-posterior diameter of bone, 7 mm.; lateral, 5.5 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 3 mm.

The medullary canal is full. Medullary index, 54%.

Structure.—The three divisions are well marked. The external circumferential lamellæ form a wide ring around the bone. It is crossed by canals and interrupted by a few crude Haversian systems of the (Ia) differentiation. Its lacunæ are long and the canaliculi are straight. The central ring is composed of well developed Haversian systems with very little inter-Haversian lamellæ. The internal circumferential lamellæ form a narrow ring around the medullary canal. The lacunæ are long and the canaliculi are straight.

Type I-III, Ia, C.

RIGHT FEMUR OF TATU NOVEMCINCTUS. ARMADILLO. NO. 357, AMER. MUS. NAT. HIST.

PL. 13, FIG. 223. SYN. TAB. VI

Antero-posterior diameter of bone, 7.5 mm.; lateral, 16 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The section has a long lateral diameter by extension of its outer wall. It is composed of lamellæ with oval and round lacunæ and bushy canaliculi, crossed in all directions by canals and interrupted by a few undeveloped Haversian systems of the (Ib) differentiation. The outer process has central cancellous bone.

Type I-III, Ib.

RIGHT FEMUR OF TAMANDUA TETRADACTYLA. ANT-EATER. NO. 14866, AMER. MUS. NAT. HIST.

PL. 13, FIG. 224. SYN. TAB. VI

Antero-posterior diameter of bone, 7 mm.; lateral, 12 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 17%.

Structure.—The longest diameter of the bone is its lateral diameter. The outer wall is projected outward into a prominent ridge. Beginning on both sides of the mid-line of the inner wall and extending around the section is a band of external circumferential lamellæ, interrupted in the anterior wall by concentrically arranged small, crude Haversian systems of the (Ia) differentiation, and in the posterior wall by a few fairly well developed Haversian systems. The band is widest in the anterior wall and narrowest in the outer wall. The lacunæ are oval and long and the canaliculi are bushy and straight.

Under this band is a central ring of Haversian systems of the (Ib) differentiation, between which is bone substance with oval and large lacunæ and bushy canaliculi. The ring nearly reaches the external surface at the mid-line of the inner wall. The systems are united by cross canals. Internal circumferential lamellæ form a rather narrow ring around the medullary canal. In the outer and inner wall it assumes a cancellous form.

Type I-III, Ia, Ib.

LEFT FEMUR OF GORILLA. GORILLA. NO. 22832, AMER. MUS. NAT. HIST.

PL. 13, FIG. 225. SYN. TAB. VI

Antero-posterior diameter of bone, 16.5 mm.; lateral, 19.5 mm.

Antero-posterior diameter of medullary canal, 7.5 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 15%.

Structure.—Beginning on both sides of the posterior ridge and extending around the external aspect of the bone is a wide horseshoe-shaped band of lamellæ with long and oval lacunæ and straight and bushy canaliculi. The lamellæ are interrupted by crude Haversian systems of the (Ia) differentiation and crossed at various angles by numerous canals.

The central ring is composed of well developed Haversian systems and inter-Haversian lamellæ. Their lacunæ are long and canaliculi are straight. The ring is narrow in the anterior wall and widens as it encircles the lateral and posterior wall. In the posterior ridge the systems form the whole thickness of the wall and are embraced by the heel of the horseshoe band. The internal circumferential lamellæ form a narrow ring around the medullary canal.

More than half of the section is lamellar. In this respect it differs from the orang-utan in the femur of which the external lamellæ form a narrower ring.

Type I-III, Ia, C.

FEMUR OF PRESBYTIS RUBICUNDA. MONKEY. NO. 153793, U. S. NAT. MUS.

PL. 13, FIG. 226. SYN. TAB. VI

Antero-posterior diameter of bone, 11 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 6.5 mm.

The medullary canal is full. Medullary index, 48%.

Structure.—A wide irregularly shaped horseshoe of lamellæ surrounds the section. The lamellæ form about one-half of the thickness of the inner and anterior wall and practically the whole thickness of the outer wall. They are well developed with narrow lacunæ and long canaliculi and are frequently interrupted by Haversian canals of the (Ia) differentiation.

The central ring is interrupted by the external lamellæ of the outer wall. It is narrow and composed of fairly well developed Haversian systems with considerable inter-lamellar structure. The posterior ridge is composed of lamellæ and Haversian systems mixed. The systems have oval and narrow lacunæ and rather infrequent canaliculi. The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia, C.

RIGHT FEMUR OF HYLOBATES. GIBBON. NO. 111988, U. S. NAT. MUS.

PL. 13, FIG. 227. SYN. TAB. VI

Antero-posterior diameter of bone, 11 mm.; lateral, 11.5 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 6.5 mm.

The medullary canal is full. Medullary index, 44%.

Structure.—The section of the bone is composed of a wide external ring of lamellæ, frequently interrupted by very incomplete Haversian systems of the (Ia) differentiation. The lamellar ring surrounds the bone with the exception of the posterior ridge, where a few Haversian systems reach the external surface and blend with a few tendon insertions.

The central ring is composed of Haversian systems of the (C) differentiation which displace the internal circumferential lamellæ in the outer lateral wall and border on the medullary canal. Their lacunæ and canaliculi are well developed. The internal circumferential lamellæ surround the medullary canal excepting a small part of the outer lateral wall.

Type I-III, Ia, C.

LEFT FEMUR OF ANTHROPOPITHECUS TROGLODYTES. CHIMPANZEE. NO. 18010, AMER. MUS. NAT. HIST.

PL. 13, FIG. 228. SYN. TAB. VI

Antero-posterior diameter of bone, 13 mm.; lateral, 16 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 8 mm.

The medullary canal is full. Medullary index, 30%.

Structure.—The external circumferential lamellæ surround the section. This lamellar ring is widest in the antero-inner lateral wall where it constitutes nearly the whole thickness of the wall. It is narrowest in the posterior wall. Its lamellæ have long lacunæ with straight canaliculi. The ring is interrupted by crude Haversian systems of the (Ia) differentiation and crossed by canals.

The central ring, irregular in width, is composed of well developed Haversian systems.

The internal circumferential lamellæ form a narrow ring around the medullary canal. Just external to this ring is a concentric row of vascular spaces. The lacunæ are long.

The bone is, however, more than half lamellæ.

Type I-III, Ia, C.

RIGHT FEMUR OF MACACUS RHESUS. INDIAN MONKEY. R. 1.

PL. 14, FIG. 229. SYN. TAB. VI

Antero-posterior diameter of bone, 8 mm.; lateral, 8.5 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 68%.

Structure.—There are no external and internal circumferential lamellæ distinct from the central ring of the bone.

A crescent of well developed Haversian systems, bordering upon the inner wall of the medullary canal, begins in the posterior region and extends around the inner and anterior to the outer wall, where it merges into the lamellar structure. The widest part of the crescent forms about one-third of the entire thickness of the inner wall.

The systems are well developed. In several places a half system borders the medullary canal. The lacunæ are long and narrow and their canaliculi are long and branching. The Haversian systems are frequently united by short inter-Haversian lamellæ. A second crescent of Haversian systems borders the medullary canal extending from the posterior prominence around the posterior and outer to about the middle portion of the anterior wall. The systems of the two crescents are the only fully developed systems present. The second crescent is narrower than the first. Its widest part is in the posterior region of the outer wall. The lacunæ are long and narrow and the canaliculi are straight.

The main structure of the inner, anterior, and outer wall is lamellar. It is composed of irregularly concentric lamellæ, interrupted by rudimentary Haversian systems of the (Ib) differentiation. This lamellar structure makes up practically the whole bone. The lacunæ are generally long, and have long, branching, and numerous canaliculi. In some places the lacunæ are curved and quite irregular in shape. The posterior wall and ridge is composed of Haversian systems, poorly developed. They are separated by lamellæ. Their outlines are not sharply defined, but appear to merge into the surrounding lamellæ.

Type I-III, Ib, C.

RIGHT FEMUR OF SCIURUS SP. (LARGE RED SQUIRREL.) CR. MED. COLL.

PL. 14, FIG. 230. SYN. TAB. VI

Antero-posterior diameter of bone, 4.5 mm.; lateral, 6 mm.

Antero-posterior diameter of the medullary canal, 3.5 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 18%.

Structure.—A ring of external circumferential lamellæ of varying widths surrounds the bone. Their lacunæ are mostly long and narrow and their canaliculi are numerous, long, and branching. A central, irregularly shaped ring of complete and incomplete Haversian systems is situated under the external lamellæ. It increases in thickness around the inner, posterior, and outer wall, and reaches the surface in the outer wall. In many places in the inner wall the systems are composed of oval lacunæ with short, bushy canaliculi arranged in a circular manner.

Internal circumferential lamellæ form an uneven, thick ring around the medullary canal. Their lacunæ are long and narrow and their canaliculi are long, numerous, and branching. The bone, therefore, is composed of three very uneven and irregularly shaped rings of structural units.

Type I-III, Ib, C.

RIGHT FEMUR OF FELIS. DOMESTIC CAT. CR. MED. COLL.

PL. 14. FIG. 231. SYN. TAB. VI

Antero-posterior diameter of bone, 7.5 mm.; lateral, 9.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—External circumferential lamellæ form more than one-half of the thickness of the wall of the bone. A few Haversian systems appear in the middle portion of the lamellar ring. They are well developed and without apparent signification. A short distance from the mid-line in the inner wall the lamellar ring divides into a wide outer and a narrow inner part which encloses a crescent shaped area of Haversian systems. About the middle of the inner wall is quite a sharp lateral ridge. The lamellar ring is widest at this point and narrowest in the outer wall. The lacunæ are long and narrow and the canaliculi are thickly set, long, and branching.

The central ring is composed of well developed, large and small Haversian systems, widest in the inner wall and narrowest in the outer wall. The systems are generally strongly developed, and are round, elliptical, or irregular in cross-section.

The internal circumferential lamellæ are in the form of laminæ. Their lacunæ are long or oval and their canaliculi are bushy. Numerous canals pass through the laminæ on their way from the medullary canal. Four femora of the domestic cat were examined and in each one there was a different development, structure, and arrangement of bone units.

Type I-II-III, C.

LEFT FEMUR OF FELIS CATUS. WILD CAT. CR. MED. COLL.

PL. 14. FIG. 232. SYN. TAB. VI

Antero-posterior diameter of bone, 13.5 mm.; lateral, 11 mm.

Antero-posterior diameter of the medullary canal, 8 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—Around the outside of the bone is a ring of lamellæ, interrupted very frequently by incomplete Haversian systems of the (Ib) differentiation. The ring forms a greater part of the thickness of the wall of the bone excepting in the posterior wall, where the Haversian systems occupy the whole width from the internal circumferential lamellæ outward to the circumference. Many canals traverse the ring. For the most part, all of the structural units are rather indistinct. Around the anterior and a portion of the inner wall is a narrow rim of external lamellæ. The lacunæ of the lamellar ring are long or oval and their canaliculi are long and branching or bushy.

The central ring is incomplete, occupying the posterior, inner, and anterior walls. It is composed of well developed Haversian systems, crossed in the anterior wall by an extension from the external lamellæ. It is wide in the posterior wall and gradually narrows as it passes around the lateral into the anterior wall.

Around the medullary canal is a well defined ring of internal circumferential lamellæ. Numerous large canals cross the ring to communicate with canals within the center of the bone. The lacunæ are long and canaliculi long and branched.

Type I-III, Ib, C.

FEMUR OF MEPHITIS MEPHITICA. SKUNK. CR. MED. COLL.

Pl. 14, Fig. 233. Syn. Tab. VI

Antero-posterior diameter of bone, 5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 127%.

Structure.—The section is composed of lamellæ with long lacunæ and straight and bushy canaliculi, frequently interrupted by irregularly shaped Haversian systems and canals. Some of the systems are round, some oval, and some have long, wide, straight, or curved canals. In some situations they are concentric. As a whole, they are well developed. There is no well defined central ring nor internal circumferential lamellæ.

Type I-III, C.

FEMUR OF PUTORIUS VISON. MINK.

Pl. 14, Fig. 234. Syn. Tab. VI

Antero-posterior diameter of bone, 3.5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 2 mm.

The medullary canal is full. Medullary index, 23%.

Structure.—The anterior wall is composed of lamellæ which form its entire thickness. The lamellæ then form an irregularly shaped, complete ring around the medullary canal. Numerous canals pass across this ring, incompletely or completely, on their way from the medullary canal to small canals of the interior. The lacunæ are long and narrow and their canaliculi are long and branching.

The Haversian systems are absent at the widest lamellar point of the anterior wall. They then begin to appear in single file, gradually increase in thickness to the posterior wall, and diminish again as they approach the anterior wall. In this manner they form an irregular long crescent enclosed within lamellæ. The crescent nearly encircles the bone. The Haversian systems are well developed, their lacunæ are oval, and their canaliculi are relatively few. Their canals frequently unite. In some places bands of lamellæ cross the crescent extending from the outer to the inner lamellæ. Numerous canals traverse the crescent. The internal circumferential lamellæ form a wide, irregular ring, fusing with the external lamellæ in the anterior wall. The lacunæ are long and narrow and their canaliculi are long and branching.

Type I-III, C.

LEFT FEMUR OF CRYPTOPROCTA FEROX. CAT-LIKE CIVET. AMER. MUS. NAT. HIST.

Pl. 14, Fig. 235. Syn. Tab. VI

Antero-posterior diameter of bone, 8.5 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—The section is surrounded by a ring of external lamellæ of varying widths. It is interrupted by numerous canals of the (Ia) differentiation. The lacunæ are long and the canaliculi are straight. The ring is distinct from the underlying central ring of Haversian systems, which are well developed. The medullary canal is surrounded by internal circumferential lamellæ of varying widths.

Type I-III, Ia, C.

RIGHT FEMUR OF HYÆNA CROCUTA. HYÆNA. NO. 35431, AMER. MUS. NAT. HIST.

Pl. 14, Fig. 236. Syn. Tab. VI

Antero-posterior diameter of bone, 14 mm.; lateral, 18 mm.

Antero-posterior diameter of medullary canal, 9 mm.; lateral, 13.5 mm.

The medullary canal is full. Medullary index, 98%.

Structure.—External lamellæ form a wide ring around the section with the exception of the outer ridge. The lamellæ are crossed by canals, interrupted by crude Haversian systems of the (Ia) differentiation, and have long lacunæ and straight canaliculi.

The central ring is composed of well developed Haversian systems with some inter-Haversian lamellæ. The systems form the whole of the outer ridge, where they are separated by bone substance with many oval lacunæ and bushy canaliculi.

A narrow ring of internal circumferential lamellæ surrounds the medullary canal. The lacunæ are long.

Type I-III, Ia, C.

RIGHT FEMUR OF THYLACINUS CYNOCEPHALUS. TASMANIAN WOLF

Pl. 14, Fig. 237. Syn. Tab. VI

Antero-posterior diameter of bone, 19.5 mm.; lateral, 15 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 8.5 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—The section is surrounded by a narrow ring of external lamellæ, interrupted here and there by crude Haversian systems of the (Ia) differentiation. Underneath this ring is a wide horseshoe of lamellæ, interrupted by many crude Haversian systems of the (Ia) differentiation arranged concentrically. The outer wall is all lamellæ.

Underneath this band is a central, incomplete ring of well developed Haversian systems with inter-Haversian lamellæ. In the posterior wall the systems form nearly the whole of the wall. Here the oval large lacunæ with bushy canaliculi are pronounced.

Internal circumferential lamellæ form a narrow ring around the medullary canal. Their lacunæ are long.

Type I-III, Ia, C.

RIGHT FEMUR OF DASYPROCTA AGOUTI. NO. 15669, AMER. MUS. NAT. HIST.

Pl. 14, Fig. 238. Syn. Tab. VI

Antero-posterior diameter of bone, 10 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 93%.

Structure.—The three divisions are well marked. A wide ring of external circumferential lamellæ, interrupted by crude Haversian systems of the (Ia) differentiation and crossed by canals, surrounds the section with the exception of the posterior ridge. The lamellar ring forms more than half of the section. The central ring is composed of well developed Haversian systems with inter-Haversian lamellæ.

The systems of the central ring reach the surface at the posterior ridge where they are separated by bone substance with oval lacunæ. The internal circumferential lamellæ form a narrow ring around the medullary canal. The lacunæ are long in the external and internal lamellæ; elsewhere they are oval.

Type I-III, Ia, C.

LEFT FEMUR OF LASIOPYGA CENTRALIS JOHNSTONI. AFRICAN MONKEY. NO. 27705, AMER. MUS. NAT. HIST.

Pl. 14, Fig. 239. Syn. Tab. VI

Antero-posterior diameter of bone, 9 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 62%.

Structure.—The section has three divisions. A wide ring of external circumferential lamellæ, interrupted by Haversian systems of the (Ia) differentiation, surrounds the bone. In the posterior wall it is interrupted by irregularly shaped Haversian systems. Canals cross the ring at various intervals. The lacunæ are long and narrow and the canaliculi are straight.

The central ring is very narrow and composed of a few well developed Haversian systems with inter-Haversian lamellæ.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia, C.

RIGHT FEMUR OF FELIS CANADENSIS. CANADA LYNX. CR. MED. COLL.

PL. 15, FIG. 240. SYN. TAB. VI

Antero-posterior diameter of bone, 13 mm.; lateral, 12 mm.

Antero-posterior diameter of medullary canal, 9.5 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 121%.

Structure.—The usual three structural rings are distinct. The external circumferential lamellæ form a wide ring around the section excepting at the ridges of the inner and posterior wall where they are deficient. They are interrupted by small, crude Haversian systems of the (Ia) differentiation; while in the posterior wall much better developed systems form an important part of the whole lamellar ring.

The central ring is composed of well developed Haversian systems with very little inter-Haversian structure. At the ridges the systems break through the external circumferential lamellæ and form the external surface of the bone at these points.

The internal circumferential lamellæ form a narrow ring around the medullary canal excepting a small portion of the posterior and inner wall. The lacunæ in all parts are well developed.

Type I-III, Ia, C.

RIGHT FEMUR OF LASIOPYGA SP. AFRICAN MONKEY.
NO. 163283, U. S. NAT. MUS.

PL. 15. FIG. 241. SYN. TAB. VI

Antero-posterior diameter of bone, 5.5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—External circumferential lamellæ of varying widths surround the bone. In the anterior and inner wall they form two-thirds of the thickness of the section and in the posterior and outer wall about one-fourth of the entire thickness. They are frequently interrupted by crude Haversian systems of the (Ia) differentiation and crossed at various angles by short canals. Their lacunæ and canaliculi are well developed. The central ring is composed of well developed Haversian systems and lamellæ with systems of the (Ia) differentiation. The ring is widest in the outer lateral wall.

In the lamellar portion of the ring are one or two concentric rows of small Haversian canals which gradually change into the more completely developed Haversian systems of the outer wall. The internal circumferential lamellæ surround the medullary canal excepting in the outer wall. The lamellar and Haversian portions of the section are about equal.

Type I-III, Ia, C.

RIGHT FEMUR OF MIDAS RUFONIGER. SOUTH AMERICAN MONKEY (UPPER AMAZON). NO. 14548, U. S. NAT. MUS.

PL. 15, FIG. 242. SYN. TAB. VI

Antero-posterior diameter of bone, 4.5 mm.; lateral, 4 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 74%.

Structure.—The three structural rings are distinctly marked. The external circumferential lamellæ form a thick enclosing ring of one-third to one-half the thickness of the wall of the bone. The lamellæ of the inner wall are very frequently dotted with small, clear, round spaces which are not present in the outer wall. The lacunæ are well developed.

The central ring is composed of rather irregularly shaped but well developed Haversian systems, separated by inter-Haversian lamellæ. They are frequently united by canals. The internal circumferential lamellæ form a narrow ring around the medullary canal, excepting in the outer wall where they are deficient.

Type I-III, Ia, C.

LEFT FEMUR OF LEMUR. NO. 84383, U. S. NAT. MUS.

PL. 15, FIG. 243. SYN. TAB. VI

Antero-posterior diameter of bone, 10 mm.; lateral, 8.5 mm.

Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 41%.

Structure.—The section is surrounded by a lamellar ring which is widest in the anterior and posterior wall. In the inner wall it is divided into laminæ, and frequently interrupted by canals and very crude Haversian systems of the (Ia) differentiation. The lacunæ are generally well developed. The central ring, of varying widths, is composed of fairly well developed Haversian systems, small, large, and irregular in shape, and frequently united by canals. Their lacunæ are well developed. In the anterior wall the ring is divided into two nearly equal parts by a narrow, crescent-shaped lamina, the horns of which begin about the middle of the lateral walls. The internal circumferential lamellæ surround the medullary canal. It is widest in the inner wall and well developed.

Type I-III, Ia, C.

RIGHT FEMUR OF LEMUR CATTA. RING-TAILED LEMUR. U. S. NAT. MUS.

PL. 15, FIG. 244. SYN. TAB. VI

Antero-posterior diameter of bone, 8.5 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 122%.

Structure.—The section is surrounded by a heavy, dark ring of varying widths composed of meshed bone work. The meshes are irregular in shape and size. The ring is narrowest in the outer wall, widest in the inner and antero-lateral, and of intermediate thickness in other situations. The meshes are filled with dense material which adheres to the mesh walls even in extremely thin places. The mesh walls are extensions of the external circumferential lamellæ.

Underneath this ring is a wide lamellar ring, interrupted by cross and longitudinal canals and crude Haversian systems of the (Ia) and (Ib) differentiations. In the posterior wall the ring is wide and coarsely lamellar and frequently interrupted by large, irregular spaces. Underneath this is an irregularly shaped ring of fairly well developed Haversian systems with numerous spaces. The internal circumferential lamellæ surround the medullary canal. It is widest in the anterior and lateral walls.

Type I-III, Ia, Ib, C.

LEFT FEMUR OF ATELES. SPIDER-MONKEY. (TEHUANTEPEC.) NO. 11842, U. S. NAT. MUS.

PL. 15, FIG. 245. SYN. TAB. VI

Antero-posterior diameter of bone, 12.5 mm.; lateral, 10.5 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—The external circumferential lamellæ form a wide ring surrounding the section, excepting a small portion of the inner wall. The lamellæ are frequently interrupted by Haversian canals of the (Ia) differentiation and small Haversian systems. The ring is widest in the posterior wall. The central ring is composed of well developed Haversian systems with some inter-Haversian lamellæ. The systems displace the external circumferential lamellæ in the anterior portion of the inner wall where they form the external boundary of the bone.

The internal circumferential lamellæ surround the medullary canal. They are most prominent in the inner wall. The lacunæ of the three rings are well developed.

Type I-III, Ia, C.

RIGHT FEMUR OF CALLICEBUS TORQUATUS. SQUIRREL-MONKEY. NO. 105539, U. S. NAT. MUS.

PL. 15, FIG. 246. SYN. TAB. VI

Antero-posterior diameter of bone, 5.5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 3.5 mm.

The medullary canal is full. Medullary index, 104%.

Structure.—The anterior and outer half of the section is surrounded by a wide band of external circumferential lamellæ, interrupted by Haversian canals of the (Ia) differentiation, underneath which is a narrow half ring of Haversian systems bordering upon the medullary canal. The lacunæ of the lamellæ and Haversian systems are oval and long and the canaliculi are generally long and straight.

The posterior and inner half of the section is composed of irregularly shaped Haversian systems forming the whole thickness of the posterior and inner wall. The external and internal circumferential lamellæ are not distinct from the remaining structure.

Type I-III, Ia, C.

LEFT FEMUR OF GENETTA. GENET. NO. 163294, U. S. NAT. MUS.

PL. 15, FIG. 247. SYN. TAB. VI

Antero-posterior diameter of bone, 9 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 107%.

Structure.—A ring of external circumferential lamellæ of varying widths surrounds the section. In the anterior wall it forms nearly the whole thickness; it then becomes narrow in the outer wall, remains about the same width in the posterior wall, and again widens in the inner anterior wall. It is interrupted by crude Haversian systems of the (Ia) differentiation in the anterior, inner, and posterior wall. The lacunæ are oval and long, and the canaliculi are long and straight. Underneath the lamellar ring is an irregular ring of Haversian systems well developed. The ring is widest in the lateral and posterior wall. The systems are irregular in shape in the outer wall. Their lacunæ are oval and the canaliculi are straight. An incomplete ring of internal circumferential lamellæ surrounds the medullary canal.

Type I-III, Ia, C.

LEFT FEMUR OF PEDETES. JUMPING HARE. U. S. NAT. MUS.

Pl. 15, Fig. 248. Syn. Tab. VI

Antero-posterior diameter of bone, 10.9 mm.; lateral, 9 mm.

Antero-posterior diameter of medullary canal, 7.5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 85%.

Structure.—The bone is surrounded by a lamellar ring of varying widths. The lamellæ are frequently interrupted by small, crude Haversian systems of the (Ia) differentiation and crossed by a few canals. The lacunæ are oval and narrow and the canaliculi are bushy and straight. Underneath the lamellæ is an irregular ring of Haversian systems separated by lamellæ and canals. The systems are fairly well developed. In the inner wall the systems are interrupted by a few laminæ. The internal circumferential lamellæ form a ring of varying widths around the medullary canal. Their lacunæ are narrow and the canaliculi are straight.

Type I-III, Ia, C.

RIGHT FEMUR OF BRADYPUS TRIDACTYLUS. THREE-TOED SLOTH. NO. 16871. AMER. MUS. NAT. HIST.

Pl. 15, Fig. 249. Syn. Tab. VI

Antero-posterior diameter of bone, 8.5 mm.; lateral, 13 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—The section has three divisions. The external circumferential lamellæ form a wide rim around the bone. It is crossed radially by numerous canals and interrupted frequently by normal and senile Haversian systems and by Haversian canals of the (Ia) differentiation. The band of lamellæ constitutes half of the wall. The lacunæ are oval and long and the canaliculi are straight.

The central ring is composed of complete and senile Haversian systems. Various stages and degrees of senility are found. Some systems are entirely gone; some occur in narrow rings; some show precipitation of inorganic material around the Haversian canal; and some show the whole systems involved but still in position. Their lacunæ are long and oval. The internal circumferential lamellæ assume a cancellous form around the medullary canal. Their lacunæ are long and the canaliculi are straight.

The bone exhibits a much greater lamellar structure than the femur of the two-toed sloth. It is quite different in shape. Senility is marked.

Type I-III, Ia, C, senile.

RIGHT FEMUR OF CASTOR CANADENSIS. BEAVER. NO. 10005, U. S. NAT. MUS.

PL. 16, FIG. 250. SYN. TAB. VI

Antero-posterior diameter of bone, 25 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 10%.

Structure.—The section has a long posterior ridge, which accounts for the long antero-posterior and short lateral measurements. The section is surrounded by a lamellar and laminar band of varying widths, interrupted by Haversian canals of the (Ia) differentiation and crossed by frequent vascular canals. The lacunæ are oval and long and the canaliculi are straight.

Underneath the lamellæ is a narrow band of irregular Haversian systems. The systems are large and small, but very well developed. They are quite irregular in shape. Their canals frequently unite. The central part of the ridge is composed of large Haversian systems, poorly developed and united by vascular canals. The internal circumferential lamellæ assume the form of cancellous bone around the medullary canal.

Type I-II-III, Ia, Ib, C.

LEFT FEMUR OF FELIS. LEOPARD. NO. 35349, AMER. MUS. NAT. HIST.

PL. 16, FIG. 251. SYN. TAB. VI

Antero-posterior diameter of bone, 18 mm.; lateral, 17 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 37%.

Structure.—The section has three divisions. A wide band of lamellæ and Haversian systems surrounds the bone. It is widest in the inner wall. The systems are numerous and do not appear to have any definite plan of arrangement. The lacunæ are long and the canaliculi are straight. The central ring, irregular in width, is composed of well developed Haversian systems with little inter-Haversian lamellæ. The internal circumferential lamellæ form a fragmentary ring around the medullary canal. Many spaces occur which appear to be the result of the disappearance of Haversian systems. Senile changes are frequent.

Type I-III, C, senile.

LEFT FEMUR OF BOS. DOMESTIC OX. CR. MED. COLL.

PL. 16, FIG. 252. SYN. TAB. VI

Antero-posterior diameter of bone, 44 mm.; lateral, 39 mm.

Antero-posterior diameter of medullary canal, 23 mm.; lateral, 21 mm.

The medullary canal is full. Medullary index, 40%.

Structure.—The bone is composed of three wide concentric rings with irregular boundaries, separated by canals containing chains of black lacunar-like bodies with connecting and very irregular canalicular extensions. In thin sections there appear to be no uniting structures in the canals of sufficient importance to hold the rings together.

The canals have an undulating course and communicate with other canals of the rings.

External or first ring: This ring is composed of concentric laminæ divided into short lengths. Occasionally a few Haversian systems interrupt the laminæ. In the anterior wall the laminæ are transformed into irregular Haversian systems which have their best development in the middle portion of the walls. The laminæ have long or oval lacunæ and branching or bushy canaliculi. Some laminæ are solid; some have central canals; and some show these canals enlarged at intervals with the lamellæ bending around the enlargements, forming aberrant Haversian systems.

Middle or second ring: The borders of the separating canals are composed of clear lamellæ with no visible canaliculi. The second ring is composed of short and long laminæ arranged vertically to the outer ring, especially in the inner wall. Along the outer border of the separating canal the lamina is concentric. As it approaches the anterior projecting wall it merges into the irregular Haversian systems of that region. In the outer wall the laminæ are much more concentric. The laminæ of this ring are folded around canalicular expansions into elliptical or elongated angular Haversian systems. As they approach the third ring they are more circular. Their lacunæ and canaliculi are like those of the outer ring.

Internal or third ring: This is composed of vertical and concentric laminæ of an Haversian system character intermixed. There are more systems in the posterior wall, and it is here that they are best developed. The laminæ of this ring run in various directions and form complex arrangements of structural units. The anterior wall of the bone is composed of irregularly shaped, large, crude Haversian systems united by short lamellæ. Around the medullary canal is an irregular ring of internal circumferential lamellæ having long, narrow lacunæ with branching canaliculi.

Type II-III, C.

LEFT FEMUR OF EQUUS CABALLUS. DOMESTIC HORSE. CR. MED. COLL.

PL. 16, FIG. 253. SYN. TAB. VI

Antero-posterior diameter of bone, 57.5 mm.; lateral, 41.5 mm.

Antero-posterior diameter of medullary canal, 32 mm.; lateral, 22.5 mm.

The medullary canal is full. Medullary index, 43%.

Structure.—The section is composed of rings of well developed Haversian systems alternating with laminæ. It has more Haversian systems than laminæ. The external circumferential lamellæ are fragmentary. The Haversian systems reach the external boundary, and in some places half-systems are present with their Haversian canals directly underneath the periosteum. The Haversian systems vary in diameter and are well developed. Their lacunæ are long and their canaliculi are long and branching. Commencing in the outer posterior region a few laminæ appear, which increase in number as they approach the posterior wall. The laminæ are well developed and are separated by Haversian systems. Internal circumferential lamellæ form a narrow ring around the medullary canal and become cancellous in the posterior wall.

Type II-III, C.

RIGHT FEMUR OF OVIS. DOMESTIC SHEEP. CR. MED. COLL.

PL. 16, FIG. 254. SYN. TAB. VI

Antero-posterior diameter of bone, 18 mm.; lateral, 14 mm.

Antero-posterior diameter of medullary canal, 10.7 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 44%.

Structure.—External circumferential laminæ surround the section. The lacunæ are long and narrow with long, branching canaliculi. Between the external laminæ and internal circumferential lamellæ are small and large Haversian systems, arranged in the form of a crescent and situated in the outer, posterior, and inner lateral wall. The thickest portion of the crescent is in the outer wall. The systems are, for the most part, small, close together, and their Haversian canals frequently unite. They have few lacunæ and few bushy canaliculi. The inner wall of the bone is composed almost entirely of laminæ, there being a few Haversian systems close to the internal circumferential lamellæ. The laminæ are separated by wide canals which frequently cross and unite with other canals. Each lamina is composed of lamellæ with oval lacunæ and bushy canaliculi. The inner wall of the bone has oblique laminæ. Internal circumferential lamellæ surround the medullary canal.

Type II-III, C.

RIGHT FEMUR OF BISON AMERICANUS. BISON. NO. 22914, AMER. MUS. NAT. HIST.

PL. 16, FIG. 255. SYN. TAB. VI

Antero-posterior diameter of bone, 56 mm.; lateral, 46 mm.

Antero-posterior diameter of medullary canal, 39 mm.; lateral, 33 mm.

The medullary canal is full. Medullary index, 100%.

Structure.—The bone is chiefly composed of laminæ. There are two aggregations of Haversian systems, one in the posterior ridge and the other in the angle of the inner wall. They are fairly well developed and occupy nearly the whole thickness of the wall. Their lacunæ are oval. The remainder of the section is composed of laminæ, interrupted by small Haversian systems. The lacunæ are oval and the canaliculi are straight.

Type II-III, C.

RIGHT FEMUR OF A MULE. NO. 227, CR. MED. COLL.

PL. 16, FIG. 256. SYN. TAB. VI

Antero-posterior diameter of bone, 60 mm.; lateral, 55 mm.

Antero-posterior diameter of medullary canal, 47 mm.; lateral, 45 mm.

The medullary canal is full. Medullary index, 179%.

Structure.—The section shows a posterior and outer ridge. The posterior ridge is composed of small Haversian systems and inter-Haversian lamellæ with oval lacunæ and bushy canaliculi. Many spaces occur and the laminæ are crossed by numerous short canals. The outer ridge consists of Haversian systems and laminæ and shows a large number of spaces. Between these two ridges the wall is composed of Haversian systems and laminæ. The remainder of the section is composed of laminæ, interrupted by Haversian systems and crossed by canals. Half of the anterior and inner walls is composed of laminæ perforated with spaces. The spaces have no walls but those of adjoining laminæ. They appear to be the result of senile changes. The bone is thin and fragile.

Type II-III, C, senile.

LEFT FEMUR OF A MULE. NO. 229, CR. MED. COLL.

PL. 16, FIG. 257. SYN. TAB. VI

Antero-posterior diameter of bone, 68 mm.; lateral, 50 mm.

Antero-posterior diameter of medullary canal, 40 mm.; lateral, 37 mm.

The medullary canal is full. Medullary index, 77%.

Structure.—The section has three ridges, a posterior ridge and one on either side of the anterior wall. The posterior ridge is composed of short lamellæ with branching canals, having a direction toward the point of the ridge.

Between the lamellæ are some Haversian systems. The lacunæ are oval and the canaliculi are straight. The anterior and inner ridges are composed of a few crude Haversian systems, laminæ, and branching canals. The anterior and outer ridges have many more Haversian systems and relatively fewer canals than the inner ridge. Between the three ridges the walls are composed of laminæ, interrupted by a few Haversian systems. The laminæ are frequently crossed by canals. Some cancellous bone appears on the medullary surfaces of the anterior and posterior walls.

Type II-III, C.

LEFT FEMUR OF A MULE. NO. 235, CR. MED. COLL.

Pl. 16, Fig. 258. Syn. Tab. VI

Antero-posterior diameter of bone, 65 mm.; lateral, 51 mm.

Antero-posterior diameter of medullary canal, 38 mm.; lateral, 40 mm.

The medullary canal is full. Medullary index, 85%.

Structure.—The posterior wall is over half cancellous. The posterior ridge is composed of Haversian systems, inter-Haversian lamellæ with oval lacunæ and many branching canals, having a direction toward the external surface of the ridge. The remaining wall is composed of laminæ, interrupted by Haversian systems and crossed by numerous canals. In the outer wall near the mid-line is a collection of Haversian systems forming a slight ridge. Around the medullary canal in the anterior and lateral walls there are many spaces of irregular shape which appear to be the result of senile changes. The lacunæ are generally oval.

Type II-III, C, senile.

LEFT FEMUR OF A MULE. NO. 236, CR. MED. COLL.

Pl. 16, Fig. 259. Syn. Tab. VI

Antero-posterior diameter of bone, 61 mm.; lateral, 50 mm.

Antero-posterior diameter of medullary canal, 40 mm.; lateral, 38 mm.

The medullary canal is full. Medullary index, 100%.

Structure.—The posterior ridge is composed of Haversian systems and inter-Haversian lamellæ with oval lacunæ. There are many short, branching canals having a direction toward the external surface. About one-third of the medullary portion of the wall is cancellous bone. The inner and anterior wall is composed of laminæ, interrupted by many Haversian systems. The systems are more numerous around the medullary canal. Many cross canals appear between the systems and extend across the laminæ. The anterior half of the outer wall is nearly all laminæ which are interrupted by Haversian systems. The posterior half is composed of irregular elongated Haversian systems and of laminæ. The femur of the mule differs from the horse in its predominating proportion of laminæ and in the frequent senile changes present in its scattering Haversian systems. The difference between the horse and the mule is found in the jackass.

Type II-III, C.

LEFT FEMUR OF ELEPHAS INDICUS. ASIATIC ELEPHANT. AMER. MUS. NAT. HIST.

PL. 17, FIG. 260. SYN. TAB. VII

Antero-posterior diameter of bone, 121 mm.; lateral, 77 mm.

Antero-posterior diameter of medullary canal, 50 mm.; lateral, 38 mm.

The medullary canal is full. Medullary index, 25%.

Structure.—The section is composed of lamellæ, laminæ, and Haversian systems, the laminæ predominating. The posterior ridge is composed of Haversian systems with inter-Haversian lamellæ. Beginning in the inner side of the ridge and extending around the external surface of the posterior inner wall is a wide band of lamellæ, frequently interrupted by Haversian systems. The lamellæ soon separate into laminæ as they extend around the section. The laminæ, frequently interrupted by Haversian systems and crossed by canals, complete the circumference of the bone to the posterior ridge. In the anterior wall they constitute two-thirds, in the inner wall one-third, and in the outer and posterior wall over half the width of the wall. As they approach the ridge they shorten and widen into elongated Haversian systems. Thus a wide horseshoe of lamellæ and laminæ surrounds the bone. In the anterior wall the toe of this shoe is very narrow, having been displaced by Haversian systems. The lacunæ and canaliculi are well developed. Underneath the laminar shoe is an irregularly shaped central ring of well developed Haversian systems with some senile changes around the medullary canal. The lacunæ are well developed. Around the medullary canal is an enclosing ring of lamellæ in the form of cancellous bone.

The bone is over half laminæ and lamellæ, and exhibits a different type of structure from that seen in the African elephant.

Type II-III, C, senile.

RIGHT FEMUR OF HIPPOPOTAMUS AMPHIBUS. HIPPOPOTAMUS

PL. 17, FIG. 261. SYN. TAB. VII

Antero-posterior diameter of bone, 70 mm.; lateral, 70 mm.

Antero-posterior diameter of medullary canal, 26 mm.; lateral, 30 mm.

The medullary canal is full. Medullary index, 19%.

Structure.—Beginning on the outer side of the posterior ridge and extending around the bone to the inner wall is a wide band of laminæ, interrupted by

Haversian systems of the (Ia) and (C) differentiations. The laminæ, separated and crossed by canals, form nearly the whole width of the outer, about one-third of the anterior, and terminate somewhat abruptly at the junction of the anterior and inner wall. The lacunæ are oval and the canaliculi are straight.

Underneath the laminar band is a central, irregularly shaped ring of Haversian systems, very narrow in the outer, wider in the anterior, and forming the whole of the inner and posterior wall. The systems are united by cross canals and exhibit some senile changes. Their lacunæ are oval and the canaliculi are straight.

Around the medullary canal is a cancellous ring of lamellæ. The bone is composed of about equal parts of Haversian systems and laminæ. The bone is unusually hard.

Type II-III, Ia, C.

LEFT FEMUR OF GIRAFFA CAMELOPARDALIS. GIRAFFE. NO. 27752, AMER. MUS. NAT. HIST.

Pl. 17, Fig. 262. Syn. Tab. VII

Antero-posterior diameter of bone, 72 mm.; lateral, 59 mm.

Antero-posterior diameter of medullary canal, 35 mm.; lateral, 30 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—Beginning in the outer wall, close to the posterior ridge and extending around the section to about the middle of the inner wall, is a wide band of laminæ, interrupted frequently by Haversian systems. The band forms the external half of the posterior, all of the outer, and two-thirds of the anterior and inner wall. The laminæ are separated and crossed by canals. Their lacunæ are well developed.

The whole posterior, inner lateral, and medullary portions of the anterior and posterior lateral wall are composed of Haversian systems with the exception of the internal circumferential lamellæ. The systems vary somewhat in size and are well developed. In the posterior wall they are separated by aggregations of oval lacunæ closely packed together.

Internal circumferential lamellæ with long lacunæ and straight canaliculi, widest in the outer wall, surround the medullary canal.

Type II-III, C.

LEFT FEMUR OF RHINOCEROS BICORNIS. RHINOCEROS. NO. 27757, AMER. MUS. NAT. HIST.

Pl. 17, Fig. 263. Syn. Tab. VII

Antero-posterior diameter of bone, 47.5 mm.; lateral, 130 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 23 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—The bone is extended laterally and outwardly by a very prominent, wide, curved process, occupying the middle portion of the femur. Only a few femora have such a process. For convenience in description the section may be divided into a body containing the medullary canal and adjoining middle portion and a curved cancellous process.

The body is composed of Haversian systems which form the entire inner wall and of Haversian systems and laminæ which form the anterior and posterior wall. The systems vary in size, communicate by cross canals, and have oval lacunæ with straight canaliculi. Around the medullary region they show senile changes and greater irregularity. Laminæ begin to appear in the anterior and posterior wall and rapidly displace the systems as they reach the middle portion. The middle portion is composed of long laminæ separated by wide canals. In the center, crude Haversian systems and short laminæ are found. The canals communicate with the medullary canal and with the cancellous spaces of the curved process. The lacunæ are oval and the canaliculi are bushy. The curved process is composed of narrow, bordering lamellæ with small Haversian systems, enclosing a wide central portion of cancellous bone, the spaces of which are relatively large. The spaces communicate with the long canals of the middle portion and also with the medullary canal. Internal circumferential lamellæ form an irregularly shaped ring around the medullary canal. Their lacunæ are oval. The bone exhibits predominating laminæ and Haversian systems with oval lacunæ and bushy and straight canaliculi. Haversian systems are found only in the inner half of the body.

Type II-III, C, senile.

RIGHT FEMUR OF EQUUS BURCHELLI GRANTI. ZEBRA. NO. 27749, AMER. MUS. NAT. HIST.

PL. 17, FIG. 264. SYN. TAB. VII

Antero-posterior diameter of bone, 43 mm.; lateral, 37 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 22 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—Three divisions are present. External circumferential lamellæ, frequently interrupted by Haversian systems, extend from the lateral boundaries of the posterior wall around the section. The lacunæ are oval and long. The systems are well developed.

The central ring is composed of a wide, horseshoe-shaped band of laminæ, interrupted in the anterior wall by groups of well developed Haversian systems. The lacunæ are oval and long and the canaliculi are straight.

The internal circumferential lamellæ form an enclosing ring around the medullary canal. In the anterior and posterior wall it takes the form of cancellous bone. The lacunæ are oval and long.

The posterior wall is composed entirely of Haversian systems of the (C) differentiation.

Type II-III, C.

LEFT FEMUR OF URSUS MARITIMUS. POLAR BEAR. NO. 35085, AMER. MUS. NAT. HIST.

PL. 17, FIG. 265. SYN. TAB. VII

Antero-posterior diameter of bone, 31 mm.; lateral, 38 mm.

Antero-posterior diameter of medullary canal, 18 mm.; lateral, 22 mm.

The medullary canal is full. Medullary index, 51%.

Structure.—The section has a rather peculiar shape. With the exception of the posterior ridge it is surrounded by laminæ, which, in the anterior wall, merge into lamellæ and are interrupted by Haversian systems. The central ring is composed of concentric rows of well developed Haversian systems alternating with laminæ, excepting in the posterior ridge which is all Haversian systems.

Internal circumferential lamellæ form a narrow ring around the medullary canal. The bone is more highly differentiated than the femur of the black bear.

Type II-III, C.

RIGHT FEMUR OF BUBALIS JACKSONI. HARTEBEEST. NO. 37815, AMER. MUS. NAT. HIST.

PL. 17, FIG. 266. SYN. TAB. VII

Antero-posterior diameter of bone, 32.5 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 16 mm.

The medullary canal is full. Medullary index, 39%.

Structure.—The section is composed mostly of laminæ. Around the bone is a wide horseshoe band of laminæ, interrupted by Haversian systems. The band forms the whole of the outer and anterior walls. Underneath the band in the inner wall is a narrow crescent of well developed Haversian systems. The posterior wall is composed of Haversian systems and short laminæ, between which are several vascular canals. A narrow ring of internal circumferential lamellæ, slightly wider in the inner wall, surrounds the medullary canal. The lacunæ are long and oval.

Type II-III, C.

LEFT FEMUR OF PHACOCHŒRUS AFRICANUS. WARTHOG. NO. 27762, AMER. MUS. NAT. HIST.

PL. 17, FIG. 267. SYN. TAB. VII

Antero-posterior diameter of bone, 24 mm.; lateral, 20.5 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 52%.

Structure.—A wide horseshoe band of laminæ surrounds the bone with the exception of the posterior ridge. The inner and outer portions of the posterior wall are composed entirely of laminæ. The anterior and lateral walls are about one half laminæ. The laminæ are long and short, have oval lacunæ and bushy canaliculi. The central ring is incomplete. It is composed of a crescent of well developed Haversian systems in the anterior and lateral wall. The systems are separated by short, oblique lamellæ. The posterior ridge is composed of Haversian systems of the (Ib) differentiation, between which lamellæ with oval lacunæ are prominent.

The internal circumferential lamellæ are fragmentary. The bone shows differentiation of structure in its laminæ and systems.

Type II-III, Ib, C.

LEFT FEMUR OF FELIS CONCOLOR. PANTHER. NO. 1492, AMER. MUS. NAT. HIST.

Pl. 18, Fig. 268. Syn. Tab. VII

Antero-posterior diameter of bone, 16 mm.; lateral, 19 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 76%.

Structure.—The external circumferential lamellæ appear only in the posterior and in the inner lateral wall. The central ring constitutes the principal part of the section. In the inner anterior wall the ring is divided into two equal portions by a narrow concentric lamina. The ring is composed of well developed Haversian systems. The internal circumferential lamellæ form a ring of varying widths around the medullary canal. It is widest in the outer wall.

Type I-II-III, C.

LEFT FEMUR OF GULO LUSCUS. WOLVERENE. NO. 22884, AMER. MUS. NAT. HIST.

Pl. 18, Fig. 269. Syn. Tab. VII

Antero-posterior diameter of bone, 10 mm.; lateral, 11.5 mm.

Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 31%.

Structure.—A wide ring of lamellæ and crude laminæ interrupted by Haversian systems surrounds the section with the exception of a small portion of the outer wall. It is frequently crossed by canals. The lacunæ are long and the canaliculi are straight.

The central ring is somewhat incomplete and composed of well developed Haversian systems. It reaches the surface in the outer wall. A ring of laminæ interrupted by a few Haversian systems surrounds the medullary canal.

Type I-II-III, C.

LEFT FEMUR OF ERIGNATHUS BARBATUS. SEAL. NO. 19347, AMER. MUS. NAT. HIST.

PL. 18, FIG. 270. SYN. TAB. VII

Antero-posterior diameter of bone, 19.5 mm.; lateral, 39 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 25 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—Three divisions are present. The external circumferential lamellæ form a narrow enclosing ring. The lacunæ are oval.

The central ring is composed of well developed Haversian systems, short laminæ, and lamellæ with cross canals intermixed. It shows no plan of arrangement, but a confusing mixture of units. The lacunæ are oval and long and the canaliculi are straight. The ring constitutes nearly all of the section. The internal circumferential lamellæ form an incomplete ring around the medullary canal. In the lateral walls the lamellæ take the cancellous form. The planless arrangement of its three units is somewhat significant.

Type II-III, C.

LEFT FEMUR OF BOS BUBALIS. WATER BUFFALO. NO. 27770, AMER. MUS. NAT. HIST.

PL. 18, FIG. 271. SYN. TAB. VII

Antero-posterior diameter of bone, 48 mm.; lateral, 45 mm.

Antero-posterior diameter of medullary canal, 24 mm.; lateral, 25 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—Beginning on the inner side of the posterior and extending around the inner, anterior, and a portion of the outer wall is a wide band of laminæ, short and long, crossed by a great number of branching canals and interrupted in the anterior and outer wall by a few Haversian systems. Underneath this band in the inner and anterior wall is a crescent of Havesian systems and lamellæ with oval lacunæ and bushy canaliculi. The crescent is crossed by numerous canals. The outer wall is composed of Haversian systems and short laminæ and the posterior wall of Haversian systems and inter-Haversian lamellæ with oval lacunæ and bushy canaliculi. The medullary canal is surrounded by a narrow ring of internal circumferential lamellæ.

Type II-III, Ib, C.

LEFT FEMUR OF OVIS MONTANA. MOUNTAIN SHEEP. CR. MED. COLL.

PL. 18, FIG. 272. SYN. TAB. VII

Antero-posterior diameter of bone, 20 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 12.5 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 60%.

Structure.—The bone is composed of short concentric laminæ enclosing the medullary canal, with the exception of the crescent of Haversian systems in the anterior and an area of Haversian systems in the posterior wall. A single concentric lamina divides the section into two parts. Each lamina is composed of a few lamellæ with well developed lacunæ and canaliculi. There is a crescent of well developed Haversian systems in the anterior wall bordering upon the internal circumferential lamellæ. The posterior wall is composed of well developed Haversian systems extending from the external surface of the bone to the internal circumferential lamellæ. A narrow ring of internal circumferential lamellæ with long lacunæ and straight canaliculi surrounds the medullary canal.

Type II-III, C.

FEMUR OF CEPHALOPHUS AFRICAN ANTELOPE. NO. 163255, U. S. NAT. MUS.

PL. 18, FIG. 273. SYN. TAB. VII

Antero-posterior diameter of bone, 15 mm.; lateral, 13.5 mm.

Antero-posterior diameter of medullary canal, 9 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 67%.

Structure.—The bone is composed of a wide horseshoe band of laminæ embracing the posterior ridge. The laminæ are long and short and are interrupted by a few Haversian canals in the external laminæ. They are crossed by numerous canals from the medullary canal. Their lacunæ are long and their canaliculi are straight. Underneath the laminæ and adjacent to the internal circumferential lamellæ is a narrow ring of Haversian systems. The systems form nearly the whole posterior ridge, and elsewhere are situated between the canals extending outward from the medullary canal. They are well developed. The medullary canal is surrounded by a narrow ring of internal circumferential lamellæ well developed.

Type II-III, C.

FEMUR OF RAPHICEROS. STEINBOK. NO. 164801, U. S. NAT. MUS.

PL. 18. FIG. 274. SYN. TAB. VII

Antero-posterior diameter of bone, 12 mm.; lateral, 12.5 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 43%.

Structure.—The section is surrounded by a narrow ring of lamellæ and Haversian systems. In the posterior lateral wall is a group of Haversian systems which forms nearly the whole wall. The lacunæ are long and their canaliculi bushy and straight. The remainder of the bone is composed of laminæ, crossed at various angles by canals and interrupted here and there by very crude Haversian systems of the (Ia) differentiation. The lacunæ are long and narrow.

Type II-III, Ia, C.

LEFT FEMUR OF GAZELLA GRANTI. GRANT'S GAZELLE. NO. 27762, AMER. MUS. NAT. HIST.

Pl. 18, Fig. 275. Syn. Tab. VII

Antero-posterior diameter of bone, 19 mm.; lateral, 19.5 mm.

Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The section is composed of a wide horseshoe band of laminæ embracing the posterior ridge. In the anterior wall they are interrupted by Haversian systems, especially near the circumference. They are long and short and their lacunæ are round and oval with bushy and straight canaliculi. Underneath the laminæ of the outer lateral, the anterior, and inner lateral wall is a crescent of Haversian systems well developed. The posterior ridge is composed mostly of Haversian systems. Internal circumferential lamellæ with narrow lacunæ and straight canaliculi surround the medullary canal.

Type II-III, C.

LEFT FEMUR OF KOBUS ELLIPSIPRYMNOS. WATER BUCK. NO. 27669, AMER. MUS. NAT. HIST.

Pl. 18, Fig. 276. Syn. Tab. VII

Antero-posterior diameter of bone, 28 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 18 mm.; lateral, 16 mm.

The medullary canal is full. Medullary index, 70%.

Structure.—Beginning on the outer side of the posterior ridge and extending around the outer and anterior wall is an external band of lamellæ, interrupted by Haversian systems of the (Ia) differentiation and by canals. Their lacunæ are long and their canaliculi are straight. The inner wall of the section is composed of laminæ which are continued around the section to the posterior ridge under the lamellar band of the anterior and outer wall. The laminæ are frequently interrupted by Haversian systems. Their lacunæ are long and their canaliculi are straight. The posterior ridge is composed of Haversian systems which are extended around the outer and anterior wall and border upon the medullary canal. Their lacunæ are long.

Type I-II-III, Ia, C.

RIGHT FEMUR OF ARCTOMYS MONAX. WOODCHUCK OR GROUND HOG. CR. MED. COLL.

Pl. 19, Fig. 277. Syn. Tab. VII

Antero-posterior diameter of bone, 6 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 4.5 mm.

The medullary canal is full. Medullary index, 74%.

Structure.—Two laminæ with long lacunæ and straight canaliculi, interrupted here and there by Haversian systems of the (Ia) differentiation, surround the section with the exception of the posterior ridge.

The central ring is composed of Haversian systems, irregular in shape and of the (C) differentiation, between which are groups of lamellæ extending in different directions. A wide ring of lamellæ, separated into laminæ, surrounds the medullary canal. The lacunæ are long and the canaliculi are straight.

Type II-III, Ia, C.

RIGHT FEMUR OF CANIS LATRANS. COYOTE. CR. MED. COLL.

PL. 19. FIG. 278. SYN. TAB. VII

Antero-posterior diameter of bone, 12 mm.; lateral, 11.5 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 68%.

Structure.—The section is surrounded by external circumferential lamellæ excepting its posterior ridge and anterior wall. Beginning on the outer lateral side of the posterior ridge the lamellæ separate into laminæ. As they pass around the outer lateral to the anterior wall the laminæ decrease in number until they are reduced to a few lamellæ. The lamellæ then pass around the inner wall as a narrow band.

Their lacunæ and canaliculi are well developed. Underneath the lamellæ and laminæ is a wide ring of well developed Haversian systems, widest in the posterior wall where they form nearly the whole thickness of the posterior ridge. The systems frequently unite by cross canals and have long, narrow lacunæ. The medullary canal is enclosed by a ring of lamellæ. In the lateral wall the lamellæ gradually thicken and separate into several laminæ which form half the thickness of the wall. They are well developed.

Type II-III, C.

RIGHT FEMUR OF CAPRA. GOAT. CR. MED. COLL.

PL. 19, FIG. 279. SYN. TAB. VII

Antero-posterior diameter of bone, 4.5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 3 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—The section is surrounded by a ring of laminæ, divided into short, long, and irregular segments by transverse canals and interrupted by small Haversian systems of the (Ib) differentiation. Underneath this is a wide central ring of laminæ arranged concentrically and obliquely and interrupted frequently by Haversian systems of the (Ib) and (C) differentiations. In the anterior and posterior wall are two crescents of Haversian systems, and in the outer portion of the posterior wall a group of Haversian systems.

A narrow ring of lamellæ surrounds the medullary canal. The lacunæ are generally oval and the canaliculi are straight.

Type II-III, Ib, C.

RIGHT FEMUR OF A BULL DOG (NOT A PURE BLOOD). NO. 292, CR. MED. COLL.

PL. 19, FIG. 279½. SYN. TAB. VII

Antero-posterior diameter of bone, 14.5 mm.; lateral, 12.5 mm.

Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 109%.

Structure.—The section is composed of a horseshoe of laminæ and lamellæ, separated into two bands by a central band of Haversian systems. The laminæ constitute the whole of the inner wall, and as they reach the anterior wall they become lamellæ, which are then separated into external and internal bands by a central band of Haversian systems. The three bands, external lamellar, central Haversian system, and internal lamellar form the outer wall. The internal lamellæ are frequently crossed by radiating canals. The posterior ridge is composed of Haversian systems with comparatively few lacunæ. Their bone substance is in excess of that usually seen. In the anterior wall near the medullary canal are four quite large openings.

Type I-II-III, C.

LEFT FEMUR OF A SHEPHERD DOG (NOT A PURE BLOOD). NO. 201, CR. MED. COLL.

PL. 19, FIG. 280. SYN. TAB. VII

Antero-posterior diameter of bone, 11 mm.; lateral, 10.5 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The section is surrounded by a horseshoe band of laminæ which constitutes the principal part of the bone. Between the laminæ are canals which widen into circular areas at intervals. The lacunæ are oval and long. The central ring is reduced to a long, narrow crescent of Haversian systems extending around the anterior, outer, and posterior wall. The posterior ridge is almost entirely composed of Haversian systems. The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type II-III, C.

RIGHT FEMUR OF A DOG. NO. 291, CR. MED. COLL.

PL. 19, FIG. 280½. SYN. TAB. VII

Antero-posterior diameter of bone, 16 mm.; lateral, 17 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 68%.

Structure.—The section is composed of a horseshoe band of lamellæ and laminæ, interrupted by Haversian systems of the (Ia) differentiation. In the outer wall the lamellæ are separated into two nearly equal concentric bands by a middle band of Haversian systems. The lamellar bands are frequently crossed by radiating canals and interrupted by crude Haversian canals. The lamellæ on reaching the anterior wall separate into laminæ, which constitute the whole inner wall. Here and there the canals between the laminæ widen into circular openings. The posterior ridge is composed of Haversian systems, between which are short lamellæ with round lacunæ. The internal circumferential lamellæ surround the medullary canal.

Type I-II-III, Ia, C.

FEMUR OF A FOX TERRIER (NOT A PURE BLOOD). NO. 202, CR. MED. COLL.

PL. 19, FIG. 281. SYN. TAB. VII

Antero-posterior diameter of bone, 11 mm.; lateral, 9.5 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 59%.

Structure.—The section is surrounded by a wide horseshoe of laminæ which forms three-fourths of the thickness of the wall of the bone. The canals between the laminæ widen at intervals into circular areas. The laminæ are frequently crossed by irregular canals. The lacunæ are oval. The central ring is a narrow crescent and is composed of well developed Haversian systems. The ring reaches the surface of the posterior ridge where it is composed of vascular canals surrounded by concentric lamellæ. Between the canals are long, minute, tendon insertions. The internal circumferential lamellæ form a narrow ring around the medullary canal. Just behind the ring are several large vascular spaces.

Type II-III, C.

RIGHT FEMUR OF A MONGREL DOG (NO CHARACTERISTIC FEATURES). NO. 200, CR. MED. COLL.

PL. 19, FIG. 282. SYN. TAB. VII

Antero-posterior diameter of bone, 12.5 mm.; lateral, 13 mm.

Antero-posterior diameter of medullary canal, 8.5 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 90%.

Structure.—The section is surrounded by a horseshoe band of laminæ and lamellæ. The laminæ form the whole width of the inner wall. They then become fewer in number as they reach the anterior wall, where they are reduced to a narrow lamellar band. The lamellæ then widen and separate into laminæ as the band reaches the posterior ridge. The central ring is reduced to a long, narrow crescent of Haversian systems which nearly encircles the section. The systems reach the surface of the posterior ridge and form nearly the whole width of the posterior wall. They are well developed. The internal circumferential lamellæ do not form an enclosing ring. In the posterior wall they form a narrow band, in the outer wall the band widens into laminæ, and in the anterior outer lateral wall the laminæ form three-fourths of the wall. In the anterior inner lateral wall the lamellæ and laminæ disappear altogether and Haversian systems form the boundary of the medullary canal.

Type II-III, C.

RIGHT FEMUR OF A BULL DOG (NOT A PURE BLOOD). NO. 204, CR. MED. COLL.

PL. 19, FIG. 283. SYN. TAB. VII

Antero-posterior diameter of bone, 13 mm.; lateral, 12 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 6.5 mm.

The medullary canal is full. Medullary index, 41%.

Structure.—The section is surrounded by a wide horseshoe of crude laminæ intermixed with Haversian systems. The shoe is widest in the outer wall where it forms half the width of the wall. In the inner wall the systems are irregular and more numerous than elsewhere. The central ring is composed of Haversian systems. It reaches the surface of the posterior ridge. Between the systems near the posterior surface and extending along the external boundary on either side of the ridge are oblique tendon insertions. The ring is narrowest in the outer wall. The internal circumferential lamellæ enclose the medullary canal. They form a thick band along the inner and anterior walls. The thick band is crossed frequently by cross canals.

Type II-III, C.

RIGHT FEMUR OF A COLLIE DOG (NOT A PURE BLOOD). NO. 203, CR. MED. COLL.

PL. 19, FIG. 284. SYN. TAB. VII

Antero-posterior diameter of bone, 13.5 mm.; lateral, 13 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 7.5 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—The section is enclosed by a horseshoe of lamellæ, interrupted by small Haversian systems and partially separated by canals. The lamellæ form nearly half of the width of the wall of the bone. The central ring is composed of well developed Haversian systems which constitute the entire posterior ridge with the exception of the internal lamellæ. The internal circumferential lamellæ form a ring of varying widths surrounding the medullary canal.

Type I-II-III, C.

RIGHT FEMUR OF A SPANIEL (NOT A PURE BLOOD). NO. 205, CR. MED. COLL.

PL. 19, FIG. 285. SYN. TAB. VII

Antero-posterior diameter of bone, 13 mm.; lateral, 13.5 mm.

Antero-posterior diameter of medullary canal, 8.5 mm.; lateral, 8.5 mm.

The medullary canal is full. Medullary index, 70%.

Structure.—The section is surrounded by a narrow horseshoe of lamellæ, widest in the inner wall. The central ring forms the greater portion of the width of the wall. It reaches the surface of the posterior ridge and constitutes nearly all of the posterior wall. The ring is composed of well developed Haversian systems. The internal circumferential lamellæ form a ring of lamellæ and laminæ extending in various directions.

Type II-III, C.

The femora of ten dogs were examined and no two of them showed the same structure. They ranged from a second to a second and third combination. In the combinations the proportions of the units varied greatly.

LEFT FEMUR OF LEPUS CUNICULUS. RABBIT. CR. MED. COLL.

Pl. 19, Fig. 286. Syn. Tab. VII

Antero-posterior diameter of bone, 5.5 mm.; lateral, 7.5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 74%.

Structure.—Around the bone is a ring of lamellæ of varying thicknesses. As a whole, it is narrow, and, in the posterior wall, merges into oblique laminæ which join the internal circumferential lamellæ. The lacunæ are long and narrow and the canaliculi are long and branching.

There is a central ring of incomplete Haversian systems and short, irregular laminæ occupying the anterior and inner wall. In the posterior wall this ring is interrupted by oblique, well developed Haversian systems and laminæ extending from the internal to the external circumferential lamellæ. In the outer wall there are wide, oblique canals separating irregular laminæ extending from the internal to the external lamellæ and interdigitating with extensions from the periosteum. These two oblique arrangements enclose a small crescent of irregular systems and lamellæ. The lacunæ are oval or long and the canaliculi are bushy.

Internal circumferential lamellæ of varying thickness and well developed surround the medullary canal. In the inner and posterior wall it merges into oblique, wide laminæ, separated by an oblique row of complete Haversian systems. To the outer side of this row of systems are three or four wide, oblique laminæ which appear to be extensions of the internal lamellæ.

Type I-II-III, C.

RIGHT FEMUR OF PROCYON LOTOR. RACCOON

Pl. 20, Fig. 287. Syn. Tab. VII

Antero-posterior diameter of bone, 9 mm.; lateral, 10 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 100%.

Structure.—The section is surrounded by external circumferential lamellæ. In the anterior and posterior inner wall the ring is thick and interrupted by Haversian systems of the (Ia) differentiation. The lacunæ are long and narrow and the canaliculi are long.

The central ring is composed of irregularly shaped Haversian systems well developed. It gradually increases in thickness in the inner wall until it reaches about the middle, where it forms two-thirds of the width of the wall. From this point it continues to increase to the middle of the anterior wall, where it forms four-fifths of the bone. The systems are strongly developed, their lacunæ are long and narrow, and their canaliculi are long and branching. Between the systems are short lamellæ. The Haversian canals frequently unite.

A ring of internal circumferential laminæ of varying thickness surrounds the medullary canal. In the inner wall and extending around the posterior region are short, oblique laminæ, forming, in some places, nearly one-half of the thickness of the bone. In the outer wall two or three laminæ form the medullary boundary. The lacunæ are long and narrow and the canaliculi are long and branching.

Type I-II-III, Ia, C.

OS PENIS OF THE RACCOON

Pl. 20, Fig. 288. Syn. Tab. VII

The os penis is introduced here because of its relation to the general bone structure of the animal and its relation of structure to function.

The antero-posterior diameter of the bone is 4 mm.; lateral, 4 mm.

The antero-posterior diameter of the central canal is 0.8 mm.; lateral, 0.8 mm.

The canal is very irregular in shape. The bone is of medium hardness.

The medullary canal is full. Medullary index, 4%.

Structure.—External circumferential lamellæ, rather incompletely developed, surround the bone. They are not equally distinct in all parts. In some places they are fairly well developed, while in others they are indistinct and interrupted by small, incomplete Haversian systems. The lacunæ are large, few in number, oval in shape, and have branching canaliculi.

A wide ring of large and small Haversian systems constitutes the central ring. The large systems occupy the inner portion of the ring, the small ones the outer portion. They are all fairly well developed. Their Haversian canals frequently communicate with each other; their cross-sections are circular; their lacunæ are few, long, and narrow; their canaliculi are long and branching; and their lamellæ are not clearly defined. Here and there short inter-Haversian lamellæ appear.

Internal circumferential lamellæ form a very irregular boundary of the medullary canal. The lacunæ are long and their canaliculi are very numerous and branching.

Type I-III, C.

FEMUR OF CANIS LUPUS. WOLF

PL. 20, FIG. 289. SYN. TAB. VII

Antero-posterior diameter of bone, 16.5 mm.; lateral, 7 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 77%.

Structure.—Beginning on both sides of the posterior ridge and extending around the two lateral portions of the wall of the bone are two wide bands of laminæ, interrupted by Haversian systems of the (Ia) and (C) differentiations. As the bands reach the anterior wall the laminæ are reduced to a narrow rim of external circumferential lamellæ. Beginning on both sides of the posterior wall, directly underneath the internal circumferential lamellæ and extending around the anterior wall, is a central crescent of well developed Haversian systems. Bordering the medullary surface of the anterior wall is an area of laminæ. The posterior ridge is composed of well developed Haversian systems. A narrow lamina surrounds the medullary canal.

Type II-III, Ia, C.

RIGHT FEMUR OF FELIS LEO. LION. AMER. MUS. NAT. HIST.

PL. 20, FIG. 290. SYN. TAB. VII

Antero-posterior diameter of bone, 26 mm.; lateral, 25.5 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 11.5 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—The section is partly surrounded by a band of lamellæ and crude laminæ, interrupted by Haversian systems of the (Ia) and (C) differentiations. The band is broken at the posterior ridge and outer antero-lateral wall by Haversian systems of the central ring.

The central ring occupies the posterior wall and the remainder of the section excepting that part immediately surrounding the medullary canal. It is composed of well developed Haversian systems, which are separated into two nearly equal portions by a narrow laminar extension of the wide band of the inner lateral wall.

The internal circumferential lamellæ form a narrow ring around the medullary canal. Immediately behind this, in the outer anterior wall, are a number of spaces.

Type I-II-III, Ia, C.

FEMUR OF CANIS. SMALL GREY FOX. CR. MED. COLL.

Pl. 20, Fig. 291. Syn. Tab. VII

Antero-posterior diameter of bone, 8 mm.; lateral, 9 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 6.5 mm.

The medullary canal is full. Medullary index, 80%.

Structure.—A ring of external circumferential lamellæ and laminæ, interrupted by Haversian systems of the (1a) differentiation, surrounds the bone. In the outer wall the lamellar ring is distinct, but in the inner wall it widens and separates into laminæ which occupy the whole thickness of the wall. The laminæ are short and are separated and crossed by intercommunicating canals. On the inner lateral side of the posterior wall is a ridge and the laminæ from the inner wall reach the surface at this point and appear to interdigitate with inward extensions from the periosteum. The lacunæ are long and narrow; the canaliculi are long and branching.

The central ring is composed of a wide crescent of well developed Haversian systems, the horns of which begin a short distance apart in the inner wall, while the widest part of the body occupies the outer wall. The systems are small and large, regular and irregular in shape. Their lamellæ are well defined; their lacunæ are long and narrow; and their canaliculi are branching. Their Haversian canals frequently communicate.

Around a portion of the medullary canal is a border of Haversian systems. The internal circumferential lamellæ form an incomplete ring around the medullary canal.

Type I-II-III, Ia, C.

LEFT FEMUR OF TAXIDEA AMERICANA. AMERICAN BADGER. AMER. MUS. NAT. HIST.

Pl. 20, Fig. 292. Syn. Tab. VII

Antero-posterior diameter of bone, 7 mm.; lateral, 8 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 40%.

Structure.—The section is surrounded in the anterior and lateral wall by external circumferential lamellæ. In the posterior wall the lamellæ are arranged obliquely. Under the lamellæ is a narrow crescent of small, well developed Haversian systems. Under the ring of systems is a wide ring of laminæ which in the posterior wall are arranged obliquely from the medullary canal. The canals between the laminæ are wide and branching. The lacunæ are oval and long.

Type I-II-III, C.

RIGHT FEMUR OF MELURSUS LABIATUS. SLOTH BEAR. NO. 22720, AMER. MUS. NAT. HIST.

PL. 20, FIG. 293. SYN. TAB. VII

Antero-posterior diameter of bone, 24 mm.; lateral, 24 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 21%.

Structure.—A horseshoe band of lamellæ, laminæ, and Haversian systems of the (Ia) differentiation embraces the posterior ridge. The band is widest in the inner wall, where it is composed of lamellæ and laminæ alternating with Haversian systems. The lacunæ are oval and long.

The central ring is composed of lamellæ, laminæ, and Haversian systems intermixed and alternating with each other. The systems are well developed. The posterior ridge is composed of Haversian systems and lamellæ having a direction from the external to the medullary surface.

The internal circumferential lamellæ form a narrow ring around the medullary canal. The lacunæ are long.

The bone is peculiar in the mixture of its units.

Type I-II-III, Ia, C.

LEFT FEMUR OF CANIS AUREUS. JACKAL. NO. 163293, U. S. NAT MUS.

PL. 20. FIG. 294. SYN. TAB. VII

Antero-posterior diameter of bone, 10 mm.; lateral, 8.5 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 85%.

Structure.—An irregular horseshoe of lamellæ and laminæ surrounds the section. On the outer side of the posterior ridge the lamellæ are wide, as they extend around the outer lateral wall they become very narrow, then widen again in the anterior wall to more than half the width, and as they pass around the inner wall they separate into laminæ, diminish in width, and terminate in the inner posterior region. The lamellæ are interrupted by Haversian systems of the (Ia) differentiation. They are frequently crossed by canals. Underneath the lamellæ and laminæ is an irregularly shaped central ring of Haversian systems. It forms the whole width of the posterior and adjacent inner wall. The systems are large and small and well developed. In the outer wall they are elongated in cross-section, especially in the anterior region. A narrow ring of internal circumferential lamellæ surrounds the medullary canal.

Type I-II-III, Ia, C.

RIGHT FEMUR OF DIDELPHYS VIRGINIANA. OPOSSUM. CR. MED. COLL.

PL. 20, FIG. 295. SYN. TAB. VII

Antero-posterior diameter of bone, 7 mm.; lateral, 8.5 mm.

Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—The bone presents a rudimentary appearance. It is composed of two wide external lamellar bands of incomplete formation, separated by a very narrow band of imperfectly developed Haversian systems, the whole occupying two-thirds of the posterior, outer, and anterior wall. The lamellar bands are composed of bone substance with large, oval lacunæ and extensive, bushy canaliculi forming an intricate network. At short intervals radiating canals appear, giving a bush-like appearance to the band. Just internal to this lamellar band is a narrow crescent of very incomplete Haversian systems occupying the anterior, outer, and posterior wall. The systems are of the (Ib) differentiation. Around the medullary canal of the anterior, outer, and posterior wall, internal circumferential lamellæ are well developed, reaching their greatest thickness in the outer wall. Their lacunæ are long and narrow and their canaliculi are long, straight, and branching.

The inner wall of the bone is extended in the form of a heavy ridge. It is composed of bone substance with heavy, oblique canals, from which are sent off dense networks of large canaliculi. This peculiar arrangement forms the external half of the ridge. The internal half is composed of incomplete Haversian systems, arranged in oblique rows, converging to a central point in the middle of the ridge. No internal circumferential lamellæ are found in this region.

Type I-III, Ib.

LEFT FEMUR OF MANIS. ANT-EATER. NO. 8351, U. S. NAT. MUS.

PL. 20, FIG. 296. SYN. TAB. VII

Antero-posterior diameter of bone, 9 mm.; lateral, 12.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5.5 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The three structural divisions appear in a somewhat modified form. A thick, incomplete ring of crude circumferential laminæ surrounds the section, excepting the posterior ridge. The laminæ are wide and composed of lamellæ having round and oval lacunæ with bushy canaliculi. They are separated by irregularly shaped canals which appear fragmentary in the section. In some situations the canals are branching and arranged in plexus form. The laminæ are frequently interrupted by Haversian canals of the (Ia) differentiation.

The central ring is composed of Haversian systems of the (Ib) differentiation. Their lacunæ are generally oval or round, in a few places long and narrow, and are at some distance from the Haversian canals. Their canaliculi are long. The rings break through the external circumferential laminæ at the inner ridge and form the whole width of the ridge, from the internal circumferential lamellæ to the external surface. The internal circumferential lamellæ of the different widths surround the medullary canal and in some places form cancellous structure. Their lacunæ are long, narrow, and well developed.

Type II-III, Ia, Ib.

RIGHT FEMUR OF HAPLODONTIA OLYMPICA. SEWELLEL, MOUNTAIN BEAVER, OR FARMER

Pl. 20, Fig. 297. Syn. Tab. VII

Antero-posterior diameter of bone, 5.5 mm.; lateral, 4 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 1.5 mm.

The medullary canal is full. Medullary index, 26%.

Structure.—The section is composed of a confusing mixture of lamellæ, laminæ, and Haversian systems of various differentiations. A narrow ring of lamellæ and crude Haversian systems surrounds the bone. The central ring is composed of crude Haversian systems, following no definite plan of arrangement and representing no definite state of development. The ring is crossed obliquely by a few laminæ and separated into two parts by concentric lamellæ. The internal circumferential lamellæ are incomplete.

Type I-II-III, Ia, Ib.

LEFT FEMUR OF ERETHIZON. PORCUPINE. CR. MED. COLL.

Pl. 20, Fig. 298. Syn. Tab. VII

Antero-posterior diameter of bone, 9.5 mm.; lateral, 7.5 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 12%.

Structure.—With the exception of the posterior wall the section is surrounded by a narrow band of external circumferential lamellæ. The posterior wall is composed of crude Haversian systems and inter-Haversian bone substance with oval lacunæ and bushy canaliculi.

The central ring is composed of Haversian systems and inter-Haversian bone substance with oval lacunæ and bushy canaliculi.

Internal circumferential lamellæ, crossed by many radiating canals and interrupted by Haversian systems of the (Ia) and (Ib) differentiation, surround the medullary canal.

Type I-III, Ia, Ib, C.

XI. MAN

One hundred and thirty-nine femora were examined.

GENERAL CHARACTER OF THE FEMUR

The femur of man presents a variety of shapes.

The medullary canals are generally full of cancellous bone, the meshes of which are filled with marrow. The medullary surfaces are almost always rough, but in some round sections the surfaces are smooth and cancellous bone is absent.

The average medullary index of the adult is 38.6%. Comparing the average index of man with that of other mammals, which is 63.3%, it will be noticed that the medullary canal is proportionately smaller and the wall of the bone thicker in man than in other mammals, or in bipeds than in quadrupeds.

The following types and combinations of types are found: the third, first and third, second and third, and first, second, and third. The third type occurs in the (Ia), (Ib), and (C) forms of differentiation. The pure third type bone without senile changes is rather infrequent. The human series consists of the fetal, infantile, adolescent, and adult femora. The fetal series includes the white and black races; the infantile, the yellow-brown, ancient Egyptian, and modern white races; the adolescent, the yellow-brown, ancient Egyptian, and white races; and the adult, all races.

FETAL HUMAN FEMORA

Seven femora were examined.

In the very young fetus of two to three months, basic bone substance is present and is marked off into regular areas by crude, branching canals. As fetal life advances the canals become less branching and more concentric. Gradually the basic bone becomes lamellated and then develops into the second type and remains so until birth. Throughout childhood and youth the laminæ tend to disappear and to be replaced by Haversian systems, until the bone development is completed.

In the formation of human fetal femora the following plan was observed. A horseshoe-shaped band of lamellæ or laminæ with oval lacunæ and bushy canaliculi is formed around the medullary canal, with the exception of the posterior ridge which appears to have an independent formation at a later date. As the bone develops the ridge fuses with the lateral wall.

RIGHT FEMUR OF A WHITE FETUS, TWO AND ONE-HALF MONTHS OLD

PL. 21, FIG. 299. SYN. TAB. VIII

Antero-posterior diameter of bone, 1.8.; lateral, 1.5 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.4 mm.

The medullary canal is full. Medullary index, 8%.

Structure.—The section is composed of two concentric rings of bone substance, external and internal. The external—much the wider—forms most of the wall of the bone, and is composed of channelled bone substance with round lacunæ and relatively few canaliculi. In some portions the elongated meshes assume the character of laminar formation.

The internal circumferential lamellæ with long lacunæ and bushy canaliculi form a narrow ring around the medullary canal.

Type I.

RIGHT FEMUR OF A WHITE FETUS, THREE AND ONE-HALF MONTHS OLD. NO. 89, CR. MED. COLL.

Pl. 21, Fig. 300. Syn. Tab. VIII

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 5%.

Structure.—The anterior wall is much thinner than the posterior. The section is composed of bone substance within which are irregularly shaped canals. Between the canals the bone substance, with oval lacunæ and short, bushy canaliculi, is arranged concentrically around the medullary canal. In some situations the canals with their adjacent lacunæ have the formations of Haversian systems of the (Ia) differentiation. The posterior ridge forms the whole posterior wall, and is composed of bone substance with wide canals having a direction from the external to the medullary surface and presenting the appearance of long canals divided into shorter ones until crude Haversian canals are formed. The bone substance has oval lacunæ and bushy canaliculi. The medullary canal is small and concentrically situated.

Type II-III, Ia.

RIGHT FEMUR OF A WHITE FETUS, FOUR MONTHS. NO. 90, CR. MED. COLL.

Pl. 21, Fig. 301. Syn. Tab. VIII

Antero-posterior diameter of bone, 3.5 mm.; lateral, 2.5 mm.

Antero-posterior diameter of medullary canal, 0.6 mm.; lateral, 0.5 mm.

The medullary canal is full. Medullary index, 3%.

Structure.—The anterior wall is much thinner than the posterior. The section is composed of bone substance with oval lacunæ and bushy canaliculi, interrupted by wide, irregular canals bent around the medullary canal in the shape of a horseshoe. A few crude, elongated Haversian systems are found in the posterior wall. The posterior ridge is composed of a few undeveloped Haversian systems of the (Ib) differentiation and inter-Haversian bone substance with wide canals, extending from the external to the medullary surface. The

Haversian systems of the ridge are somewhat better developed than in the three months' fetus.

Type II-III, Ib.

RIGHT FEMUR OF A WHITE FETUS, FIVE TO SEVEN MONTHS. NO. 248045, U. S. NAT. MUS.

PL. 21, FIG. 302. SYN. TAB. VIII

Antero-posterior diameter of bone, 3.5 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 0.5 mm.; lateral, 0.5 mm.

The medullary canal is very small and occupies a very eccentric position. Medullary index, 2%.

Structure.—The section is composed of a wide horseshoe band of long and short laminæ arranged around the medullary canal. The toe forms the very narrow anterior wall and the heel embraces the very wide posterior ridge. The laminæ have central canals and are composed of lamellæ with oval lacunæ and bushy canaliculi. They widen and shorten as they approach the posterior ridge and on either side of it they have become Haversian systems of the (Ib) differentiation. The posterior ridge is composed of long and short spaces surrounded by lamellæ extending from the external to the medullary surface. The section exhibits the early formation of laminæ, the horseshoe arrangement, the formation of Haversian systems, and the later formation of the posterior ridge. Two laminæ with round and oval lacunæ and short bushy canaliculi surround the medullary canal.

Type II-III, Ib.

RIGHT FEMUR OF A WHITE FETUS, EIGHT TO NINE MONTHS. NO. 228842, U. S. NAT. MUS.

PL. 21, FIG. 303. SYN. TAB. VIII

Antero-posterior diameter of bone, 4.5 mm.; lateral, 5 mm.

Antero-posterior diameter of medullary canal, 1 mm.; lateral, 1 mm.

The medullary canal is irregular in shape and is situated in the anterior half of the microsection. Medullary index, 4%.

Structure.—Around the outside of the section—posterior ridge excepted—is a narrow band of incompletely developed lamellæ with oval lacunæ and short, bushy canaliculi. The remainder of the anterior and lateral wall is composed of a wide, horseshoe-shaped band enclosing the medullary canal. It is composed of long laminæ with central canals gradually shortening and widening as they pass around the lateral wall until they are transformed into oval Haversian systems close to the posterior ridge. The posterior ridge is composed of elongated, crude Haversian systems of the (Ib) differentiation, and short laminæ extending from the external to the medullary surface and at right angles to the laminæ of the lateral wall. In the center of the ridge is a narrow space where the wall of the bone has united or is about to unite. Many large oval lacunæ are found in the bone substance between the systems. The bone shows the formation of Haversian systems, the filling of the posterior ridge by laminæ at right angles to the lateral walls, and the line of union as the walls fuse together in the posterior ridge. A wide band of lamellæ with oval lacunæ and bushy canaliculi surrounds the medullary canal.

Type II-III, Ib.

RIGHT FEMUR OF AMERICAN NEGRO FETUS, NINE MONTHS. NO. 228801, U. S. NAT. MUS.

PL. 21, FIG. 304. SYN. TAB. VIII

Antero-posterior diameter of bone, 4.5 mm.; lateral, 5.5 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 15%.

Structure.—The anterior wall is composed of a few external circumferential lamellæ, which, as they leave the mid-line, soon spread out and enclose elongated, crude Haversian systems of the (Ib) differentiation. The systems, which appear to be laminæ crudely bent around and along wide, short canals, assume a concentric arrangement and enclose the medullary canal in the form of a horseshoe. The posterior ridge is then formed and fuses with the lateral wall. The lacunæ are oval; the canaliculi are comparatively few and bushy. In the mid-line of the anterior wall the external circumferential lamellæ are distinctly separated from the crude Haversian systems, but this line of separation soon becomes indistinct. The Haversian systems vary in shape and completeness in the different portions of the wall. In the anterior portion they are round or oval, especially just beneath the external circumferential lamellæ where they are most complete. The Haversian canals are relatively wide. The lacunæ of the systems form single concentric rings around the Haversian canals and at some distance from them. They are oval with short, bushy canaliculi. The Haversian systems gradually elongate and become extremely elliptical as they approach the posterior ridge. Here the Haversian canals are long, wide, and generally parallel. They occupy nearly the whole thickness of the posterior wall and extend from the external to the medullary surface. The Haversian canals of the lateral wall are wide, irregular, and long, but are generally parallel with the external surface of the bone. The lacunæ are oval, few, and confined to a single concentric row situated at some distance from the canal. The posterior ridge appears to be formed at a later date than the anterior and lateral walls. The internal circumferential lamellæ with long lacunæ and straight canaliculi are present in the anterior wall, but not elsewhere.

Type II-III, Ib.

RIGHT FEMUR OF CRANIORRHACHISCHISIS—WHITE FETUS. NO. 91, CR. MED. COLL.

Pl. 21, Fig. 305. Syn. Tab. VIII

Antero-posterior diameter of bone, 6 mm.; lateral, 6 mm.

Antero-posterior diameter of medullary canal, 3 mm.; lateral, 2.5 mm.

The medullary canal is full. Medullary index, 26%.

Structure.—The bone has no distinct divisions. The anterior wall is thinnest; the posterior is thickest. The bone is composed of a wide horseshoe of irregular, concentric laminæ with wide canals surrounding the medullary canal. The laminæ of the posterior ridge with their wide canals shorten, widen, and become crude, elongated Haversian systems, running from the external to the medullary surface and at right angles to the laminæ of the lateral wall. The lacunæ are oval and the canaliculi are bushy. The femur is larger than that of the normal fetus of the same age.

Type II-III, Ib.

In the development of human fetal femora some of the Haversian systems appear to be produced by the aberrant method of formation; that is, by the transformation of laminæ into Haversian systems.

XII. MAN—BLACK RACE

General Character of the Femur

The bones vary in shape. The medullary canals are full and cancellous bone is prominent. The medullary surfaces are very much corrugated and irregular in character. The medullary index varies from 17% to 92%, with an average of 41.9%. The type of structure ranges from a first and third to a complete third, and the majority are type combinations rather than single types. The first and third and first, second and third are the most frequent combinations. Senile changes are found in many femora. The bone units are incompletely and completely differentiated.

Detailed Examination

LEFT FEMUR OF NEGRO. NO. 228481, U. S. NAT. MUS.

Pl. 21, Fig. 306. Syn. Tab. VIII

Antero-posterior diameter of bone, 29 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—The external circumferential lamellæ, in fragments, surround the bone. The lacunæ are long and narrow and the canaliculi are straight.

The central ring, forming nearly the whole thickness of the wall of the bone, is composed of well developed Haversian systems with little or no inter-Haversian lamellæ. The horseshoe areas have been displaced entirely by well developed Haversian systems. The internal circumferential lamellæ with long lacunæ and straight canaliculi surround the medullary canal.

Type III, C.

The degree of development of a human femur is proportionate to the degree of displacement of its lamellæ or laminæ by Haversian systems.

FEMUR OF WHITE AND NEGRO MIXED, AT LEAST ONE-HALF WHITE.

NO. 247368, U. S. NAT. MUS.

PL. 21, FIG. 307. SYN. TAB. VIII

Antero-posterior diameter of bone, 22 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 30%.

Structure.—The external circumferential lamellæ, in fragments, surround the bone. Their lacunæ and canaliculi are well developed. There is little evidence of the horseshoe band of lamellæ. The central ring is composed of Haversian systems and forms nearly the whole width of the wall. The systems are of unequal sizes, some are small and others are large relatively, but generally they are rather small. There is also a corresponding variation in the diameters of the Haversian canals. The lacunæ and canaliculi of the Haversian systems are of the fully developed variety. Many Haversian systems are senile.

The internal circumferential lamellæ with long lacunæ and straight canaliculi surround the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A NEGRO. NO. 3, MED. DEPT. TULANE UNIV.

PL. 21, FIG. 308. SYN. TAB. VIII

Antero-posterior diameter of bone, 30 mm.; lateral, 24 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 41%.

Structure.—External circumferential lamellæ with long lacunæ and straight canaliculi are fragmentary. The central ring forms most of the bone and is composed of Haversian systems of the (C) differentiation. Many show senile changes. A narrow ring of internal circumferential lamellæ surrounds the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A NEGRO. NO. 87, MED. DEPT. TULANE UNIV.

PL. 22, FIG. 309. SYN. TAB. VIII

Antero-posterior diameter of bone, 27.5 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 17 mm.

The medullary canal is full. Medullary index, 54%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of large, small, and irregular Haversian systems, which show marked senile changes. The internal lamellæ form a fragmentary ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A NEGRO. NO. 7, MED. DEPT. TULANE UNIV.

PL. 22, FIG. 310. SYN. TAB. VIII

Antero-posterior diameter of bone, 27 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 19 mm.; lateral, 18 mm.

The medullary canal is full. Medullary index, 74%.

Structure.—The external lamellæ are fragmentary. The central ring is composed of Haversian systems with few senile changes. The internal lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A NEGRO. NO. 4, MED. DEPT. TULANE UNIV.

PL. 22, FIG. 311. SYN. TAB. VIII

Antero-posterior diameter of bone, 30 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 21 mm.; lateral, 13 mm.

The medullary canal is full. Medullary index, 65%.

Structure.—The external circumferential lamellæ form a narrow enclosing ring, excepting in the posterior ridge where it is absent. The central ring forms most of the section and is composed of regular, well developed Haversian systems, excepting in the inner wall where the systems are much elongated.

The internal circumferential lamellæ are fragmentary.

Type III, C.

LEFT FEMUR OF A NEGRO. NO. 84, MED. DEPT. TULANE UNIV.

PL. 22, FIG. 312. SYN. TAB. VIII

Antero-posterior diameter of bone, 24 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 13 mm.

The medullary canal is full. Medullary index, 48%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of well developed Haversian systems. A narrow ring of internal circumferential lamellæ surrounds the medullary canal.

Type III, C.

LEFT FEMUR OF A NEGRO. NO. 10, MED. DEPT. TULANE UNIV.

Pl. 22, Fig. 313. Syn. Tab. VIII

Antero-posterior diameter of bone, 26 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—The section is composed of a wide background of the lamellar horseshoe occupying the lateral wall. The lamellæ are frequently interrupted by Haversian systems of the (C) differentiation. In the anterior wall the lamellæ are replaced by Haversian systems.

The remainder of the section is composed of well developed Haversian systems. Cancellous bone surrounds the medullary canal.

Type I-III, C.

RIGHT FEMUR OF A FEMALE NEGRO. AGE 40. NO. 123, MED. DEPT. TULANE UNIV.

Pl. 22, Fig. 314. Syn. Tab. VIII

Antero-posterior diameter of bone, 28 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 25%.

Structure.—The external circumferential lamellæ appear only in fragments. The central ring, which constitutes most of the bone, is composed of Haversian systems, many of which are senile. The internal circumferential lamellæ form a narrow ring around the medullary canal. The lacunæ of all units are oval and long and the canaliculi are straight.

Type III, C, senile.

LEFT FEMUR OF A NEGRO. AGE 40. NO. 79, MED. DEPT. TULANE UNIV.

Pl. 22, Fig. 315. Syn. Tab. VIII

Antero-posterior diameter of bone, 30.5 mm.; lateral, 26.5 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 46%.

Structure.—The external circumferential lamellæ appear only in fragments. The central ring forms most of the section and is composed of Haversian systems. Around the medullary region nearly half of the wall of the bone is composed of Haversian systems in an extremely senile condition. The systems of the peripheral portion are in pretty good condition, although senile changes are present to some extent.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A NEGRO. NO. 224714, U. S. NAT. MUS.

Pl. 22, Fig. 316. Syn. Tab. VIII

Antero-posterior diameter of bone, 34 mm.; lateral, 36 mm.

Antero-posterior diameter of medullary canal, 21 mm.; lateral, 21 mm.

The medullary canal is full. Medullary index, 56%.

Structure.—Beginning on the inner side of the posterior ridge and extending around the lateral to the anterior wall is one-half of the lamellar horseshoe described in the foregoing femora. The lamellar shoe is studded with many Haversian systems. The central ring is narrow and composed of Haversian systems, many of which are senile. The posterior ridge and adjoining outer wall are composed entirely of Haversian systems. Internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, C, senile.

LEFT FEMUR OF A NEGRO. NO. 11, MED. DEPT. TULANE UNIV.

Pl. 22, Fig. 317. Syn. Tab. VIII

Antero-posterior diameter of bone, 32 mm.; lateral, 26.5 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 22%.

Structure.—The remains of the lamellar horseshoe band are evident. It is narrow in the outer posterior, widens to one-third the width of the anterior, and extends along the inner wall as a wide band. The band is interrupted by Haversian systems in the lateral wall and by Haversian canals of the (Ia) differentiation in the anterior wall. The central ring is composed of well developed Haversian systems. The internal lamellæ form a wide ring around the medullary canal.

Type I-III, Ia, C.

RIGHT FEMUR OF A NEGRO. NO. 2, MED. DEPT. TULANE UNIV.

Pl. 23, Fig. 318. Syn. Tab. VIII

Antero-posterior diameter of bone, 30 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 36%.

Structure.—The external circumferential lamellæ are fragmentary. Beginning on the outer side of the posterior ridge and extending around the external half of the outer wall is a wide band of alternating laminæ and Haversian systems. Underneath the band is a central ring of Haversian systems. The anterior, inner, and posterior wall is composed almost entirely of Haversian systems. The internal circumferential lamellæ form a narrow, enclosing ring around the medullary canal.

Type I-II-III, C.

LEFT FEMUR OF A NEGRO. NO 56, MED. DEPT. TULANE UNIV.

PL. 23, FIG. 319. SYN. TAB. VIII

Antero-posterior diameter of bone, 27.5 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 43%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of a wide band of lamellæ with Haversian systems in the outer and anterior wall and of Haversian systems with some inter-Haversian lamellæ in the inner and posterior wall. The systems are well developed but senile to a great extent. The internal circumferential lamellæ are fragmentary.

Type I-III, C, senile.

LEFT FEMUR OF A NEGRESS. NO. 220, CR. MED. COLL.

PL. 23, FIG. 320. SYN. TAB. VIII

Antero-posterior diameter of bone, 30 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 18 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—A wide circumferential horseshoe band of lamellæ forms the background of the section. It is narrowest in the inner, forms two-thirds of the anterior, and over half of the outer wall. In these situations the lamellæ are to some extent displaced by Haversian systems of the (Ia) and (C) differentiations. The central ring is narrow and is composed of Haversian systems, many of which are senile. There are relatively few cross canals. The internal circumferential lamellæ form a narrow ring which becomes cancellous.

Type I-III, Ia, C, senile.

RIGHT AMPUTATED FEMUR OF A NEGRESS. NO. 220, CR. MED. COLL.

PL. 23, FIG. 321. SYN. TAB. VIII

The femur is amputated at lower third.

Antero-posterior diameter of bone, 30 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 24 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 92%.

Structure.—A wide circumferential horseshoe of lamellæ surrounds the section. It gradually increases in width in the inner and outer, and constitutes nearly the whole of the anterior wall. It is interrupted by Haversian systems of the (Ia) and (C) differentiations. The central ring is composed of Haversian systems of varying sizes. The communicating canals between the systems are few. There seems to be great variation in the different femora in this respect, and their variation affords a possible explanation of senile changes in bone. Near the medullary canal the senility is marked. The Haversian systems here are practically gone. The wall of the bone, including the posterior ridge, is very thin. The internal circumferential lamellæ are fragmentary. The senile changes are much more pronounced than in the left femur and may be the result of disuse.

Type I-III, Ia, C, senile.

LEFT FEMUR OF A NEGRESS. AGE 14. NO. 226, CR. MED. COLL.

PL. 23, FIG. 322. SYN. TAB. VIII

The mother is white and the father is not a pure black. The child died from the effects of carbolic acid taken for suicidal purposes. The upper third of the femur has a very small medullary canal.

Antero-posterior diameter of bone, 24 mm.; lateral, 18 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 34%.

Structure.—The posterior ridge is thick and composed of irregularly shaped Haversian systems, separated in the circumferential portion by bone substance with round and oval lacunæ and bushy canaliculi. Numerous canals surrounded by clear areas appear. The external circumferential lamellæ form an enclosing ring. The central ring is composed of Haversian systems, which are oval and round in cross-section and separated in places by short laminæ. Their lacunæ are generally oval; otherwise the systems are fairly well developed. The internal circumferential lamellæ are fragmentary, excepting in the inner wall where they form a wide crescent. The bone is not quite complete.

Type I-III, C.

FEMUR OF A NEGRO. NO. 1, MED. DEPT. TULANE UNIV.

PL. 23, FIG. 323. SYN. TAB. VIII

Antero-posterior diameter of bone, 23 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—Beginning on both sides of the posterior ridge and extending around the section is a horseshoe of lamellæ, laminæ, and Haversian systems of the (Ia) and (C) differentiations. The shoe is crossed by frequent canals. Under the horseshoe is a middle ring of well developed Haversian systems which reaches the external surface of the posterior ridge.

Internal circumferential lamellæ form a narrow ring around the medullary canal. The section is nearly half lamellæ.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A KAFFIR NEGRO. NO. 263196, U. S. NAT. MUS.

Pl. 23, Fig. 324. Syn. Tab. VIII

Antero-posterior diameter of bone, 27 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 11.5 mm.

The medullary canal is partly surrounded by cancellous bone and is full. Medullary index, 32%.

Structure.—The external circumferential lamellæ are fragmentary. Beginning on the outer side of the posterior ridge and extending around the outer lateral wall is a wide external band of elongated Haversian systems in a background of lamellæ. This band, one-half the width of the wall, bends inward toward the internal circumferential lamellæ as it approaches the anterior wall and then merges into the Haversian systems of that wall. In the inner wall is a similar, narrower external band beginning near the posterior ridge, extending around the lateral, widening, curving inward toward the medullary canal, and merging into the Haversian systems of the anterior wall. These bands are the remains of the lamellar horseshoe. Their lacunæ are oval and narrow. Underneath these bands is an irregularly shaped ring of well developed Haversian systems forming nearly the whole width of the anterior and posterior wall. They communicate freely by cross canals and their lacunæ are well developed. The internal circumferential lamellæ surround the medullary canal as cancellous bone. In the lateral inner wall they widen and separate into laminæ, which spread toward the external surface and occupy half of the width of the wall in the widest place. The lacunæ are oval and narrow.

Type I-III, C.

RIGHT FEMUR OF A NEGRO. NO. 248674, U. S. NAT. MUS.

Pl. 23, Fig. 325. Syn. Tab. VIII

Antero-posterior diameter of bone, 30 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 12.5 mm.

There is little cancellous bone around the medullary canal. The bone is a little larger than the left femur.

The medullary canal is full. Medullary index, 32%.

Structure.—The external circumferential lamellæ are not distinct from the underlying structures. Beginning on both sides of the posterior ridge and extending around the section is a wide horseshoe-shaped band of laminæ and lamellæ. The toe of the shoe forms nearly the whole of the anterior wall and the heel nearly one-third of the posterior wall. In the outer lateral wall the heel of the shoe is composed of laminæ, separated by canals and crude Haversian systems. The laminæ gradually widen and increase in number and bend inwards nearly to the medullary canal as they reach the anterior wall. Here the laminar structure spreads out into a wide band of lamellæ which forms nearly all of the anterior wall. In this band are a great number of crude Haversian systems of the (Ia) differentiation arranged in concentric lines. After leaving the anterior, the lamellæ gradually become narrow until they form about one-third the width of the posterior wall. Underneath the horseshoe band is an irregularly shaped ring of Haversian systems which widens and forms nearly the whole posterior ridge. The systems are often separated by lamellæ. The internal circumferential lamellæ surround the medullary canal and are widest in the outer wall. The lacunæ are oval and narrow.

Type I-II-III, Ia, C.

LEFT FEMUR OF A NEGRO. NO. 248674, U. S. NAT. MUS.

Pl. 24, Fig. 326. Syn. Tab. VIII

Antero-posterior diameter of bone, 29 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—Beginning on both sides of the posterior ridge and extending around the external portion of the section is a wide horseshoe-shaped band of laminæ, lamellæ, and Haversian systems. In the outer wall the heel is composed of a wide band of lamellæ, interrupted by a few Haversian systems of the (Ia) differentiation, and in the inner wall of laminæ with many systems of the same grade. The lamellar and laminar bands rapidly widen about the mid-lateral wall and bend inward nearly to the medullary canal as they reach the anterior and form the whole width of the anterior wall, excepting the internal circumferential lamellæ. In the anterior wall the lamellæ form a background which is thickly set with crude Haversian systems of the (Ia) differentiation. Underneath the horseshoe and between it and the medullary canal the following structures are found: In the inner wall short, wide, irregular bands appear, interrupted by Haversian systems, well developed. In the outer wall the systems are much more closely set and better developed. The posterior ridge is composed entirely of systems, well developed. The lacunæ are well developed.

The internal circumferential lamellæ surround the medullary canal, widest in the outer wall.

Type I-II-III, Ia, C.

Since the lamellar and laminar structures constitute such an important part of the femora of the negro, No. 248674, it was thought best to examine sections of all of the long bones of this negro in order to ascertain, if possible, whether or not the lamellar and laminar structures are accidental or characteristic of all the long bones of that individual. The following long bones have, therefore, been examined: Tibia and fibula, radius and ulna, humerus, clavicle and metatarsal bone of the great toe.

TIBIA OF NEGRO, NO. 248674, U. S. NAT. MUS.

PL. 24, FIG. 327. SYN. TAB. VIII

Structure.—Beginning with the inner ridge and extending laterally in both directions is a wide external band of lamellæ and laminæ, interrupted by Haversian systems of the (Ia) differentiation. A wide external band of lamellæ and laminæ also forms the boundary of the outer wall. The anterior and posterior walls are mostly Haversian systems. Underneath the horseshoe is an irregular central ring of Haversian systems, well developed. The internal circumferential lamellæ are arranged in places in the form of cancellous bone. The lacunæ are oval and long and the canaliculi are bushy. The tibia has practically the same type combination as the femur.

Type I-II-III, Ia, C.

FIBULA OF NEGRO, NO. 248674, U. S. NAT. MUS.

PL. 24, FIG. 328. SYN. TAB. VIII

Structure.—A wide lamellar and laminar band, interrupted in places by Haversian systems of the (Ia) and (C) differentiations, surrounds the bone, excepting the anterior wall where the Haversian systems form the circumference. The band is widest in the posterior wall. Underneath the band is an irregular ring of Haversian systems well developed. The lacunæ are oval and long. The internal circumferential lamellæ form the boundary of the medullary canal and are thickest in the posterior wall. The bone shows the same structure as the femur.

Type I-II-III, Ia, C.

ULNA OF NEGRO, NO. 248674, U. S. NAT. MUS.

PL. 24, FIG. 329. SYN. TAB. VIII

Structure.—The section is surrounded—posterior ridge excepted—by a wide horseshoe of lamellæ, interrupted by Haversian systems of the (Ia) and

(C) differentiation. The central ring is composed of well developed Haversian systems, separated in some places by laminæ. Internal circumferential lamellæ, wide in some places and interrupted by Haversian systems of the (Ia) differentiation, surround the central canal.

Type I-II-III, Ia, C.

RADIUS OF NEGRO, NO. 248674, U. S. NAT. MUS.

Pl. 24, Fig. 330. Syn. Tab. VIII

Structure.—The section is surrounded by a wide horseshoe band of lamellæ, interrupted by scattering Haversian systems of the (Ia) and (C) differentiations. The central ring, narrow and irregular, is composed of Haversian systems and inter-Haversian lamellæ. The systems are well developed. Internal circumferential lamellæ of varying widths surround the central canal.

Type I-III, Ia, C.

HUMERUS OF NEGRO, NO. 248674, U. S. NAT. MUS.

Pl. 24, Fig. 331. Syn. Tab. VIII

Structure.—About half of the section is composed of lamellæ, interrupted by scattering, well developed Haversian systems and Haversian systems of the (Ia) differentiation, and the remaining half of well developed Haversian systems. Internal circumferential lamellæ form a ring of varying widths around the medullary canal.

Type I-III, Ia, C.

CLAVICLE OF NEGRO, NO. 248674, U. S. NAT. MUS.

Pl. 24, Fig. 332. Syn. Tab. VIII

Structure.—The section is about half surrounded by a wide band of lamellæ and laminæ, which alternate with concentric rows of Haversian systems. The remaining half is composed of well developed Haversian systems, separated in some places by short laminæ. External and internal circumferential lamellæ form narrow rings around the bone and central canal.

Type I-II-III, C.

METATARSAL BONE OF THE GREAT TOE. NEGRO, NO. 248674, U. S. NAT. MUS.

Pl. 24, Fig. 333. Syn. Tab. VIII

Structure.—The inner one-half of the wall of the bone is composed of lamellæ with a few crude Haversian systems of the (Ia) differentiation. The outer half is composed of well developed Haversian systems between narrow external and internal circumferential lamellæ.

Type I-III, Ia, C.

Reviewing the long bones of this negro, No. 248674, it may be observed that they all conform to the first and third or first, second, and third types of structure, which types must be considered basic for this individual.

LEFT FEMUR OF A NEGRO. NO. 224713, U. S. NAT. MUS.

Pl. 24, Fig. 334. Syn. Tab. VIII

Antero-posterior diameter of bone, 35 mm.; lateral, 24 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 12 mm.

The medullary canal is full; cancellous bone is prominent in the posterior wall. Medullary index, 40%.

Structure.—The section is surrounded by a more or less fragmentary ring of lamellæ, laminæ, and Haversian systems. The ring is wide and broken by Haversian systems of the central ring in the posterior and inner wall. The central ring is composed of well developed Haversian systems and inter-Haversian lamellæ. Internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A NEGRO. NO. 83, MED. DEPT. TULANE UNIV.

Pl. 25, Fig. 335. Syn. Tab. VIII

Antero-posterior diameter of bone, 30 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 19%.

Structure.—Beginning on both sides of the posterior ridge and extending around the section is a horseshoe of lamellæ, laminæ, and Haversian systems of the (Ia) and (C) differentiations. It is thin in the outer and thick in the remaining wall. The central ring is irregular and incomplete and composed of well developed Haversian systems with long, narrow lacunæ and straight canaliculi. The internal circumferential lamellæ form a very irregular ring, which, in the outer wall, spreads out into a curved, fan-shaped area of laminæ occupying most of that wall. The leaves of the fan then merge into a wide band of lamellæ, which bends inward to the medullary surface of the anterior wall. The fan encloses several complete Haversian systems and short canals.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A NEGRO. NO 6, MED. DEPT. TULANE UNIV.

PL. 25, FIG. 336. SYN. TAB. VIII

Antero-posterior diameter of bone, 33.5 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 17%.

Structure.—With the exception of the posterior ridge, the section is surrounded by a band of lamellæ of varying widths, interrupted by Haversian systems of the (Ia) and (C) differentiations. On both sides of the ridge the lamellæ are separated into crude laminæ by short concentric canals. The lamellæ occupy nearly the whole of the anterior wall. The central ring is very irregular and limited to the posterior and inner wall. It is composed of well developed Haversian systems and inter-Haversian lamellæ.

Internal circumferential lamellæ form a very irregular ring around the medullary canal. In the outer wall it expands into a wide semicircular area of laminæ, interrupted by Haversian systems of the (Ia) and (C) differentiations.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A NEGRO. NO. 63, MED. DEPT. TULANE UNIV.

PL. 25, FIG. 337. SYN. TAB. VIII

Antero posterior diameter of bone, 32 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—A narrow ring of external circumferential lamellæ surrounds the bone. Beginning on the outer side of the posterior ridge and extending around the outer lateral and anterior wall is a wide band of lamellæ, laminæ, and Haversian systems. After leaving the anterior wall the lamellar band is displaced by Haversian systems and as the posterior wall is approached the lamellar band again appears. These interrupted bands are the remains of the horseshoe. Underneath the band is an incomplete central ring of well developed Haversian systems.

The internal circumferential lamellæ form an enclosing ring around the medullary canal. It is widest in the inner wall.

Type I-II-III, Ia, C.

LEFT FEMUR OF A NEGRO. NO. 5, MED. DEPT. TULANE UNIV.

PL. 25, FIG. 338. SYN. TAB. VIII

Antero-posterior diameter of bone, 25 mm.; lateral, 24 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 67%.

Structure.—A wide horseshoe band of lamellæ and laminæ, interrupted by Haversian systems of the (Ia) and (C) differentiations, surrounds the section. The band is narrow in the inner wall. The central ring is narrow and irregular and composed of Haversian systems and inter-Haversian lamellæ.

Internal circumferential lamellæ form an irregular ring around the medullary canal. In the inner wall they extend outward in an oblique direction and are separated by canals having the same direction.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A NEGRO. NO. 8, MED. DEPT. TULANE UNIV.

PL. 25, FIG. 339. SYN. TAB. VIII

Antero-posterior diameter of bone, 27 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 12.5 mm.; lateral, 9 mm.

The bone is small. The medullary canal is full. Medullary index, 20%.

Structure.—On both sides of the posterior ridge are two wide external bands of lamellæ of unequal length. They are interrupted by small, crude Haversian canals of the (Ia) differentiation. The band of the inner increases in width as it reaches the anterior wall where it forms nearly the whole wall. It is then displaced by Haversian systems. The band of the outer wall is much shorter and is displaced by Haversian systems about the middle of the wall. The lacunæ are generally long. The Haversian systems of the section occupy irregularly shaped areas. The internal circumferential lamellæ form a wide ring around the medullary canal and it is crossed by frequent canals.

Type I-III, Ia, C.

LEFT FEMUR OF A NEGRO. NO. 7, MED. DEPT. TULANE UNIV.

PL. 25, FIG. 340. SYN. TAB. IX

Antero-posterior diameter of bone, 30 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring constitutes practically the whole bone, and is composed of Haversian systems which show extensive senility. Around the medullary canal many systems have entirely disappeared, leaving irregularly shaped spaces.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

XIII. MAN—YELLOW-BROWN RACE

General Character of the Femur

With one exception the femora of the yellow-brown race are pre-Columbian. The series includes infantile, adolescent, and adult bones from the Pueblo, Chicama, and Pachacamac Indians.

The general shape of these femora is nearer circular than it is in the black or white races. The medullary canals were filled with marrow and cancellous bone. The medullary surfaces are irregular and corrugated. The medullary index varies from 19% to 100%, with an average of 43.8%.

Nearly all of the femora are composed of type combinations. The proportion of first type units is larger than it is in other races.

Detailed Examination

RIGHT FEMUR OF A PUEBLO INDIAN CHILD, ONE YEAR OLD. NO. 258675(z), U. S. NAT. MUS.

Pl. 25, Fig. 341. Syn. Tab. IX

Antero-posterior diameter of bone, 8 mm.; lateral, 7.5 mm.

Antero-posterior diameter of medullary canal, 4.5 mm.; lateral, 4 mm.

The medullary canal is full. Medullary index, 43%.

Structure.—Around the external portion of the section is a horseshoe-shaped band of crude Haversian systems in various stages of differentiation. Some are round, some elongated, and many are irregular in shape. Their Haversian canals of the (Ib) differentiation are relatively large and surrounded by lamellæ with oval lacunæ and rather infrequent canaliculi. The toe of the shoe is best developed and widest.

Underneath the Haversian band is a wider horseshoe band, forming the remainder of the section, and composed of laminæ, between which are concentric canals. In the anterior and outer wall the laminæ are assuming the shape of very much elongated Haversian systems. The posterior ridge is composed of crude, elongated Haversian systems, which extend from the external to the medullary surface and at right angles to the laminæ of the lateral wall. The systems have wide Haversian canals, surrounded by lamellæ with oval lacunæ and bushy canaliculi. A large vascular canal is seen in the inner posterior wall.

The internal circumferential lamellæ surround the medullary canal in the form of cancellous bone.

Type II-III, Ib.

RIGHT FEMUR OF A PUEBLO INDIAN CHILD, SIX YEARS OLD. NO. 258675(L), U. S. NAT. MUS.

PL. 25, FIG. 312. SYN. TAB. IX

Antero-posterior diameter of bone, 12 mm.; lateral, 10.5 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 6 mm.

The medullary canal is full. Medullary index, 61%.

Structure.—Beginning on both sides of the posterior ridge and extending around the section is a horseshoe-shaped band of laminæ and lamellæ, interrupted by Haversian systems of the (Ia) differentiation. In the inner wall the band is composed of laminæ, separated by rather short, wide canals. The laminæ gradually merge into a narrow band of lamellæ as they pass around the inner lateral into the anterior wall. The band of lamellæ then widens in the outer wall and separates into laminæ, which form the whole width of the wall just before reaching the posterior ridge. The lacunæ are oval.

Underneath this band is a central ring of large, small, and irregularly shaped Haversian systems with inter-Haversian lamellæ. Many large canals occur which are irregular in shape and surrounded by clear areas of bone substance with few oval lacunæ. The systems communicate by canals which, in some portions, assume the form of a network. The ring reaches the external surface of the posterior ridge.

The internal circumferential lamellæ surround the medullary canal, excepting in the outer posterior wall where the systems form the border of the canal.

Type I-II-III, Ia, C.

LEFT FEMUR OF A PUEBLO INDIAN, TWELVE YEARS OLD. NO. 258675(S2), U. S. NAT. MUS.

PL. 25. FIG. 312½. SYN. TAB. IX

Antero-posterior diameter of bone, 17 mm.; lateral, 16 mm.

Antero-posterior diameter of medullary canal, 9 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—Around the outside of the section is a horseshoe-shaped band of lamellæ, separated into fragmentary laminæ by short concentric canals. The toe of the shoe is the widest part of the band and the heel of the inner is wider than that of the outer wall. The band is frequently interrupted by spaces of various sizes and shapes, the significance of which is not clear, and by Haversian systems of the (Ia) differentiation. The spaces are generally visible to the naked eye, and some of them are surrounded by clear areas crossed by a few canaliculi.

Underneath the horseshoe band is a central ring of incomplete Haversian systems with intervening lamellæ. The ring is also frequently interrupted by spaces similar to those mentioned above. The systems are round, oval, and irregular in shape with oval lacunæ and straight canaliculi. They communicate by cross canals. The posterior ridge is nearly all Haversian systems.

A ring of internal circumferential lamellæ of varying widths surrounds the medullary canal. In the lateral wall it spreads out into a fan-shaped area, which occupies about half the wall and is interrupted by a few canals.

Type I-II-III, Ia, C.

FEMUR OF A PUEBLO INDIAN, NO. 258675(x), U. S. NAT. MUS.

Pl. 26, Fig. 343. Syn. Tab. IX

Antero-posterior diameter of bone, 20 mm.; lateral, 20 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 22%.

Structure.—The posterior ridge, not prominent, is composed of Haversian systems which are well developed. Beginning on both sides of the ridge and extending completely around the bone is a wide horseshoe of lamellæ, separating in places into laminæ, which are interrupted by Haversian systems of the (Ia) differentiation. The horseshoe varies in thickness. The toe constitutes two-thirds the width of the anterior wall, while the heel is considerably narrower. In the anterior wall the lamellæ are very frequently interrupted by elongated Haversian systems arranged concentrically. These systems are crude and of a low development.

Underneath the lamellar horseshoe is a central ring of complete Haversian systems. They are well developed with long, narrow lacunæ and straight canaliculi. Internal circumferential lamellæ enclose the medullary canal. In the posterior wall they form a wide band. In other situations they are reduced to a narrow ring.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A PUEBLO INDIAN, ADULT. NO. 227339, U. S. NAT. MUS.

Pl. 26, Fig. 344. Syn. Tab. IX

Antero-posterior diameter of bone, 25 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 37%.

Structure.—The external circumferential lamellæ appear in scattered fragments around the section, and whole or half Haversian systems occupy the intervals between the fragments. The lacunæ are oval and long. A thick central ring of Haversian systems forms the chief part of the wall of the bone. The systems are well developed, their lacunæ are long and narrow. Extending across the prominence of the inner wall and forming its external boundary the Haversian systems are somewhat elongated and arranged in a direction parallel with the external surface of the bone. The internal circumferential lamellæ surround the medullary canal. Their lacunæ are long.

Type III, C.

LEFT FEMUR OF A PERUVIAN INDIAN. NO. 266469(b), U. S. NAT. MUS.

PL. 26, FIG. 345. SYN. TAB. IX

Antero-posterior diameter of bone, 27 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 21 mm.; lateral, 19 mm.

The medullary canal is full. Medullary index, 91%.

Structure.—The section is surrounded by a narrow ring of external lamellæ. The inner wall is extended in the form of a ridge and is composed of laminæ parallel with the ridge surface. The laminæ are perforated by irregularly shaped spaces. The central ring is wide and composed of well developed Haversian systems, many of which are senile, especially those of the outer wall.

The internal circumferential lamellæ form an irregular ring around the medullary canal. In some places the lamellæ are indistinctly separated into laminæ.

Type I-II-III, C, senile.

LEFT FEMUR OF A PERUVIAN INDIAN. NO. 266469(a), U. S. NAT. MUS.

PL. 26, FIG. 346. SYN. TAB. IX

Antero-posterior diameter of bone, 22 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 12 mm.

The posterior ridge is small, while a very prominent heavy ridge occurs in the inner wall. This gives to the bone a peculiar shape.

The medullary canal is full. Medullary index, 36%.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed almost entirely of well developed Haversian systems with some inter-Haversian lamellæ.

The internal circumferential lamellæ are fragmentary.

Type III, C.

LEFT FEMUR OF A CHICAMA INDIAN. NO 2, U. S. NAT. MUS.

PL. 26, FIG. 347. SYN. TAB. IX

Antero-posterior diameter of bone, 31 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 13 mm.

The walls of the bone are thick. Medullary index, 22%.

Structure.—A wide horseshoe of lamellæ, interrupted by Haversian systems of the (Ia) differentiation surrounds the section. The central ring, composed of large, small, and irregularly shaped Haversian systems, constitutes nearly all of the bone. A few senile systems appear. In the outer posterior wall elongated systems occur. The Haversian systems generally are separated by short lamellæ with oval lacunæ. The internal circumferential lamellæ, of varying widths and irregularities, crossed by radiating canals and interrupted by Haversian systems, surround the medullary canal.

Type I-III, Ia, C.

RIGHT FEMUR OF A CHICAMA VALLEY INDIAN OF PERU. NO. 3, U. S. NAT. MUS.

PL. 26, FIG. 348. SYN. TAB. IX

Antero-posterior diameter of bone, 27 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 11 mm.

Medullary index, 35%.

Structure.—The external circumferential lamellæ are incomplete. The central ring constitutes most all of the section and is composed of large, small, and irregularly shaped Haversian systems, between which are some inter-Haversian lamellæ with oval lacunæ. The lamellæ are most prominent in the anterior wall, and here the systems are somewhat elongated in cross-section.

The internal circumferential lamellæ are fragmentary.

Type I-III, C.

RIGHT FEMUR OF A CHICAMA INDIAN. NO. 1, U. S. NAT. MUS.

PL. 26, FIG. 349. SYN. TAB. IX

Antero-posterior diameter of bone, 26.5 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 16 mm.

Medullary index, 27%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring constitutes nearly all of the section and is composed of Haversian systems, large, small, and irregular. In the outer wall they have a more or less elongated shape arranged concentrically and separated by short lamellæ with oval lacunæ.

The posterior ridge is composed of Haversian systems with inter-Haversian bone substance and oval lacunæ.

A ring of internal circumferential lamellæ surrounds the medullary canal.

Type III, C.

LEFT FEMUR OF A CHICAMA INDIAN. NO. 4, U. S. NAT. MUS.

PL. 26, FIG. 350. SYN. TAB. IX

Antero-posterior diameter of bone, 30 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 18 mm.; lateral, 16 mm.

Medullary index, 52%.

Structure.—Beginning on the outer side of the posterior ridge is a wide band of lamellæ in which are many Haversian systems. The band occupies about one-half of the wall and is gradually displaced by Haversian systems in the anterior wall. In the inner wall the continuation of the band is indicated by concentric rows of elongated systems. Underneath the band is a central ring of Haversian systems with senile changes. Many canals extend in all directions in the two bands. The two bands taken together are the remains of the horseshoe of lamellæ so often present in the lower types of bone. The posterior ridge is composed of small, irregularly shaped Haversian systems with inter-Haversian lamellæ.

A narrow band of internal circumferential lamellæ surrounds the medullary canal.

Type I-III, C, senile.

LEFT FEMUR OF AN ADOLESCENT CHICAMA INDIAN. NO. 7, U. S. NAT. MUS.

PL. 27, FIG. 351. SYN. TAB. IX

Antero-posterior diameter of bone, 18.5 mm.; lateral, 19 mm.

Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 9 mm.

Medullary index, 37%.

Structure.—The external circumferential lamellæ, interrupted by Haversian systems surround the section. The central ring is composed of lamellæ and Haversian systems. In the anterior wall the toe of the shoe is for the most part displaced by Haversian systems. A wide ring of internal circumferential lamellæ surrounds the medullary canal. In the inner wall the lamellæ become laminæ. The posterior ridge is composed of elongated Haversian systems.

Type I-II-III, C.

* LEFT FEMUR OF A CHICAMA INDIAN. NO. 9, U. S. NAT. MUS.[1]

SYN. TAB. IX

Antero-posterior diameter of bone, 22 mm.; lateral, 23.5 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 11 mm.

Medullary index, 30%.

Structure.—A horseshoe of lamellæ, laminæ, and crude Haversian systems surrounds the section. The toe of the shoe is narrow and the heel wide.

The central ring is wide and composed of small and large irregularly shaped Haversian systems with short inter-Haversian lamellæ, numerous canals, and spaces.

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[1] The femora marked (*) have been described, but not drawn.

The internal circumferential lamellæ enclose the medullary canal. It is a fairly wide band in the lateral walls. The lacunæ of the section are generally oval.

Type I-II-III, Ia, C.

* RIGHT FEMUR OF AN ADULT PACHACAMAC INDIAN. NO. 14, U. S. NAT. MUS.

Syn. Tab. IX

Antero-posterior diameter of bone, 24 mm.; lateral, 21 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 10 mm.

Medullary index, 38%.

Structure.—Slight evidences of the horseshoe band are present. The lamellæ are most pronounced in the anterior wall where they form a fairly wide band. In the lateral wall the lamellæ are separated into laminæ, between which are small Haversian systems of the (Ia) differentiation.

The central ring is composed of Haversian systems. In the outer and inner wall inter-Haversian lamellæ are present. The internal circumferential lamellæ enclose the medullary canal. In the outer wall they expand into a wide crescent, which is broken into irregularly shaped fragments by interrupting Haversian systems. The lacunæ are long, narrow, and oval.

Type I-II-III, Ia, C.

* RIGHT FEMUR OF A PACHACAMAC INDIAN. NO. 13, U. S. NAT. MUS.

Syn. Tab. IX

Antero-posterior diameter of bone, 16 mm.; lateral, 15 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 7 mm.

Medullary index, 30%.

Structure.—The section is surrounded, with the exception of the posterior ridge, by a horseshoe band of laminæ in the outer and anterior wall and of Haversian systems of the (Ia) differentiation in the inner wall. The laminæ are frequently perforated by small canals and in the anterior wall they suddenly widen and occupy the whole wall. As they approach the inner wall they bend around the inner anterior angle and are then displaced by very crude Haversian systems.

The central ring is reduced to a crescent in the outer wall. It is composed of crude Haversian systems and lamellæ.

The posterior ridge is not distinguishable from the lateral wall and consists of Haversian systems and short laminæ having a direction parallel with the external surface.

The internal circumferential lamellæ surround the medullary canal. They expand in both lateral walls into two wide crescents composed of wide lamellar bands and crossed by numerous canals from the medullary surfaces. The lacunæ of all parts are oval.

Type II-III, Ia, C.

* LEFT FEMUR OF AN ADOLESCENT PACHACAMAC INDIAN. NO. 8, U. S. NAT. MUS.

Syn. Tab. IX

Antero-posterior diameter of bone, 22.5 mm.; lateral, 18 mm.

Antero-posterior diameter of medullary canal, 9 mm.; lateral, 7 mm.

Medullary index, 19%.

Structure.—The remains of the external horseshoe of lamellæ are evident. In this section the lamellæ are separated into laminæ which are interrupted by frequent Haversian systems.

The central ring is wide and composed of well developed Haversian systems with very little inter-Haversian lamellæ. There are many canals running in various directions.

A narrow ring of internal circumferential lamellæ encloses the medullary canal. The lacunæ are oval and round.

Type II-III, C.

* RIGHT FEMUR OF A PACHACAMAC INDIAN CHILD. NO. 11, U. S. NAT. MUS.

Syn. Tab. IX

Antero-posterior diameter of bone, 10 mm.; lateral, 9 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 6.5 mm.

Medullary index, 100%.

Structure.—The section is composed of lamellæ and laminæ in the form of a horseshoe embracing the posterior ridge. The shoe is crossed by canals and interrupted by Haversian systems which are developing from the vascular canals. The lacunæ are oval and round. The posterior ridge is composed of developing Haversian systems, between which are coarse canaliculi and large, round lacunæ embedded in bone substance. The ridge is distinctly marked off from the enclosing laminæ.

Type II-III, Ia, Ib.

LEFT FEMUR OF A PACHACAMAC INDIAN CHILD. NO. 12, U. S. NAT. MUS.

Pl. 27, Fig. 357. Syn. Tab. IX

Antero-posterior diameter of bone, 10 mm.; lateral, 12.5 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 7.5 mm.

Medullary index, 72%.

Structure.—With the exception of the posterior ridge the section is surrounded by a band of laminæ and Haversian systems. In the outer wall the laminæ are perforated by small longitudinal canals.

The central ring forms nearly all of the inner wall and little or none of the outer wall. It is composed of crude Haversian systems. The systems are irregular in shape with oval lacunæ.

The posterior ridge has blended with the lateral walls and is composed of crude Haversian systems. The lacunæ are oval.

The internal circumferential lamellæ enclose the medullary canal.

Type II-III, Ib.

* RIGHT FEMUR OF AN ADULT PACHACAMAC INDIAN. NO. 10, U. S. NAT. MUS.

SYN. TAB. IX

Antero-posterior diameter of bone, 21.5 mm.; lateral, 20 mm.

Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 8.5 mm.

Medullary index, 23%.

Structure.—The horseshoe band around the section is evident. It is composed of a lamellar background, most pronounced in the inner and anterior wall, interrupted by numerous irregularly shaped Haversian systems.

The central ring is composed of Haversian systems.

The medullary canal is enclosed by internal circumferential lamellæ which expand into a crescent in the inner wall. It is crossed by radiating canals and interrupted by scattering Haversian systems. The lacunæ are oval.

Type I-III, Ia, C.

* LEFT FEMUR OF A PACHACAMAC INDIAN. NO. 5, U. S. NAT. MUS.

SYN. TAB. IX

Antero-posterior diameter of bone, 20 mm.; lateral, 21 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 9 mm.

Medullary index, 31%.

The bone is adolescent.

Structure.—The section is surrounded by external circumferential lamellæ. Many canals enter the section from the external surface. Here and there an Haversian system appears. The lacunæ are oval and round.

The central ring is composed of short lamellæ and irregularly shaped Haversian systems which are still undeveloped. Their lacunæ are oval and round.

The internal circumferential lamellæ surround the medullary canal. In the outer wall the lamellæ take the form of a crescent which occupies half of the width of the wall. Near the anterior wall the lamellæ of the crescent cross the medullary canal as a narrow band. The crescent is interrupted by a few Haversian systems. The lacunæ are long and narrow.

Type I-III, Ia, C.

RIGHT FEMUR OF A PACHACAMAC INDIAN. NO. 15, U. S. NAT. MUS.

PL. 27, FIG. 360. SYN. TAB. IX

Antero-posterior diameter of bone, 24 mm.; lateral, 20 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 9 mm.

Medullary index, 27%.

Structure.—The section is surrounded, with the exception of the posterior ridge, by a horseshoe of lamellæ and Haversian systems of the (Ia) and (C) differentiations. The shoe becomes narrowest at the junction of the anterior and outer wall where it is displaced by a wide expansion of the internal lamellæ.

The central ring, irregular in width, is composed of Haversian systems and inter-Haversian lamellæ.

The internal circumferential lamellæ form a wide, irregular ring around the medullary canal.

In the outer wall it expands into a wide crescent composed of lamellæ indistinctly separated into laminæ.

The lacunæ are oval.

Type I-III, Ia, C.

LEFT FEMUR OF AN ADOLESCENT PACHACAMAC INDIAN. NO. 7, U. S. NAT. MUS.

PL. 27, FIG. 361. SYN. TAB. IX

Antero-posterior diameter of bone, 20.5 mm.; lateral, 18.5 mm.

Antero-posterior diameter of medullary canal, 9 mm.; lateral, 7 mm.

The bone is adolescent. Medullary index, 20%.

Structure.—The section is surrounded by external circumferential lamellæ, which are very frequently interrupted by small, crude Haversian systems. In the posterior ridge the lamellæ are deficient.

The central ring is wide and composed of irregularly shaped Haversian systems, cross canals, and short inter-Haversian lamellæ with oval lacunæ. The internal circumferential lamellæ enclose the medullary canal. In the outer wall they assume the form of a crescent and are crossed by frequent radiating canals.

Type I III, C.

RIGHT FEMUR OF A JAPANESE MALE. NO. 245, CR. MED. COLL.

PL. 27, FIG. 362. SYN. TAB. IX

Antero-posterior diameter of bone, 30 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 18 mm.

The medullary canal is full. Medullary index, 65%.

Structure.—The external circumferential lamellæ form an enclosing ring of various widths. It is widest in the anterior and inner wall, and is interrupted by Haversian canals of the (Ia) differentiation. The central ring is composed of Haversian systems, large and small, interrupted by irregularly shaped areas of lamellæ. Numerous vascular canals occur, and some senile systems appear. The internal circumferential lamellæ form a fragmentary ring around the medullary canal.

Type I-III, Ia, C, senile.

XIV. MAN—ANCIENT EGYPTIAN

Nine femora were examined.

GENERAL CHARACTER OF THE FEMUR

The Egyptian femora were taken from the cemeteries of Egypt of the Twelfth Dynasty (2000 B. C.). The series includes the femora of the child, adolescent, and adult.

The femora are rather small in size and variable in shape.

The medullary surface is less corrugated than it is in modern white bones.

The medullary index varies from 27% to 111%, with an average of 39.5%.

The type varies from a third to a second and third, or first and third, depending upon the age in years. The femur of a child about one year old shows the formation of Haversian systems directly from the circulation. It is the only femur examined which shows such an origin (figs. 363 and 363a, pl. 27). This formation of the Haversian system is especially interesting.

DETAILED EXAMINATION

FEMUR OF AN EGYPTIAN CHILD, ONE YEAR OLD. NO. 256479(de) U. S. NAT. MUS.

PL. 27, FIG. 363. SYN. TAB. IX

Antero-posterior diameter of bone, 9 mm.; lateral, 11.5 mm.

Antero-posterior diameter of medullary canal, 7 mm.; lateral, 8 mm.

The medullary canal is full. Medullary index, 111%.

Structure.—The section shows three concentric, parallel groups of blood vessels. One group is near the external surface (fig. 363D), a second occupies the middle of the wall (fig. 363E), and the third is near the medullary canal (fig. 363F). From these groups of vessels small branches originate, and from the branches intricate plexuses of minute vessels are formed and occupy the intervals between the groups of large vessels. The posterior wall is composed, almost entirely, of plexuses of blood vessels and a little bone substance with a few oval lacunæ between them. Figure 363a is an enlarged drawing of figure 363A. In this bone may be seen an Haversian system formation unlike any noticed in other femora. A short branch is given off from one of the large concentric vessels (figs. 363-1 and 363a1) and divides into small branches, which assume a circular arrangement (fig. 363a2). The small branches send off numerous twigs which break into capillaries and surround a central opening (fig. 363a3). This gives the whole figure a circular form. Slight enlargements of the peripheral capillaries are nipped off at intervals, from which arise many minute canals (fig. 363a4). The enlargements become lacunæ and the minute canals canaliculi (fig. 363a5). The lacunæ are round and the canaliculi are long and straight.

From this it would appear that the foundations of Haversian systems are laid in the vascular system. Osteoblasts either lodge in the capillaries or are produced by endothelium, and by growth and obstruction to the circulation, separate, throw out processes, and secrete bone substance in which they are enclosed. In this manner an Haversian system seems to be formed. These developments take place in the concentric intervals or rings between the concentric groups of vessels and transform them into bone (fig. 363B). In this femur the intervals between the three vascular groups are occupied by Haversian systems. At quite regular intervals large, irregularly shaped spaces occur, the significance of which does not appear (fig. 363C). Although this bone presents great vascularity, yet it is hard enough to be sawed. Around the external and medullary surfaces the bone formation is farther advanced. Lamellæ are beginning to be evident in these regions.

Type III, Ia, Ib.

FEMUR OF AN EGYPTIAN CHILD. NO. 256479(d), U. S. NAT. MUS.

Pl. 27, Fig. 364. Syn. Tab. IX

Antero-posterior diameter of bone, 9.5 mm.; lateral, 10 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 27%.

Structure.—The bone is nearly round. The posterior ridge is coarsely serrated on its external surface. The serrations consist of projecting loops of lamellæ, enclosing long, elliptical canals and presenting the appearance of rather crude Haversian systems. Underneath the serrated border the ridge is composed of bone substance enclosing more or less circularly shaped spaces. Some of these spaces and lamellæ present outlines of crude Haversian systems. The lacunæ are round and oval and the canaliculi are short and bushy. Beginning on one side of the posterior ridge and extending around the external surface of the bone to the opposite side are a few rather coarse laminæ with undulating borders, frequently interrupted by small Haversian systems formed by bending lamellæ of the laminæ around the central canals. The systems are elliptical. Under the external laminæ the bone is composed of channelled bone substance, with large meshes visible to the naked eye and having a concentric horseshoe arrangement. Underneath this is a narrow concentric lamina with long lacunæ, and under this again is a wide ring of channelled bone substance resembling the external one, but rather more advanced. Around the medullary canal is a very narrow ring of lamellæ. The arrangement of the several rings of thin bone correspond to the groups of vessels and inter-vascular structures seen in figure 363, and appears to be a more complete formation.

Type I-II-III, Ia, Ib.

RIGHT FEMUR OF AN EGYPTIAN. NO. 256479(a3), U. S. NAT. MUS.

PL. 27, FIG. 365. SYN. TAB. IX

Antero-posterior diameter of bone, 12 mm.; lateral, 12.5 mm.

Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 35%.

This femur belongs to the same series and shows a further advancement, since the cancellous structure has disappeared and a compact bone has taken its place.

Structure.—The posterior ridge is composed of Haversian systems and vascular canals. Their lacunæ are narrow and their canaliculi are long.

Beginning on one side of the posterior ridge and extending around the section to the other side is a horseshoe band of lamellæ of varying widths. It is widest in the posterior wall and remains of uniform width in other situations. The lamellæ are interrupted by Haversian systems of the (Ia) differentiation. Underneath the lamellar band is the middle ring of Haversian systems and inter-Haversian lamellæ. Around the medullary canal is a wide band of lamellæ with long lacunæ and straight canaliculi. This bone is more lamellar than Haversian system, but it shows a much more advanced stage of formation than those preceding. The completed units have appeared.

Type I-III, Ia, C.

FEMUR OF AN EGYPTIAN. NO. 258675(a), U. S. NAT. MUS.

PL. 27, FIG. 366. SYN. TAB. IX

Antero-posterior diameter of bone, 18 mm.; lateral, 16.5 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 9 mm.

The bone belongs to the same series as the foregoing.

The medullary canal is full. Medullary index, 44%.

Structure.—The section is composed of wide external and internal lamellæ with a central ring of Haversian systems. The enclosing horseshoe-shaped band of lamellæ is clearly marked. It is fairly uniform in width, and interrupted by crude Haversian systems of the (Ia) differentiation. Around the medullary canal is a wide ring of lamellæ of varying widths. It is widest in the inner wall and interrupted by a few incomplete Haversian systems. Between these two bands of lamellæ is a narrow middle ring of Haversian systems and inter-Haversian lamellæ. The lacunæ are oval and long and their canaliculi are long.

Type I-III, Ia, C.

RIGHT FEMUR OF AN ADULT EGYPTIAN. NO. 256481(d), U. S. NAT. MUS.

PL. 28. FIG. 367. SYN. TAB. IX

Antero-posterior diameter of bone, 18.5 mm.; lateral, 17.5 mm.

Antero-posterior diameter of medullary canal, 9 mm.; lateral, 8 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—The bone is surrounded by a lamellar ring, within which are a few Haversian systems of the (Ia) and (C) differentiations. The ring is separated by concentric canals into laminæ.

The medullary canal is surrounded by a wide band of lamellæ with long lacunæ and straight canaliculi, which in the inner wall rather abruptly widens into a semicircular area of laminæ occupying nearly the whole thickness of the wall. The laminæ are interrupted by numerous Haversian systems of the (Ia) differentiation. Between these two bands is an irregularly shaped central ring of Haversian systems and inter-Haversian lamellæ. The lacunæ are long and narrow and their canaliculi are long.

Type I-II-III, Ia, C.

LEFT FEMUR OF AN ADULT EGYPTIAN. NO. 256481(a), U. S. NAT. MUS.

PL. 28. FIG. 368. SYN. TAB. IX

Antero-posterior diameter of bone, 18 mm.; lateral, 16 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 7 mm.

The medullary canal is full. Medullary index, 24%.

The bone is very hard and brittle instead of chalky like the other femora described. It is small and nearly round.

Structure.—The posterior ridge, which is not very prominent, is composed of well developed Haversian systems.

Beginning on either side of this ridge and extending completely around the bone is a very wide horseshoe-shaped band of lamellæ with long lacunæ and straight canaliculi. It forms more than half the thickness of the wall of the bone. It is perforated at frequent intervals by irregularly shaped spaces or openings, surrounded by very narrow rims of lamellæ. The openings are more numerous in the inner wall where they take a concentric arrangement. Between the openings are Haversian systems which are wide apart in the inner and close together in the outer wall. The lamellæ are clearly marked, their lacunæ are long and oval and the canaliculi are very numerous, long, and branching. The Haversian systems are well developed.

This wide lamellar band is distinctly distinguished from the narrow, central ring of Haversian systems underneath. The systems are somewhat irregular in shape, but well developed. In all of them the canaliculi are extremely numerous. The internal circumferential lamellæ surround the medullary canal. They form a thick band in the inner wall, a narrower band in the outer, and a narrow rim in the anterior and posterior wall.

The bone, therefore, has three concentric rings in section, an extremely wide lamellar ring over half the thickness, a narrow central Haversian ring one-fourth the thickness, and an irregular ring of internal circumferential lamellæ.

Type I-III, Ib, C, senile.

RIGHT FEMUR OF AN ANCIENT EGYPTIAN. NO. 258675(e), U. S. NAT. MUS.

PL. 28, FIG. 369. SYN. TAB. IX

Antero-posterior diameter of bone, 26 mm.; lateral, 21.5 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 44%.

The bone is chalky. The femur is pear-shaped in cross-section.

Structure.—The posterior ridge is composed of large, uniformly developed Haversian systems and large, vascular canals surrounded by a few concentric lamellæ.

Beginning on both sides of the ridge and extending around the section is a wide horseshoe of lamellæ with long lacunæ and straight canaliculi, frequently interrupted by Haversian systems. The toe of the shoe forms nearly all of the anterior, and the heel, half of the posterior wall. The lacunæ are long, narrow and oval and their canaliculi are long and closely branching. Underneath the horseshoe, between it and the internal circumferential lamellæ, is an irregularly shaped crescent of Haversian systems situated eccentrically.

The internal circumferential lamellæ surround the medullary canal.

In the inner wall the internal lamellæ widen abruptly and occupy one-third of the width of the wall. In the anterior, outer, and posterior wall they form a narrow band around the medullary canal. The lacunæ and canaliculi are well developed.

Type I-III, C.

FEMUR OF AN ADULT EGYPTIAN. NO. 256478(23), U. S. NAT. MUS.

PL. 28. FIG. 370. SYN. TAB. IX

Antero-posterior diameter of bone, 24 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 10 mm.; lateral, 10 mm.

The bone is chalky.

The medullary canal is full. Medullary index, 16%.

Structure.—The external circumferential lamellæ surround the bone. Their lacunæ are long and narrow and their canaliculi are long and branching.

The central ring, of well developed Haversian systems, forms nearly the whole thickness of the wall of the bone. The systems are close together, which means that there are little or no inter-Haversian lamellæ, and they are generally large and uniform in size and shape. Their lacunæ are long and narrow and their canaliculi are long and branching, or the lacunæ may be oval and their canaliculi short and bushy.

The internal circumferential lamellæ surround the medullary canal. The ring varies in thickness.

Type III, C.

RIGHT FEMUR OF AN ADULT EGYPTIAN. NO. 256478(x), U. S. NAT. MUS.

PL. 28. FIG. 371. SYN. TAB. IX

Antero-posterior diameter of bone, 23 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 11 mm.

The femur is small. The medullary canal is full. Medullary index, 27%.

Structure.—The external circumferential lamellæ are fragmentary. Beginning on the inner side of the posterior ridge and extending around the external surface of the inner lateral wall is a band of lamellæ enclosing Haversian systems. As the band reaches the mid-lateral wall it is displaced by Haversian systems. In the inner anterior wall concentric systems and lamellæ alternate. The remaining portion of the section is composed of Haversian systems somewhat irregular in shape and size. The lacunæ are oval in some places and narrow in others, the oval predominating. The external part of the posterior ridge is composed of large, oval lacunæ with bushy canaliculi.

The internal circumferential lamellæ are fragmentary. The evidence of the lamellar horseshoe is present to a small extent as a background in the inner wall, while the section is nearly all Haversian systems.

Type I-III, C.

XV. MAN—MODERN WHITE

General Character of the Femur

The femora of the white race vary in shape to a marked degree. The medullary canals occupy central, eccentric, and oblique positions. They are filled with cancellous bone and marrow. The medullary surfaces are very uneven. The average medullary index is 35.8%.

The type of structure varies from the third to the first and third. A great many first and third type combinations are found in the various femora, and the proportions of the first to the third type vary greatly. In some, it forms a narrow surrounding band; in others, the band increases in thickness until it forms a quarter, third, half, or more than half of the whole section; in still others, it remains as a background of inter-Haversian lamellæ.

Detailed Examination

FEMUR OF A WHITE MALE, NO. 1629, U. S. NAT. MUS.

Pl. 28, Fig. 372. Syn. Tab. X

Antero-posterior diameter of bone, 28 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 18 mm.; lateral, 17 mm.

The medullary canal is full. Medullary index, 64%.

Structure.—The external circumferential lamellæ form a very narrow ring around the section. Beginning a little to the inner side of the posterior ridge and extending around the inner wall, beneath the external circumferential lamellæ, is a narrow band of elliptical Haversian systems in cross-section. They disappear as they approach the anterior wall. These structures are the remains of the lamellæ and laminæ seen so frequently in lower bones in the same situation. The middle ring of the section is composed of well developed Haversian systems with many communicating canals. The medullary canal is surrounded by a narrow ring of internal circumferential lamellæ. The lacunæ and canaliculi are generally well developed.

Type III, C.

RIGHT FEMUR OF A WHITE FEMALE. NO. 147, MED. DEPT. NORTHWESTERN UNIV.

Pl. 28, Fig. 373. Syn. Tab. X

Antero-posterior diameter of bone, 33.5 mm.; lateral, 32 mm.

Antero-posterior diameter of medullary canal, 19 mm.; lateral, 18.5 mm.

The medullary canal is surrounded by cancellous bone and is full. Medullary index, 49%.

Structure.—External circumferential lamellæ appear only in scattered fragments. They are most pronounced in the posterior inner wall. The central ring of well developed Haversian systems constitutes practically the whole bone. In most parts they form the external border directly under the periosteum, and here and there a half system bounds the section. The systems are fairly uniform in size and circular in cross-section. Many of these have relatively large Haversian canals and show slight senile changes. The Haversian canals frequently communicate by cross canals. On the two sides of the posterior ridge, near the circumference, they are a little elongated and show faint traces of a former laminar condition.

The internal circumferential lamellæ form a narrow ring around the medullary canal. For the most part the lamellæ assume the form of cancellous bone. All bone units are well developed.

Type III, C, senile.

RIGHT FEMUR OF A WHITE CHILD, LESS THAN ONE YEAR OLD. NO. 249588, U. S. NAT. MUS.

PL. 29, FIG. 374. SYN. TAB. X

Antero-posterior diameter of bone, 6.5 mm.; lateral, 7.5 mm.

Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5 mm.

The medullary canal is full. Medullary index, 70%.

Structure.—Extending around the circumference of the section—posterior ridge excepted—is a narrow ring of lamellæ with oval lacunæ and bushy canaliculi. The lamellæ are frequently interrupted by canals running longitudinally.

Beginning on both sides of the posterior ridge and extending around the section underneath the external lamellæ is a horseshoe band of laminæ and Haversian systems forming the remainder of the bone. The inner wall is almost entirely laminæ. As the laminæ reach the anterior wall they are mostly displaced by rather crude, elongated Haversian systems, which, however, generally maintain concentric arrangements. In the outer wall the Haversian systems occupy the medullary half and the laminæ the circumferential half of the section. The lacunæ are oval. The Haversian canals are irregular in shape and extend in various directions. The internal circumferential lamellæ are fragmentary.

The posterior ridge is incompletely formed and is composed of large canals, surrounded by oval lacunæ with infrequent bordering canaliculi. Here and there an Haversian system appears. The ridge is obviously a later formation than the remaining walls.

Type II-III, Ia, Ib.

FEMUR OF A WHITE MALE. NO. 53, CR. MED. COLL.

PL. 29, FIG. 375. SYN. TAB. X

Antero-posterior diameter of bone, 28 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 17 mm.

Cancellous bone surrounds the medullary canal and is most prominent in the anterior wall. The medullary canal is full. Medullary index, 48%.

Structure.—The external circumferential lamellæ surround the bone at scattered intervals. Their lacunæ are long and narrow and their canaliculi are long. The central ring, constituting nearly the entire thickness of the wall of the bone, is composed of Haversian systems, which, in places, form the external boundary of the bone. At some points in the periphery, only half or three-quarter systems appear directly under the periosteum. The systems vary in size, but are highly developed. Their lacunæ are long and narrow and their canaliculi are long. The Haversian canals intercommunicate. The internal circumferential lamellæ surround the medullary canal in the form of cancellous bone.

Type III, C.

RIGHT FEMUR OF A WHITE MALE. NO. 171, MED. DEPT. NORTHWESTERN UNIV.

PL. 29, FIG. 376. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 33 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 35%.

Structure.—The external circumferential lamellæ appear in fragments.

The section is composed almost entirely of Haversian systems with very little inter-Haversian lamellar structure. The systems vary in size and some of them show senile changes.

The internal circumferential lamellæ form a very narrow ring around the medullary-canal. The bone is high in development, since practically all lamellar and laminar formations have disappeared and Haversian systems have taken their places. It shows, however, senile changes.

Type III, C, senile.

LEFT FEMUR OF A WHITE MAN. NO. 95, CR. MED. COLL.

PL. 29, FIG. 377. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 27.5 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 16 mm.

The medullary canal is full. Medullary index, 42%.

Structure.—The external circumferential lamellæ appear in fragments. The central ring is composed of Haversian systems and constitutes almost the entire wall of the bone. Many systems are senile. They reach the external surface between the lamellar fragments and form the posterior ridge. They are large, small, and irregular in shape and frequently communicate by canals. Their lacunæ are narrow and oval. Around the internal circumferential lamellæ the systems show senile changes. There is very little inter-Haversian structure.

The internal circumferential lamellæ form a very narrow ring around the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 96, CR. MED. COLL.

PL. 29, FIG. 378. SYN. TAB. X

Antero-posterior diameter of bone, 29.5 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 14.5 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—A few fragments of the external circumferential lamellæ appear here and there around the surface of the bone. The central ring of Haversian systems constitutes almost entirely the whole section.

There are some inter-Haversian lamellæ which are the remains of the laminar and lamellar structures seen in lower bones. The systems are large, small, and irregular in shape and frequently communicate by canals. Some of them show senile changes. On the whole, they are well developed.

The internal circumferential lamellæ form a very narrow, irregular ring around the medullary canal. It is displaced at intervals by Haversian systems of the central ring.

Type III, C, senile.

LEFT FEMUR OF A WHITE MALE, AGE 45. NO. 168, MED. DEPT. NORTHWESTERN UNIV.

PL. 29, FIG. 379. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 17 mm.

The medullary canal is full. Medullary index, 40%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of large, small, and irregularly shaped Haversian systems, many of which show senile changes. The internal circumferential lamellæ form a narrow fragmentary ring around the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A WHITE MALE, AGE 50. NO. 10, MED. DEPT. NORTHWESTERN UNIV.

Pl. 29, Fig. 380. Syn. Tab. X

Antero-posterior diameter of bone, 30 mm.; lateral, 31.5 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 20%.

Structure.—The external circumferential lamellæ appear only in short fragments. The central ring is composed of large, small, and irregular Haversian systems with many senile changes. The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

FEMUR OF A SENILE WHITE AMERICAN FEMALE, AGE 52. NO. 227876, U. S. NAT. MUS.

Pl. 29, Fig. 381. Syn. Tab. X

Antero-posterior diameter of bone, 22 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 13.5 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 42%.

There is a difference of eight years between the senile femora of figures 381 and 382. The two femora have about the same external diameter, but figure 381 has an index of 42%, and figure 382, 74%.

Structure.—Femur (fig. 381) is of a slightly lower type of structure than figure 382. This may be seen by the concentric arrangement of the oblong Haversian systems of the inner wall. The external circumferential lamellæ are fragmentary. The central ring is composed of large and small Haversian systems in different stages of senility. A few are normal; that is, their Haversian canals are about the usual size. Some have large Haversian canals and crescent-shaped lamellæ; some have large canals and narrow rings of granular lamellæ; some have large canals and perfectly black, opaque rings or crescents around them; and some are entirely gone.

The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

FEMUR OF A SENILE WHITE FEMALE, AGE 60. NO. 227880, U. S. NAT. MUS.

Pl. 29, Fig. 382. Syn. Tab. X

Antero-posterior diameter of bone, 24 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 16 mm.

Cancellous bone is present in places. The bone is extremely soft, light, and thin-walled. The medullary canal is relatively large. In the wall of the bone are large, irregularly shaped spaces.

The medullary canal is full. Medullary index, 74%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of large, small, and irregularly shaped Haversian systems, most of which show marked degrees of senility. Some are black and partly gone and others have entirely disappeared, leaving spaces. The internal circumferential lamellæ are fragmentary, appearing only here and there.

Type III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 162, MED. DEPT. NORTHWESTERN UNIV.

PL. 30, FIG. 384. SYN. TAB. X

Antero-posterior diameter of bone, 25 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 35%.

Structure.—The external circumferential lamellæ are fragmentary.

The central ring is composed of Haversian systems of various shapes and sizes with round and oval lacunæ and bushy and straight canaliculi, many of which are senile.

The internal circumferential lamellæ with long, narrow lacunæ and straight canaliculi surround the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 244, CR. MED. COLL.

PL. 30, FIG. 385. SYN. TAB. X

Antero-posterior diameter of bone, 35 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 32%.

Structure.—Slight remains of the lamellar horseshoe are found on both sides of the posterior ridge.

The external circumferential lamellæ are fragmentary.

The central ring constitutes most all of the section, and is composed of Haversian systems with many senile changes.

The internal circumferential lamellæ form a narrow fragmentary ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF AN EAST INDIAN. NO. 223, CR. MED. COLL.

PL. 30, FIG. 386. SYN. TAB. X

Antero-posterior diameter of bone, 29 mm.; lateral, 24 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—External circumferential lamellæ surround the section. In the inner and anterior wall they are interrupted by crude Haversian systems of the (Ia) differentiation.

The central ring is composed of large, small, and irregularly shaped, well developed Haversian systems. Here and there a few, short, inter-Haversian lamellæ appear. Some of the systems are senile. But, on the whole, the Haversian systems are strong and well developed.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, Ia, C.

LEFT FEMUR OF AN EAST INDIAN. NO. 223, CR. MED. COLL.

PL. 30, FIG. 387. SYN. TAB. X

The leg had been amputated below the knee and the femur had not exercised its normal function for years.

Antero-posterior diameter of bone, 28 mm.; lateral, 22 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 49%.

Structure.—The section is surrounded by external circumferential lamellæ, thinnest in the anterior wall. The lamellæ are interrupted by crude Haversian systems of the (Ia) differentiation.

The central ring is composed of large, small, and irregularly shaped Haversian systems, showing senile changes which are most numerous around the medullary canal.

Internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, Ia, C, senile.

A comparison of the two foregoing femora shows that the femur of the amputated leg is smaller than the other, the index is higher, the wall of the bone is thinner, and senile changes are more marked.

RIGHT FEMUR OF A WHITE MALE, AGE 55. NO. 228479, U. S. NAT. MUS.

PL. 30, FIG. 388. SYN. TAB. X

Antero-posterior diameter of bone, 32 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 17 mm.

The medullary canal is full. Medullary index, 36%. There is considerable cancellous bone.

Structure.—The external circumferential lamellæ are fragmentary and show the remains of the lamellar or laminar horseshoe.

The central ring constitutes almost the whole thickness of the walls and is composed of Haversian systems with some inter-Haversian lamellæ. The systems are large, small, and irregular, and show some senile changes. There are very few cross canals. Their lacunæ are oval and narrow.

The internal circumferential lamellæ form a narrow ring around the medullary canal and in the anterior wall assume the form of cancellous bone.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE, AGE 45. NO. 154, MED. DEPT. NORTHWESTERN UNIV.

PL. 30, FIG. 389. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 26%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of Haversian systems, which, in the inner wall, alternate with concentric laminæ. Many systems are senile.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 146, MED. DEPT. NORTHWESTERN UNIV.

PL. 30, FIG. 390. SYN. TAB. X

Antero-posterior diameter of bone, 28 mm.; lateral, 24 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 24%.

Structure.—The external circumferential lamellæ are fragmentary. Half systems frequently occur on the external border of the section. The central ring forms practically all of the bone and is composed of irregularly shaped Haversian systems. Senile changes are marked. The lacunæ are oval and long and the canaliculi are bushy and straight. The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

LEFT FEMUR OF A WHITE MALE, AGE 60. NO. 159, MED. DEPT. NORTHWESTERN UNIV.

PL. 30, FIG. 391. SYN. TAB. X

Antero-posterior diameter of bone, 32 mm.; lateral, 31.5 mm.

Antero-posterior diameter of medullary canal, 17.5 mm.; lateral, 18 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of Haversian systems showing many senile changes.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 167, MED. DEPT. NORTHWESTERN UNIV.

PL. 30, FIG. 392. SYN. TAB. X

Antero-posterior diameter of bone, 27 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 30%.

Structure.—The external circumferential lamellæ are fragmentary. For the most part, Haversian systems form the external boundary of the section. The central ring is composed of Haversian systems and inter-Haversian lamellæ in the inner wall and of Haversian systems elsewhere. The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 172, MED. DEPT. NORTHWESTERN UNIV.

PL. 30, FIG. 393. SYN. TAB. X

Antero-posterior diameter of bone, 32 mm.; lateral, 31.5 mm.

Antero-posterior diameter of medullary canal, 17.5 mm.; lateral, 18 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—A narrow band of external circumferential lamellæ, somewhat fragmentary, forms the external boundary of the section. The central ring is composed of Haversian systems, well developed and of varying sizes. In the anterior and inner wall, the systems are separated by a little inter-Haversian structure. Many senile systems appear. Few cross canals are seen. The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 242, CR. MED. COLL.

PL. 31, FIG. 394. SYN. TAB. X

Antero-posterior diameter of bone, 32 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 19 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 49%.

Structure.—The external circumferential lamellæ are fragmentary. Remains of the lamellar horseshoe are found in the inner wall.

The central ring forms nearly the whole of the section and is composed of Haversian systems, many of which show senile changes.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE, AGE 60. NO. 145, MED. DEPT. NORTHWESTERN UNIV.

PL. 31, FIG. 395. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 18 mm.

The medullary canal is full. Medullary index, 49%.

Structure.—The external circumferential lamellæ are fragmentary and half systems occur on the external boundary of the section. The central ring is composed of well developed, large and small Haversian systems. Many senile changes occur in the anterior and posterior wall. Few cross canals are seen. The internal circumferential lamellæ form a narrow ring around the medullary canal and in the anterior and posterior wall cancellous bone.

Type III, C, senile.

LEFT FEMUR OF A WHITE FEMALE. NO. 174, MED. DEPT. NORTHWESTERN UNIV.

PL. 31, FIG. 396. SYN. TAB. X

Antero-posterior diameter of bone, 27 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 13 mm.

The medullary canal is full. Medullary index, 35%.

Structure.—The external circumferential lamellæ surround the section. In the outer wall they form a wide background of about half the width of the wall in which are numerous Haversian systems. The background gradually disappears in the anterior wall and the lamellæ are reduced to a very narrow rim. In the inner wall the narrow rim gradually widens again as it approaches the posterior ridge. The central ring is composed of large and small Haversian systems, many of which are senile. Near the external surface of the posterior ridge groups of round and oval lacunæ appear between the systems. The internal circumferential lamellæ are fragmentary.

Type I-III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 157, MED. DEPT. NORTHWESTERN UNIV.

PL. 31, FIG. 397. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 16.5 mm.; lateral, 16 mm.

The medullary canal is full. Medullary index, 44%.

Structure.—The external circumferential lamellæ, separated into laminæ in the lateral wall, surround the section. The central ring is composed of Haversian systems, and senile changes are abundant. In the inner wall may be seen distinct remains of the lamellar horseshoe. The internal circumferential lamellæ are fragmentary.

Type I-II-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 161, MED. DEPT. NORTHWESTERN UNIV.

PL. 31, FIG. 398. SYN. TAB. X

Antero-posterior diameter of bone, 28 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 26%.

Structure.—The external lamellæ are practically absent. The central ring is composed of various forms of Haversian systems with considerable inter-Haversian lamellæ, especially in the inner wall. This is the remains of the horseshoe. Many senile changes are present. Near the posterior ridge the systems are oval and assume a concentric arrangement. The internal lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 153, MED. DEPT. NORTHWESTERN UNIV.

PL. 31, FIG. 399. SYN. TAB. X

Antero-posterior diameter of bone, 27.5 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 27%.

Structure.—A wide horseshoe band of lamellæ extends around the external border of the section and is interrupted by numerous crude Haversian systems of the (Ia) differentiation and crossed by canals. The central ring is composed of large, small, and irregular Haversian systems, some of which are senile. The internal lamellæ form a broken ring around the medullary canal.

Type I-III, Ia, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 243, CR. MED. COLL.

PL. 31, FIG. 400. SYN. TAB. X

Antero-posterior diameter of bone, 30 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 23%.

Structure.—The section is surrounded for the most part by a wide horseshoe band of lamellæ, interrupted frequently by Haversian systems of the (Ia) differentiation.

The central ring is composed of Haversian systems with fragments of lamellæ running between them in all directions. This is especially true in the outer wall. A few senile systems appear. Internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 148, MED. DEPT. NORTHWESTERN UNIV.

PL. 31, FIG. 401. SYN. TAB. X

Antero-posterior diameter of bone, 24 mm.; lateral, 33 mm.

Antero-posterior diameter of medullary canal, 13.5 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 30%.

Structure.—Remains of the lamellar horseshoe band are seen as a background in the lateral and anterior wall. The band is interrupted by numerous Haversian systems. The central ring is incomplete and composed of large, small, and irregular Haversian systems. Senile changes are frequent in the anterior and posterior wall. The internal lamellæ form a narrow ring around the medullary canal.

Type I-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 230, CR. MED. COLL.

PL. 31, FIG. 402. SYN. TAB. X

Antero-posterior diameter of bone, 31 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 33%.

Structure.—The horseshoe band of lamellæ, widest in the outer and absent in the anterior wall, remains as a background. It forms half of the outer and one-third of the posterior inner wall. In the lamellar background are oval and round Haversian systems. The central ring is composed of large, small, and irregular Haversian systems. Senile changes are frequent. The lacunæ are generally oval. The internal circumferential lamellæ appear in fragments and as cancellous bone in the anterior wall.

Type I-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 97, CR. MED. COLL.

PL. 32, FIG. 403. SYN. TAB. X

Antero-posterior diameter of bone, 28.5 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 45%.

Structure.—A wide horseshoe band of laminæ and lamellæ surrounds the section. On both sides of the ridge the heel of the shoe constitutes nearly the whole thickness of the wall, while the toe constitutes more than one-half of the anterior wall. In the inner wall the band is narrow and in the outer wall, wide. On both sides of the posterior ridge the heel of the shoe is composed of laminæ with inter-laminar Haversian systems and canals. The laminæ merge together to some extent as they reach the anterior wall, but are still evident in that region. The Haversian systems of the horseshoe band are of the (Ia) and (C) differentiations, the former predominating. Their locations between adjacent laminæ produce irregular borders of the laminæ. In the anterior wall the systems are all poorly developed, being little more than Haversian canals. The lacunæ of the lamellæ are long and narrow; of the laminæ, somewhat oval.

The central ring is narrow and composed of well developed Haversian systems in the outer, a wide band of lamellæ and Haversian systems in the anterior, lamellæ and Haversian systems in the inner wall, and Haversian systems in the posterior ridge. No senile changes appear. The posterior ridge is composed of Haversian systems and inter-Haversian lamellæ with many oval lacunæ. The internal circumferential lamellæ form an irregular ring of varying widths around the medullary canal. The bone is more than one-half laminæ and lamellæ.

Type I-II-III, Ia, C.

LEFT FEMUR OF A WHITE MALE. NO. 99, CR. MED. COLL.

Pl. 32, Fig. 404. Syn. Tab. X

Antero-posterior diameter of bone, 30 mm.; lateral, 27.5 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 20%.

Structure.—Beginning on the outer side of the posterior ridge and extending around the lateral wall are coarse laminæ, interrupted by a few Haversian systems of the (C) differentiation and by many of the (Ia) differentiation. As the laminæ reach the anterior wall they merge into lamellæ, which terminate in the anterior inner wall, and are then completely displaced by well developed Haversian systems. The laminæ again appear in the posterior wall. The lacunæ are generally oval and their canaliculi straight. In the outer wall is a wide semicircular area of laminæ, which, with those of the external band, constitute the whole wall. These laminæ are also interrupted by Haversian systems similar to those of the external band.

The central ring is incomplete, since it is limited to a narrow portion of the anterior, nearly the whole of the inner anterior and posterior wall. It is composed of well developed Haversian systems without senile changes.

The medullary canal is surrounded by laminæ, interrupted by Haversian systems of the (Ia) differentiation. The section is more than half lamellæ and laminæ.

Type I-II-III, Ia, C.

RIGHT FEMUR OF A WHITE MALE. NO. 160, MED. DEPT. NORTHWESTERN UNIV.

PL. 32, FIG. 405. SYN. TAB. X

Antero-posterior diameter of bone, 28 mm.; lateral, 28.5 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—Beginning on the inner side of the posterior ridge and extending around the inner and a part of the anterior wall is a wide band of lamellæ in which are many well developed Haversian systems. The band forms the entire thickness of the inner posterior wall. In the anterior outer wall the band has been displaced by Haversian systems, and in the outer posterior wall the lamellar band again appears.

The central ring is composed of Haversian systems of the (C) differentiation, many of which show senile changes.

The internal circumferential lamellæ are fragmentary. The section is about half lamellæ.

Type I-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 163, MED. DEPT. NORTHWESTERN UNIV.

PL. 32, FIG. 406. SYN. TAB. X

Antero-posterior diameter of bone, 28 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 11.5 mm.

The medullary canal is full. Medullary index, 32%.

Structure.—Beginning on the inner side of the posterior ridge and extending around the external border of the inner and anterior wall is a wide band of lamellæ, interrupted by Haversian systems. The band forms about half of the inner and the whole of the anterior wall, and is then displaced by Haversian systems. The lacunæ are oval and long. Around the external surface of the outer wall is a narrower band of lamellæ, interrupted by canals of the (Ia) differentiation. The central ring of the inner and outer wall is composed of Haversian systems, some of which exhibit senile changes. In the posterior ridge the systems are separated by lamellæ with oval lacunæ. The medullary canal is enclosed by a narrow ring of lamellæ.

Type I-III, Ia, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 156, MED. DEPT. NORTHWESTERN UNIV.

PL. 32, FIG. 407. SYN. TAB. X

Antero-posterior diameter of bone, 31 mm.; lateral, 23.5 mm.

Antero-posterior diameter of medullary canal, 11 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 20%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring constitutes nearly all of the section and is composed of large, small, and irregularly shaped Haversian systems in a wide band of lamellæ, especially in the inner and posterior wall. The band is nearly displaced by Haversian systems in the outer wall. Senile changes are frequent. The internal circumferential lamellæ are fragmentary. The section shows an unusually large, inner posterior ridge.

Type I-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 169, MED. DEPT. NORTHWESTERN UNIV.

Pl. 32, Fig. 408. Syn. Tab. X

Antero-posterior diameter of bone, 31 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 37%.

Structure.—Beginning on the inner side of the posterior ridge and extending around the inner lateral wall is a wide lamellar background in which are numerous Haversian systems. In the anterior wall the band narrows to an interrupted rim and widens again to a background in the outer wall.

The central ring is composed of Haversian systems, large and small, with some senile changes. Along the external surface of the posterior ridge the systems are separated by lamellæ with oval and round lacunæ. The internal circumferential lamellæ form a narrow ring around the medullary canal. Senile changes are numerous in the systems in close proximity to the medullary canal.

Type I-III, C, senile.

RIGHT FEMUR OF A WHITE MALE, AGE 35. NO. 151, MED. DEPT. NORTHWESTERN UNIV.

Pl. 32, Fig. 409. Syn. Tab. X

Antero-posterior diameter of bone, 28 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 11.5 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 19%.

Structure.—The external circumferential lamellæ surround the bone. They form thin bands in the lateral wall and are displaced by bone substance with large oval lacunæ and bushy canaliculi in the posterior ridge. The anterior wall is over half lamellæ, in which are parallel rows of crude Haversian systems of the (Ia) differentiation, arranged concentrically. The lamellæ and systems form the external part of the wall, and, as they approach and pass into the lateral wall, they are replaced by wide bands of irregularly shaped Haversian systems. Senile changes are frequent in the inner lateral wall. Underneath the lamellar and Haversian system band is a central ring of regular Haversian systems, well developed.

The internal circumferential lamellæ form a wide band in the lateral and posterior wall. In the posterior, outer lateral wall several laminæ extend obliquely from the interior of the wall to the medullary surface. The external half of the posterior ridge is composed of Haversian systems, between which is bone substance with many oval lacunæ, while the medullary half is composed of Haversian systems with a little inter-Haversian lamellæ.

Type I-II-III, Ia, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 100, CR. MED. COLL.

PL. 32, FIG. 410. SYN. TAB. X

Antero-posterior diameter of bone, 24 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 17.5 mm.; lateral, 13.5 mm.

The medullary canal is full. Medullary index, 46%.

Structure.—The external circumferential lamellæ form the boundary of a part of the outer wall. In some places, however, Haversian systems form the external boundary. In the outer wall laminæ separate the Haversian systems of the central ring. Their lacunæ are well developed.

The central ring constitutes the greater part of the section, and especially is this true of the outer wall.

In the inner wall is a wide external band of laminæ and oblong Haversian systems extending from the posterior ridge around to the outer antero-lateral junction. In the anterior wall is a wide band of lamellæ. The systems are large, small, and irregular in shape. In those around the medullary canal, senile changes appear. The internal circumferential lamellæ form an extremely narrow ring around the medullary canal.

Type I-II-III, C, senile.

RIGHT FEMUR OF A WHITE FEMALE. NO. 150, MED. DEPT. NORTHWESTERN UNIV.

PL. 32, FIG. 411. SYN. TAB. X

Antero-posterior diameter of bone, 26 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 21 mm.

The medullary canal is full. Medullary index, 16%.

Structure.—The section is irregular in shape and is composed of a background of lamellæ, in which are irregularly shaped Haversian systems with senile changes.

Type I-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 152, MED. DEPT. NORTHWESTERN UNIV.

PL. 33, FIG. 412. SYN. TAB. XI

Antero-posterior diameter of bone, 26 mm.; lateral, 37 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 16 mm.

The medullary canal is full. Medullary index, 30%.

Structure.—The section is the first portion of a double femur. The original femur (fig. 412B) is composed of Haversian systems almost entirely. In the posterior wall they are separated by short lamellæ with oval lacunæ. Many senile changes occur. In some systems the Haversian canals have increased in diameter to such an extent that only a narrow rim of bone remains. Around the medullary canal are large spaces. The lacunæ of the systems are of the oval type and not very numerous. The external and internal circumferential lamellæ appear in fragments. Between the original and accessory growth is a concentric series of spaces partly surrounded by enclosing lamellæ. A sharp line appears between the two bones (fig. 412C). The accessory bone is composed of a background of lamellæ in which are Haversian systems of the (Ib) differentiation and numerous radiating canals. The inter-Haversian lamellæ with oval lacunæ predominate. Many of the systems are senile. The external circumferential lamellæ are fragmentary. The accessory portion shows an earlier development than the original bone by its predominating lamellæ and relatively few Haversian systems.

Type I-III, Ib, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 152, MED. DEPT. NORTHWESTERN UNIV.

PL. 33, FIG. 413. SYN. TAB. XI

Antero-posterior diameter of original bone, 27 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal of original bone, 16 mm.; lateral, 17 mm.

The medullary canal is full. Medullary index, 67%.

Antero-posterior diameter of accessory bone, 23 mm.; lateral, 18 mm.

Antero-posterior diameter of accessory medullary canal, 10 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 31%.

Antero-posterior diameter of the whole bone, 25 mm.; lateral, 45 mm.

The section was taken 33 mm. below figure 412.

Structure.—In this section the accessory development has formed an additional femur. The original bone is composed of Haversian systems for the most part, but their senile changes are markedly increased (fig. 413B). The accessory bone is composed of lamellæ with oval lacunæ, interrupted by numerous Haversian systems of the (Ib) differentiation. The two bones are separated by a narrow partition of cancellous bone (fig. 413C). Internal and external circumferential lamellæ in both bones are fragmentary.

Type I-III, Ib, C, senile.

LEFT FEMUR OF A WHITE FEMALE. NO. 164, MED. DEPT. NORTHWESTERN UNIV.

PL. 33, FIG. 414. SYN. TAB. XI

Antero-posterior diameter of bone, 28 mm.; lateral, 27.5 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 20 mm.

The medullary canal is full. Medullary index, 55%.

Structure.—The external circumferential lamellæ appear only in short fragments. The central ring is composed of large and small, irregularly shaped Haversian systems in a background of lamellæ which extends around the bone. The systems are generally senile. The wall of the bone is thin. The anterior and inner wall is nearly half destroyed by senile losses.

Internal circumferential lamellæ occur in fragments.

Type I-III, C, senile.

LEFT FEMUR OF A WHITE FEMALE. NO. 166, MED. DEPT. NORTHWESTERN UNIV.

PL. 33, FIG. 415. SYN. TAB. XI

Antero-posterior diameter of bone, 26.5 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 13 mm.

The medullary canal is full. Medullary index, 34%.

Structure.—Beginning on both sides of the posterior ridge and extending around the lateral wall are two bands of lamellæ, incompletely separated into laminæ and interrupted by Haversian systems. The band disappears entirely in the anterior and antero-lateral wall. The external surface of the posterior ridge shows many large, oval lacunæ between the Haversian systems. The central ring is composed of Haversian systems, large and small, with considerable inter-Haversian lamellæ. The systems show many senile changes. The internal circumferential lamellæ are fragmentary.

Type I-III, C, senile.

RIGHT FEMUR OF A WHITE MALE (SUICIDE), AGE 22. NO. 175, CR. MED. COLL.

PL. 33, FIG. 416. SYN. TAB. XI

Antero-posterior diameter of bone, 27 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 19 mm.

The medullary canal is full. Medullary index, 53%.

Structure.—The section is surrounded by a band of lamellæ and laminæ. In the anterior and inner wall the band is lamellar and perforated by numerous canals of the (Ia) differentiation. In the outer and posterior wall the band is laminar and interrupted by elongated Haversian systems of the (Ib) formation.

The central ring is irregular. In the outer wall it is thick and composed of well developed Haversian systems; in the antero-inner lateral wall it is thin; and in the posterior inner lateral it is almost entirely absent.

Internal circumferential lamellæ form a narrow cancellous ring around the medullary canal. The lamellæ are separated into laminæ in the inner wall.

Type I-II-III, Ia, Ib, C.

LEFT FEMUR OF A WHITE MALE. NO. 98, CR. MED. COLL.

Pl. 33, Fig. 417. Syn. Tab. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 39%.

Structure.—External circumferential lamellæ and laminæ surround the section. In the inner wall are two rows of elongated Haversian systems extending in a concentric direction from the external laminæ to the medullary surface of the anterior wall. The central ring of Haversian systems constitutes almost the entire thickness of the wall of the bone. The inner wall shows the borders of a wide external crescent composed of very much flattened Haversian systems.

The Haversian systems are large, small, and irregular in shape. Nearly one-half of them in the outer and a few in the inner wall show senile changes. The various stages of senility are well marked in this bone. In the early stage the lamellæ of the Haversian systems are prominent. The organic portion of the lamellæ seems to separate from the inorganic and the mineral salts begin to appear as granules in the lamellæ around the Haversian canals. In this stage the systems appear brown with sharply defined lamellæ. In the next stage the mineral deposit is heavy and the systems are black. Here and there a system can be seen in the last stage. The lamellæ around the Haversian canal are absorbed and little by little the Haversian canal widens until a narrow black ring is all that remains of the system, or the entire system disappears. The inorganic salts are deposited in the Haversian canals (pl. 34, figs. 424-426). After this manner the bone becomes light and the walls become thin as the process extends outward from the medullary canal. The internal circumferential lamellæ appear in fragments.

Type I-II-III, C, senile.

LEFT FEMUR OF A WHITE MALE. NO. 91, CR. MED. COLL.

PL. 33. FIG. 418. SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 13 mm.

The medullary canal is full. Medullary index, 39%.

Structure.—External circumferential lamellæ surround the section, excepting the posterior ridge. The central ring is composed of Haversian systems with the remains of a laminar horseshoe in the posterior lateral wall. No senile changes are found.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-II-III, C.

FEMUR OF AN AUSTRALIAN. NO. 227420, U. S. NAT. MUS.

PL. 34, FIG. 419. SYN. TAB. XI

Antero-posterior diameter of bone, 28 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 25%.

Structure.—The external circumferential lamellæ enclose the bone, excepting the anterior wall and posterior ridge. Beginning on either side of the posterior ridge and extending around the lateral to the anterior wall are two wide bands composed of lamellæ and elongated Haversian systems, arranged in concentric rows. Their long diameters are parallel to the external surface of the bone. As the bands approach the anterior wall they are displaced by Haversian systems, which form the whole width of the wall. These bands are the remains of the horseshoe.

The anterior wall and posterior ridge are composed entirely of Haversian systems. The lacunæ are oval and narrow. The internal circumferential lamellæ form a broken narrow ring around the medullary canal.

Type I-III, C.

LEFT FEMUR OF A WHITE MALE. NO. 94, CR. MED. COLL.

PL. 34, FIG. 420. SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—External circumferential lamellæ form a narrow ring around the section. Beginning on both sides of the posterior ridge and extending around the lateral wall are wide bands of elongated and well developed Haversian systems with considerable inter-Haversian lamellæ. As the band of the inner wall approaches the anterior it is entirely displaced by Haversian systems, while the band of the outer wall is displaced about the mid-lateral region. The central ring, therefore, is irregular in shape and position. It is composed of well developed Haversian systems.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, C.

RIGHT FEMUR OF A WHITE MALE, AGE 40. NO. 142, MED. DEPT. NORTHWESTERN UNIV.

PL. 34, FIG. 421. SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 27.5 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 11.5 mm.

The medullary canal is full. Medullary index, 22%.

Structure.—Beginning on both sides of the posterior ridge and extending around the section is an enclosing band of varying widths composed of lamellæ, interrupted by small Haversian systems of the (Ia) differentiation. The band is widest in the outer and anterior wall.

Underneath this band is a wide central ring of well developed Haversian systems. They vary in size and present some senile changes around the medullary canal.

The internal circumferential lamellæ form a narrow ring around the medullary canal. The bone units are well developed.

Type I-III, Ia, C, senile.

HAVERSIAN SYSTEMS SHOWING STAGES OF SENILITY

PL. 34, FIGS. 423-24-25-26

These systems were taken from figure 417 and enlarged. Figure 423 shows an Haversian system before senile changes are visible. It is composed of a number of concentric lamellæ with serrated edges united by cement. The lacunæ are long and narrow and are situated either between the lamellæ or within them. There does not seem to be any regularity in the arrangement.

Figure 424 shows an early stage of senility. In this Haversian system there is a deposit of opaque granules in the lamellæ around the Haversian canal. The density of the granules diminishes from the canal toward the periphery.

Figure 425 shows a later stage. The density has increased and expanded. The central lamellæ have dropped out and the Haversian canal is larger. The whole system is more or less involved. In the external portion the granules are brown and the lamellæ are somewhat dim. The central ring is black.

Figure 426 shows the last stage. The lamellæ have nearly all disappeared, and a narrow black ring only remains. The Haversian canal is large and irregular in shape. The medullary canal is very much increased in size and the bone is light in weight.

Senile changes are more frequent around the medullary canal than elsewhere, although they may occur in any part of the bone.

As the lamellæ around the Haversian canals become more and more opaque with inorganic salts they gradually disintegrate, the inorganic matter enters the blood vessels and is carried into the general circulation to be removed from the body or deposited in the degenerating wall of blood vessels.

RIGHT FEMUR OF A WHITE MALE (CONVICT). NO. 2, MED. DEPT. NEBRASKA UNIV.

PL. 35, FIG. 428. SYN. TAB. XI

Antero-posterior diameter of bone, 32 mm.; lateral, 27.5 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 21%.

Structure.—A narrow band of external circumferential lamellæ surrounds the section.

The central ring is composed of large, small, and variously shaped Haversian systems with relatively small Haversian canals. On account of the small canals the Haversian systems have thick walls. Many of the canals are situated eccentrically. Scattered throughout the wall of the section are many Haversian systems in various stages of senility. In some, the two or three lamellæ around the Haversian canal are involved; in others, half of the system is senile; and in others, the whole system is black with mineral precipitation. In the posterior inner wall a few elliptical Haversian systems occur.

Internal circumferential lamellæ surround the medullary canal. The lacunæ of the section are generally oval.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE (CONVICT). NO. 3, MED. DEPT. NEBRASKA UNIV.

PL. 35, FIG. 429. SYN. TAB. XI

Antero-posterior diameter of bone, 26.5 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 12 mm.

The medullary canal is full. Medullary index, 39%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring is composed of variously shaped, large and small Haversian systems with no inter-Haversian lamellæ. Some of the systems are well developed; some have small Haversian canals; some show early stages of senility; some later; and some the latest. The lacunæ are generally oval. A narrow ring of internal circumferential lamellæ surrounds the medullary canal.

Type III, C, senile.

* LEFT FEMUR OF A WHITE MALE, AGE 50. NO. 268, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 12 mm.

Medullary index, 21%.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed almost entirely of small, large, and irregularly shaped Haversian systems and a small amount of inter-Haversian lamellæ. In the vicinity of the medullary canal many of the systems are senile. The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 269, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 29 mm.; lateral, 33.5 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 20 mm.

Medullary index, 54%.

Structure.—A wide background of lamellæ, enclosing Haversian canals and small Haversian systems, forms the external half of the anterior wall and is mostly displaced by Haversian systems as it extends around the lateral wall to the posterior ridge. The systems vary in size and shape and many show senile changes. There is a scarcity of communicating cross canals.

In the inner wall a short, fan-shaped band of laminæ, interrupted by small Haversian systems, extends from the medullary surface of the posterior ridge outward. This has been observed in a number of femora, but not in all. Its significance is not clear.

The internal circumferential lamellæ form a very narrow fragmentary ring around the medullary canal.

Type I-II-III, Ia, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 270, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 31 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 13 mm.

Medullary index, 29%. The section is almost quadrangular in shape.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed, for the most part, of well developed Haversian systems with very little inter-Haversian bone substance. Many of the systems are senile. The cross canals are fairly numerous.

The internal circumferential lamellæ form a very narrow ring around the medullary canal.

Type III, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 271, CR. MED. COLL.

Syn. Tab. XI

Antero-posterior diameter of bone, 31 mm.; lateral, 32 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

Medullary index, 35%.

Structure.—The external circumferential lamellæ form a narrow ring around the bone.

The section is composed almost entirely of large, small, and irregularly shaped Haversian systems. Their lacunæ are generally oval. The cross canals are not numerous. Senile changes are few.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C.

* RIGHT FEMUR OF A WHITE MALE. NO. 272, CR. MED. COLL.

Syn. Tab. XI

Antero-posterior diameter of bone, 33 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 27 mm.; lateral, 25 mm.

Medullary index, 26%.

Structure.—The external circumferential lamellæ appear as rather wide bands on both sides of the posterior ridge. These bands are interrupted by small Haversian systems and become narrower as they approach the anterior wall where they are fragmentary. The remainder of the section is composed of Haversian systems with oval and long lacunæ.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C.

* RIGHT FEMUR OF A WHITE MALE. NO. 273, CR. MED. COLL.

Syn. Tab. XI

Antero-posterior diameter of bone, 28 mm.; lateral, 29 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 12 mm.

Medullary index, 29%.

Structure.—The external circumferential lamellæ form a complete narrow ring around the bone. The section is composed of well developed Haversian systems closely packed together. Some are large, some small, and some are irregular. Senile changes are frequent.

The internal circumferential lamellæ enclose the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 274, CR. MED. COLL.

PL. 35, FIG. 436. SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 35 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 16 mm.

Medullary index, 30%.

Structure.—The external circumferential lamellæ are fragmentary. The rest of the section is composed almost entirely of Haversian systems, many of which are large in size and have large, irregularly shaped Haversian canals. They are more numerous around the medullary canal than elsewhere. They give to the section a general porous appearance when observed with the naked eye.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 275, CR. MED. COLL.

PL. 35, FIG. 437. SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 19 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 50%.

Structure.—The section is surrounded by a wide band of lamellæ, interrupted by numerous Haversian systems of the (Ia) and (C) differentiations. The central ring, about equal in width to the external lamellar band, is composed of well developed Haversian systems, many of which are senile.

A narrow ring of internal lamellæ surrounds the medullary canal.

Type I-III, Ia, C, senile.

* LEFT FEMUR OF A WHITE MALE. NO. 276, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 28 mm.; lateral, 33.5 mm.

Antero-posterior diameter of medullary canal, 26 mm.; lateral, 17.5 mm.

Medullary index, 100%.

Structure.—The external circumferential lamellæ form a narrow ring around the bone.

The section is composed of Haversian systems, which, in the anterior wall, are separated by the fragments of a lamellar horseshoe band described elsewhere. Many systems are senile.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 277, CR. MED. COLL.

Pl. 35, Fig. 439. Syn. Tab. XI

Antero-posterior diameter of bone, 32 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 11 mm.

The medullary canal is full. Medullary index, 28%.

Structure.—External circumferential lamellæ, interrupted by many Haversian systems, surround the section. The central ring, irregular in width, is composed of Haversian systems, somewhat irregular in shape, but well developed. The internal circumferential lamellæ, expanded into a wide semicircular area in the inner wall, surround the medullary canal.

Type I-III, C.

* RIGHT FEMUR OF A WHITE MALE. NO. 278, CR. MED. COLL.

Syn. Tab. XI

Antero-posterior diameter of bone, 29 mm.; lateral, 34 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

Medullary index, 35%.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed almost entirely of large, small, and irregularly shaped Haversian systems.

The internal circumferential lamellæ form a narrow enclosing ring around the medullary canal.

Type III, C.

* RIGHT FEMUR OF A WHITE MALE. NO. 279, CR. MED. COLL.

Syn. Tab. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 14 mm.

Medullary index, 38%.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed almost entirely of large, small, and irregular Haversian systems, between which are some areas of short lamellæ. The lacunæ are oval; senile changes are frequent. The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 280, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 24.5 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 11 mm.

Medullary index, 29%.

Structure.—The external circumferential lamellæ form a narrow ring around the bone. The section is mostly composed of well developed Haversian systems with little inter-Haversian bone substance.

The internal circumferential lamellæ surround the medullary canal.

Type III, C.

* LEFT FEMUR OF A WHITE MALE. NO. 281, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 31 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 10 mm.

Medullary index, 19%.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed of large, small, and irregularly shaped Haversian systems, some of which show senile changes.

The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type III, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 282, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 31.5 mm.

Antero-posterior diameter of medullary canal, 16 mm.; lateral, 13.5 mm.

Medullary index, 30%.

Structure.—The external circumferential lamellæ are fragmentary. The section is composed of well developed, closely arranged Haversian systems. As a rule, they are clearly distinct, but some of them are senile and obscure.

The internal circumferential lamellæ are fragmentary.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 284, CR. MED. COLL.

PL. 35. FIG. 445. SYN. TAB. XI

Antero-posterior diameter of bone, 26.5 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 12.5 mm.

The medullary canal is full. Medullary index, 31%.

Structure.—Beginning on both sides of the posterior ridge and surrounding the section is a wide horseshoe of crude laminæ and lamellæ, frequently interrupted by Haversian systems of the (Ia) and (C) differentiations. The horseshoe forms half of the outer, nearly all of the anterior, and a third of the inner wall. The Haversian systems have, generally, concentric positions. The canals separating the laminæ are short. In the inner posterior wall is a fan-shaped area of laminæ, interrupted by a few Haversian systems. The remainder of the central ring, of which the fan is a part, is composed of Haversian systems with some senile changes. In the outer wall it has some inter-Haversian lamellæ. The posterior ridge is composed of Haversian systems.

A narrow ring of internal circumferential lamellæ surrounds the medullary canal.

Type I-II-III, Ia, C, senile.

This femur is characterized by units of low differentiations. Only a small portion of it is composed of well developed Haversian systems.

* RIGHT FEMUR OF A WHITE MALE. NO. 285, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 29 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 35%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring constitutes nearly all of the section and is composed of Haversian systems with some inter-Haversian lamellæ. Many senile changes occur around the medullary canal. Internal circumferential lamellæ surround the medullary canal.

Type III, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 286, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 32 mm.; lateral, 27.5 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 14 mm.

The medullary canal is full. Medullary index, 36%.

Structure.—The external circumferential lamellæ are fragmentary. The central ring constitutes nearly all of the section and is composed of Haversian systems exhibiting many senile changes.

Internal circumferential lamellæ surround the medullary canal.

Type III, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 287, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 25 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 9 mm.

The medullary canal is full. Medullary index, 21%.

Structure.—Around the outer and anterior wall is a wide band of lamellæ, interrupted by Haversian systems of the (Ia) differentiation. The band is displaced in the inner wall by Haversian systems. The central ring constitutes all of the inner wall, the posterior ridge, two-thirds of the outer and one-third of the anterior wall. It is composed of Haversian systems of the (C) differentiation, large and small, separated in the outer wall by wide inter-Haversian lamellæ. Some senile changes occur. The internal circumferential lamellæ form a narrow ring around the medullary canal.

Type I-III, Ia, C, senile.

* RIGHT FEMUR OF A WHITE MALE. NO. 288, CR. MED. COLL.

SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 38%.

Structure.—A narrow ring of external circumferential lamellæ surrounds the section.

The central ring constitutes nearly all of the bone and is composed of Haversian systems, many of which are senile. The systems are united by cross canals.

A narrow ring of internal circumferential lamellæ surrounds the medullary canal.

Type III, C, senile.

RIGHT FEMUR OF A WHITE MALE. NO. 289, CR. MED. COLL.

PL. 35, FIG. 451. SYN. TAB. XI

Antero-posterior diameter of bone, 30 mm.; lateral, 33 mm.

Antero-posterior diameter of medullary canal, 14 mm.; lateral, 15 mm.

The medullary canal is full. Medullary index, 27%.

Structure.—The external circumferential lamellæ, separated into short laminæ and interrupted by many Haversian systems, surround the section. The central ring blends with the external and internal rings and is composed of Haversian systems and lamellæ.

The internal circumferential lamellæ, expanding into a semicircular laminar area in the inner wall, surround the medullary canal.

Type I-II-III, C.

LEFT FEMUR OF A WHITE MALE. NO. 296, CR. MED. COLL.

Pl. 35, Fig. 452. Syn. Tab. XI

Antero-posterior diameter of bone, 27.5 mm.; lateral, 23 mm.

Antero-posterior diameter of medullary canal, 12 mm.; lateral, 10 mm.

The medullary canal is full. Medullary index, 23%.

Structure.—A horseshoe band of lamellæ, frequently interrupted by complete and crude Haversian systems of the (Ia) differentiation, surrounds the section. It is widest in the anterior wall. The lacunæ are round, oval, long, and narrow.

The central ring, irregular in shape, is composed of well developed Haversian systems and forms the entire thickness of the posterior wall. The lacunæ are oval. The systems are united by many cross canals.

Internal circumferential lamellæ form a narrow ring around the medullary canal with the exception of the posterior wall. In the anterior wall it becomes cancellous.

Type I-III, Ia, C.

LEFT FEMUR OF A WHITE MALE, AGE 40. NO. 1, NEBRASKA STATE HOSPITAL

Pl. 35, Fig. 453. Syn. Tab. XI

Case of idiopathic epilepsy. Patient had 20 convulsions the day of his death.

Antero-posterior diameter of bone, 27 mm.; lateral, 22 mm.

Antero-posterior diameter of medullary canal, 24 mm.; lateral, 18 mm.

Medullary index, 277%.

General character of the bone.—The femur was small in size. With the exception of a surrounding shell of bone from 1 mm. to 2 mm. thick, the entire medullary portion had suffered an extensive softening and the bone structure had disappeared.

Structure.—The external circumferential lamellæ were fragmentary. Quite large canals penetrated the bone from the periosteum.

The central ring was composed of large, small, and irregularly shaped Haversian systems and inter-Haversian lamellæ. In some systems the Haversian canals were very large and irregular, and in the others they were normal in size. The lacunæ were oval. In some portions of the section, large, irregularly shaped spaces were present. The internal circumferential lamellæ formed a narrow ring around the medullary canal.

Type III, C.

XVI. HISTOLOGICAL EXAMINATION OF TWO ENTIRE HUMAN FEMORA

1. Left Femur, 41 Cm. Long, No. 300, Cr. Med. Coll.

This bone was cut into pieces 2.5 cm. in length, and a cross-section of each piece was examined microscopically. The first section was made through the equatorial diameter of the head, the second through the middle of the neck, the third through the lesser trochanter, and the following sections through the shaft and lower extremity.

HEAD

This section was a circle with a diameter of 44 mm. It was surrounded by an enclosing envelope of bone 0.5 mm. in thickness and composed of lamellæ with round and oval lacunæ and rather infrequent canaliculi.

The remainder of the section was made up of cancellous bone, the meshes of which were filled with marrow. In the central portion of the section the cancellous bone was much heavier than elsewhere. The walls of the meshes were composed of lamellæ with oval and long lacunæ and radiated from the center toward the periphery. No Haversian systems were found.

NECK

Antero-posterior diameter of bone, 33 mm.; lateral, 27 mm.

This section was surrounded by an envelope of bone, varying in thickness from 1 mm. in the anterior to 3 mm. in the posterior wall. It was composed of lamellæ with oval lacunæ and bushy canaliculi, interrupted by a few Haversian systems.

The remainder of the section was made up of cancellous bone, heavier in the posterior than it was in the anterior wall, and having a radiating direction from the posterior toward the anterior boundary of the section. The cancellous bone, as a whole, was considerably denser than it was in the head and was composed of lamellæ, interrupted by a few crude Haversian systems.

SECTION THROUGH THE LESSER TROCHANTER

Antero-posterior diameter of bone, 37 mm.; lateral, 28 mm.

This section is surrounded by an envelope of bone, ranging in thickness from 1 mm. in the posterior to 4 mm. in the outer, 2.5 mm. in the anterior and 5 mm. in the inner wall.

From the inner wall the calcar femorale, an extension inward of the surrounding envelope, gradually separated into cancellous bone which then merged into that occupying the whole central portion of the section.

Structure.—The envelope was composed of indistinctly lamellated bone with diffusely arranged lacunæ and bushy canaliculi, interrupted by crude Haversian systems. The walls of the cancellous meshes were composed of lamellæ without Haversian systems.

FOURTH SECTION

Antero-posterior diameter of bone, 33 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 19 mm.; lateral, 19 mm.

Medullary index, 67%.

Structure.—With the exception of the posterior ridge this section was surrounded by a wide horseshoe-shaped background of lamellæ, forming half of the thickness of the entire wall of the bone, and containing many Haversian systems of the (Ia) and (C) differentiations.

The posterior ridge was composed of Haversian systems, between which were lamellæ with many large, oval lacunæ and bushy canaliculi. The central ring was narrow and composed of Haversian systems with some inter-Haversian lamellæ. Many of the Haversian systems were senile. A narrow ring of internal circumferential lamellæ surrounded the medullary canal.

FIFTH SECTION

Antero-posterior diameter of bone, 31 mm.; lateral, 31 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 14 mm.

Medullary index, 28%.

SIXTH SECTION

Antero-posterior diameter of bone, 28 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 10 mm.

Medullary index, 22%.

SEVENTH SECTION

Antero-posterior diameter of bone, 28 mm.; lateral, 25 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 10 mm.

Medullary index, 23%.

EIGHTH SECTION

Antero-posterior diameter of bone, 28 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 13 mm.; lateral, 12 mm.

Medullary index, 27%.

NINTH SECTION

Antero-posterior diameter of bone, 28 mm.; lateral, 26 mm.

Antero-posterior diameter of medullary canal, 15 mm.; lateral, 14 mm.

Medullary index, 36%.

TENTH SECTION

Antero-posterior diameter of bone, 28 mm.; lateral, 27 mm.

Antero-posterior diameter of medullary canal, 17 mm.; lateral, 17 mm.

Medullary index, 62%.

ELEVENTH SECTION

Antero-posterior diameter of bone, 30 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 21 mm.; lateral, 20 mm.

Medullary index, 100%.

TWELFTH SECTION

Antero-posterior diameter of bone, 31 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 24 mm.; lateral, 21 mm.

Medullary index, 140%.

Structure.—The above sections resembled in structure the fourth, a description of which is already given. There was, however, an increasing proportion of the lamellar background from the fourth to the twelfth section. Senile systems were numerous.

THIRTEENTH SECTION

Antero-posterior diameter of bone, 34 mm.; lateral, 30 mm.

Structure.—The section is surrounded by a wide lamellar background in which are variously shaped Haversian systems. The remainder of the section is cancellous.

FOURTEENTH SECTION

Antero-posterior diameter of bone, 30 mm.; lateral, 40 mm.

Structure.—The section is surrounded by lamellæ with a few Haversian systems. The remainder of the section is cancellous.

FIFTEENTH SECTION

Antero-posterior diameter of bone, 31 mm.; lateral, 52 mm.

Structure.—The section is surrounded by lamellæ with a few Haversian systems. The remainder is cancellous.

The type of bone of this femur was I-III, C, senile. The characteristic units of structure were lamellæ.

2. LEFT FEMUR OF A WHITE FEMALE, 38 CM. LONG. NO. 301, CR. MED. COLL.

Transverse sections were made at intervals of 2.5 cm. and in the same situations as they were in femur No. 300.

HEAD

Antero-posterior diameter of the equatorial section, 41 mm.; lateral, 41 mm.

Structure.—The section was surrounded by a thin envelope of bone, 0.5 mm. in thickness, and composed of lamellæ with a few very crude Haversian systems. The remainder of the section was made up of cancellous bone much more dense in the central portion than elsewhere and composed of lamellæ. The walls of the meshes radiated from the central portion toward the periphery.

NECK

Antero-posterior diameter, 30 mm.; lateral, 27 mm.

Structure.—The section was surrounded by an envelope of bone, varying in thickness from 3 mm. in the posterior to 1 mm. in the lateral wall. The enclosing envelope was composed of Haversian systems and some inter-Haversian lamellæ. The remainder of the section was made up of cancellous bone, denser near the posterior wall, and radiating from this location toward the periphery. It was considerably heavier than that of the head, and the walls of the meshes were composed of lamellæ with a few Haversian systems.

SECTION THROUGH THE LESSER TROCHANTER

Antero-posterior diameter, 34 mm.; lateral, 33 mm.

Structure.—The section was surrounded by an envelope of bone, varying in thickness from 4 mm. in the posterior to 1 mm. in the lateral wall. It was composed chiefly of Haversian systems, between which were some inter-Haversian lamellæ. The calcar femorale was well marked and composed of lamellæ with many Haversian systems. The remainder of the section was made up of a heavy cancellous bone composed of lamellæ.

FOURTH SECTION

Antero-posterior diameter of bone, 30 mm.; lateral, 27 mm.
Antero-posterior diameter of medullary canal, 22 mm.; lateral, 18 mm.
Medullary index, 97%.

FIFTH SECTION

Antero-posterior diameter of bone, 29 mm.; lateral, 25 mm.
Antero-posterior diameter of medullary canal, 20 mm.; lateral, 15 mm.
Medullary index, 72%.

SIXTH SECTION

Antero-posterior diameter of bone, 27 mm.; lateral, 24 mm.
Antero-posterior diameter of medullary canal, 18 mm.; lateral, 13 mm.
Medullary index, 58%.

SEVENTH SECTION

Antero-posterior diameter of bone, 26 mm.; lateral, 24 mm.
Antero-posterior diameter of medullary canal, 16 mm.; lateral, 13 mm.
Medullary index, 50%.

EIGHTH SECTION

Antero-posterior diameter of bone, 27 mm.; lateral, 24 mm.
Antero-posterior diameter of medullary canal, 17 mm.; lateral, 13 mm.
Medullary index, 87%.

As the foregoing five sections have practically the same minute structure one description will be sufficient for all.

Structure.—These sections were composed of small and large Haversian systems with a small amount of inter-Haversian lamellæ. Some of the systems are senile. The external and internal circumferential lamellæ were fragmentary. The cancellous bone disappeared at the seventh section.

NINTH SECTION

Antero-posterior diameter of bone, 27 mm.; lateral, 25 mm.
Antero-posterior diameter of medullary canal, 17 mm.; lateral, 15 mm.
Medullary index, 61%.

TENTH SECTION

Antero-posterior diameter of bone, 27 mm.; lateral, 25 mm.
Antero-posterior diameter of medullary canal, 18 mm.; lateral, 16 mm.
Medullary index, 75%.

ELEVENTH SECTION

Antero-posterior diameter of bone, 32 mm.; lateral, 30 mm.

Antero-posterior diameter of medullary canal, 26 mm.; lateral, 21 mm.

Medullary index, 69%.

Structure of the ninth, tenth, and eleventh sections.—With the exception of the posterior ridges these sections were composed of an external horseshoe-shaped band of lamellæ, which was wide in the anterior and very narrow in the lateral wall. The lamellar band was frequently interrupted by Haversian systems, some of which were senile. The central ring was composed of well developed, small and large Haversian systems, some of which were senile. The internal circumferential lamellæ were fragmentary.

The principal variations in these sections were seen in the appearance of the band of lamellæ and reappearance of the cancellous bone.

TWELFTH SECTION

Antero-posterior diameter of bone, 33 mm.; lateral, 28 mm.

Antero-posterior diameter of medullary canal, 20 mm.; lateral, 19 mm.

Medullary index, 126%.

THIRTEENTH SECTION

Antero-posterior diameter of bone, 27 mm.; lateral, 36 mm.

Cancellous.

FOURTEENTH SECTION

Antero-posterior diameter of bone, 28 mm.; lateral, 44 mm.

Cancellous.

FIFTEENTH SECTION

Antero-posterior diameter of bone, 35 mm.; lateral, 70 mm.

Cancellous.

Structure of twelfth, thirteenth, fourteenth, and fifteenth sections.—These were composed of Haversian systems and some inter-Haversian lamellæ. The band of lamellæ was not present. The systems were small and large, and some were senile. The external circumferential lamellæ were fragmentary and the internal were cancellous.

The type was III, C, senile.

SYNOPTIC TABLE I

Class		Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
					III				Bone		Medullary canal								
					Incomplete differentiation			Complete differentiation											
			I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
Amphibians.	Rana catesbiana (large bull frog) ....C. M. C.	R	×	..	..	..	..	..	3.5	4.5	1	2	16	×	..	......	..	1	1
	Rana catesbiana (medium bull frog) .... "	"	×	..	..	..	..	..	2.5	3	1.4	1.6	42	×	..	......	..	2	1
	Rana catesbiana (small bull frog) .... "	"	×	..	..	..	..	..	1	1.3	0.5	0.6	29	×	..	......	..	3	1
	Rana catesbiana (small bull frog) .... "	"	×	..	..	..	..	..	1	1.5	0.5	0.6	24	×	..	......	..	4	1
	Rana catesbiana (small, fractured and repaired) "	..	×	..	..	..	..	..	1.5	1.7	0.6	0.7	20	×	..	......	..	5	1
	Amblystoma tigrinum (most prim. amphib.) A. M. N. H.	R	×	..	..	..	..	..	2	2.5	0	0	0	×	..	cancellous	..	6	2
	Hyla versicolor (tree frog) ....U. S. N. M.	"	×	..	..	..	..	..	0.8	0.8	0.2	0.2	7	×	..	......	..	7	2
	Hyla arenicolor ....E. 50.30 "	"	×	..	..	..	..	..	0.5	0.5	0.2	0.2	19	×	..	......	..	8	2
	Hyla femoralis ....E. 60.23 "	"	×	..	..	..	..	..	0.5	0.4	0.2	0.2	24	×	..	......	..	9	2
	Hyla evittata ....E. 55.17 "	"	×	..	..	..	..	..	0.5	0.2	0.4	0.1	104	×	..	......	..	10	2
	Hyla cinerea ....E. 130.95 "	"	×	..	..	..	..	..	1.5	1	0.5	0.4	14	×	..	......	..	11	2
	Hyla regilla ....E. 62.39 "	"	×	..	..	..	..	..	1	0.9	0.5	0.5	38	×	..	......	..	12	2
	Hyla squirella ....E. 51.2 "	"	×	..	..	..	..	..	0.8	0.5	0.5	0.4	92	×	..	......	..	13	2
	Hyla gratiosa ....E. 40.14 "	"	×	×	..	..	..	..	1	0.8	0.5	0.5	44	×	..	......	..	14	2
	Dendrobates tinctorius ....E. 14.36 "	"	×	..	..	..	..	..	0.6	0.5	0.2	0.2	15	×	..	......	..	15	2
	Leptodactylus albilabris ....G. 13.11 "	"	×	..	..	..	..	..	1	0.8	0.8	0.3	59	×	..	......	..	16	2
	Chorophilus feriarum ....E. 52.47 "	"	×	..	..	..	..	..	0.5	0.4	0.2	0.2	24	×	..	......	..	17	2
	Acris gryllus .... "	"	×	..	..	..	..	..	0.5	0.3	0.2	0.1	16	×	..	......	..	18	2
	Rana catesbiana ....A. M. N. H.	"	×	..	..	..	..	..	2.5	2.5	1.5	1.5	56	×	..	......	..	19	2
	Rana palustris ....F. 52.22 U. S. N. M.	"	×	..	..	..	..	..	1	0.8	0.5	0.5	44	×	..	......	..	20	2
	Rana areolata circulosa...........F. 72.3 "	"	×	..	..	..	..	..	2	2	1.5	1.4	110	×	..	......	..	21	2
	Rana aurora ....F. 50.10 "	"	×	..	..	..	..	..	1.5	1	0.5	0.5	19	×	..	......	..	22	2
	Rana pretiosa ....F. 75.11 "	"	×	..	..	..	..	..	2	1.5	1	0.8	41	×	..	......	..	23	2
	Rana draytonii ....F. 70.14 "	"	×	..	..	..	..	..	3	3	1.5	1.5	33	×	..	......	..	24	2
	Spelerpes ruber (red salamander).........A. M. N. H.	"	×	..	..	..	..	..	1	1.5	0.3	0.2	4	×	..	......	..	25	2
	Cryptobranchus alleghenlensis (hellbender) "	"	×	..	..	..	..	..	2.5	1.5	0.5	0.5	7	×	..	......	..	26	2
	Necturus maculatus (necturus)............ "	"	×	..	..	..	..	..	2	1.5	0.5	0.5	9	×	..	......	..	27	2
	Scaphiopus holbrookii (spade-foot toad)... "	"	×	..	..	..	..	..	1.5	1	0.5	0.5	11	×	..	......	..	28	2
	Scaphiopus couchii ....E. 50.20 U. S. N. M.	"	×	..	..	..	..	..	1	1.5	0.5	0.6	24	×	..	......	..	29	2
	Scaphiopus hammondii ....F. 20.6 "	"	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	30	2
	Pipa americana (Surinam toad)..........A. M. N. H.	"	×	..	×	..	..	..	3.5	5.5	0.8	0.8	3	×	..	......	..	31	3
	Bufo agua (Bermuda toad).......No. 1113 "	"	×	..	×	..	..	..	5	3.5	2.5	2	39	×	..	......	..	32	3
	Bufo halophilus ....E. 35.8 U. S. N. M.	"	×	..	×	..	..	..	2	2	1.5	1.5	129	×	..	......	..	33	3
	Bufo columbiensis ....E. 40.2 "	"	×	..	×	..	..	..	2	2	1.4	1.5	111	×	..	......	..	34	3
	Bufo lentiginosus woodhousii.......E. 45.9 "	"	×	..	×	..	..	..	2.5	2	1.5	1	45	×	..	......	..	35	3
	Bufo americana (American toad)..........A. M. N. H.	"	×	×	×	..	..	..	2.5	2	1	0.6	15	×	..	......	..	36	3
	Bufo lentiginosus cognatus.........E. 13.11 U. S. N. M.	"	×	..	×	..	..	..	2	1.5	1	0.9	42	×	..	......	..	37	3
	Bufo valliceps ....E. 21.5 "	"	×	..	×	..	..	..	2	1.5	0.9	0.8	31	×	..	......	..	38	3
	Rana boylii ....F. 61.20 "	"	×	..	..	..	..	..	1	0.6	0.5	0.4	47	×	..	......	..	39	3
	Average diameters and medullary index.............	..	..	..	..	..	..	..	1.7	1.6	0.7	0.7	36.6	..	..	......	..	..	..

SYNOPTIC TABLE II

Class		Right or left femur	Types and type combinations						Measurements					Medullary canal				Reference	
					III				Bone		Medullary canal								
					Incomplete differentiation			Complete differentiation											
			I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special	Senility	Figure	Plate
Reptiles.	Sphenodon punctatus (most prim. rept.) ... A. M. N. H.	R	×	..	..	..	..	..	3	2.5	1.5	1	26	×	..	......	..	40	3
	Phrynosoma cornutum .... “	“	×	..	..	..	..	..	2.8	1.5	0.8	0.5	10	×	..	......	..	41	3
	Chamæleo vulgaris .... “	L	×	..	..	..	..	..	1.8	1.5	1	0.8	42	×	..	......	..	42	3
	Phrynosoma douglassii .... L. 50.12 U. S. N. M.	R	×	..	..	..	..	..	2	1	0.5	0.5	12	×	..	......	..	43	3
	Ptychozoon homalocephalum (gecko) No. 684 A. M. N. H.	“	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	44	3
	Iguana tuberculata .... “	“	×	..	..	..	..	..	3.5	3	2	2	61	×	..	......	..	45	3
	Varanus salvator .... “	L	×	..	×	..	..	..	11	10	7	6	51	×	..	......	..	46	3
	Amphibolurus barbatus .... “	R	×	..	..	..	..	..	3	4	1.5	2.5	49	×	..	......	..	47	3
	Varanus arenarius .... “	L	×	..	..	..	..	..	4.5	3	3	2	45	×	..	......	..	48	3
	Varanus nuchalis (monitor) .... “	R	×	..	×	..	..	..	4.5	3.5	3	2.5	88	×	..	......	..	49	3
	Heloderma suspectum (gila monster) No. 583 “	“	×	..	..	..	..	..	3	3	0.7	0.7	5	×	..	......	..	50	4
	Sceloporus clarkii .... I. 61.17 U. S. N. M.	“	×	..	..	..	..	..	1.5	1.5	0.5	0.5	12	×	..	......	..	51	4
	Sceloporus spinosus floridanus ..... I. 73.12 “	“	×	..	..	..	..	..	1.5	1.5	0.5	0.5	12	×	..	......	..	52	4
	Sceloporus occidentalis .... I. 74.3 “	“	×	..	..	..	..	..	1.5	1	0.6	0.5	24	×	..	......	..	53	4
	Sceloporus magister .... J. 71.2 “	“	×	..	..	..	..	..	1.5	1	0.5	0.5	19	×	..	......	..	54	4
	Cyclura carinata .... “	“	×	..	..	..	..	..	5	5	3	3	56	×	..	......	..	55	4
	Anolis cristatellus .... L. 15.13 “	“	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	56	4
	Crotaphytus collaris .... J. 21.12 “	“	×	..	..	..	..	..	1.5	1.5	1	1	80	×	..	......	..	57	4
	Crotaphytus collaris .... J. 32.9 “	L	×	..	..	..	..	..	1.5	1.5	0.8	0.8	40	×	..	......	..	58	4
	Ameiva exul .... L. 21.11 “	R	×	..	..	..	..	..	2	2	0.5	0.5	33	×	..	......	..	59	4
	Eumeces fasciatus .... H. 31.4 “	“	×	..	..	..	..	..	1.5	1	0.6	0.5	24	×	..	......	..	60	4
	Sauromalus .... J. 40.6 “	“	×	..	..	..	..	..	3	2.5	1.5	1.2	32	×	..	......	..	61	4
	Gerrhonotus grandis .... I. 22.4 “	“	×	..	..	..	..	..	1.5	1	0.4	0.4	11	×	..	......	..	62	4
	Python regius .... “	“	×	..	..	..	..	..	1	0.6	0.4	0.3	24	×	..	......	..	63	4
	Python regius .... “	L	×	..	..	..	..	..	1	1	0.5	0.4	28	×	..	......	..	64	4
	Alligator mississippiensis .... C. M. C.	“	×	×	×	×	..	..	17	15	7	6	20	×	..	......	..	65	4
	Chelydra serpentina (snapping turtle) .... “	..	×	×	×	×	..	..	8	8.5	1	1	1.5	×	..	cancellous	..	66	4
	Trionyx spinifer (soft-shelled turtle) ...... A. M. N. H.	R	×	..	×	×	..	..	3.5	5.5	0	0	0	×	..	“	..	67	4
	Cinosternum pennsylvanicum (mud turtle). “	“	×	..	..	×	..	..	3	3.5	0	0	0	×	..	“	..	68	4
	Chelopus guttatus (spotted turtle) .... “	“	×	..	×	×	..	..	2.5	4	0	0	0	×	..	“	..	69	4
	Chrysemys picta (painted turtle) .... “	L	×	..	×	×	..	..	2.5	4	0	0	0	×	..	“	..	70	4
	Aromochelys odoratus (musk turtle) ...... “	R	×	..	..	×	..	..	1.8	1.4	0.3	0.3	4	×	..	“	..	71	4
	Pseudemys floridana (turtle) .... “	“	×	×	..	×	..	..	4	3	0	0	0	×	..	“	..	72	4
	Testudo (Gopherus) polyphemus (turtle) .. “	“	×	..	×	×	..	..	8.5	6	0	0	0	×	..	“	..	73	4
	Average diameters and medullary index with the turtles	..	..	..	..	..	..	..	3.4	3.2	1.2	1.1	26.1	..	..	......	..	..	..
	Average diameters and medullary index without the turtles	..	..	..	..	..	..	..	3.3	2.9	1.5	1.4	33	..	..	......	..	..	..

SYNOPTIC TABLE III

Class		Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
					III				Bone		Medullary canal								
					Incomplete differentiation			Complete differentiation											
			I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
Birds.	Cyanocitta stelleri azteca (Aztec jay)......A. M. N. H.	R	×	×	..	..	..	..	3	2.5	2	1.5	68	×	..	......	..	74	5
	Mergus serrator (red-breasted merganser). “	L	×	×	..	..	×	..	6.5	4.5	4.5	2.5	68	×	..	......	..	75	5
	Ajaia ajaja (roseate spoonbill).......... “	R	×	×	..	..	..	..	7	6	5	4.5	114	..	..	......	..	76	5
	Tympanuchus americanus (prairie chicken)..C. M. C.	“	×	..	..	..	..	..	5	6	4	4.5	148	..	×	......	..	77	5
	Numida meleagris (guinea fowl)............ “	“	..	×	..	..	×	..	7	8	5	6	116	×	..	......	..	77½	5
	Cyanocitta cristata (blue jay)............... “	“	..	×	..	..	×	..	2.5	2.5	1.5	1.5	56	×	..	......	..	78	5
	Pteroglossus torquatus (banded toucan)...A. M. N. H.	L	×	..	..	..	..	..	3	3	2	2	80	×	..	......	..	79	5
	Charadrius pluvialis (golden plover)....... “	“	..	×	..	..	..	..	2.5	2.5	1.5	1.5	56	×	..	......	..	80	5
	Amazona oratrix (Mexican parrot)........ “	“	..	×	×	..	×	..	4	3.5	3	3	177	×	..	......	..	81	5
	Turdus migratorius (robin)................C. M. C.	R	×	..	..	..	×	..	2	2	1.5	1.5	129	×	..	......	..	82	5
	Pelecanus erythrorhynchus (white pelican)... “	..	×	..	..	..	×	..	12	10	0	0	0	×	..	cancellous	..	83	5
	Ara macao (macaw)....................... “	R	..	×	..	..	×	..	5.5	4.5	4.5	3.5	178	×	..	......	..	84	5
	Nyctherodius violaceus (night heron)........ “	“	..	×	..	..	×	..	5	6	4	4.5	148	×	..	......	..	85	5
	Pavo cristatus (peafowl).................. “	..	..	×	..	..	×	..	10	11	8	10	277	..	×	......	..	86	5
	Haliäetus leucocephalus (eagle)............. “	..	..	×	..	..	×	..	13	14	11	11.5	227	..	×	......	..	87	5
	Aramus vociferus (courlan)...............A. M. N. H.	L	..	×	..	..	..	..	6.5	6	5.5	5	239	..	×	......	..	88	5
	Centrocercus urophasianus (sage hen).......C. M. C.	“	..	×	..	..	..	..	7	6	6	5	252	..	×	......	..	89	5
	Meleagris gallipavo (wild turkey)........... “	“	..	×	×	..	×	..	15	17.5	10.5	13	109	×	..	......	..	90	6
	Meleagris gallipavo (domestic turkey)........ “	“	..	×	×	..	×	..	9	11	7	8	129	×	..	......	..	91	6
	Dendragapus obscurus (blue grouse)......... “	“	..	×	..	..	..	..	5	5.5	4	5	277	..	×	......	..	92	6
	Rhea americana (rhea)..................A. M. N. H.	“	..	×	..	..	×	..	25.5	20.5	19	15	120	×	..	......	..	93	6
	Struthio (ostrich) .... “	“	..	×	..	..	×	..	54	40	47	32	240	..	×	......	..	94	6
	Haversian system of the ostrich..................	..	..	..	..	..	..	..	..	..	..	..	..	..	..	......	..	95	6
	Phasianus torquatus (Chinese pheasant).....C. M. C.	L	..	×	..	..	×	..	6	6	4.5	4.5	129	..	×	......	..	95½	6
	Dromæus novæ hollandiæ (emu)..........A. M. N. H.	R	..	×	..	..	×	..	30	26	22	19.5	122	..	..	......	..	96	6
	Anas boscas (mallard duck).................C. M. C.	..	..	×	..	..	×	..	4.5	6.5	3.5	5	141	..	×	......	..	97	6
	Emberiza citrinella (yellow hammer)......... “	..	×	..	..	..	×	..	2.5	3	0	0	0	..	..	cancellous	..	98	6
	Chauna cristata (crested screamer)........A. M. N. H.	R	..	..	..	..	×	..	12.5	12	10.5	10.5	277	..	×	......	..	99	6
	Pandion carolinensis (American osprey)......C. M. C.	L	..	×	..	..	×	..	7.5	8	6	6.5	188	×	..	......	..	100	6
	Sarcorhamphus gryphus (Andean condor)..A. M. N. H.	R	×	..	..	..	×	..	18.5	17.5	15	14.5	204	..	..	......	..	101	7
	Olor sp.? (swan)......................... “	“	..	×	..	..	×	..	11.5	10.5	7	8	87	..	..	......	..	102	7
	Gavia stellata (red-throated loon)......... “	L	×	..	..	..	×	..	8.5	6.5	5	4	184	..	..	......	..	103	7
	Gallus (domestic chicken)...................C. M. C.	..	×	..	..	..	×	..	9	9	7	7	153	×	..	......	..	104	7
	Corvus americanus (American crow)......... “	..	×	..	..	..	×	..	4	3	2.5	2	70	×	..	......	..	105	7
	Asio wilsonianus (long-eared owl)........... “	..	×	×	..	..	×	..	8	7	6	6	178	×	..	......	..	106	7
	Bernicla canadeusis (wild goose)............ “	R	..	×	..	..	×	..	9	8.5	7	7	178	×	..	......	..	107	7
	Leptoptilos sp.? (stork)..................A. M. N. H.	L	×	..	..	..	×	..	17	15	14.5	13.5	327	..	×	......	..	108	7
	Anthracoceros malabaricus (hornbill)..... “	R	×	..	..	..	×	..	6.5	6	5.5	5	240	..	×	......	..	109	7
	Astur atricapillus (goshawk)................C. M. C.	..	×	..	..	..	×	..	4	4.3	3	3.3	139	..	×	......	..	110	7
	Inocotis papillosus (ibis).................A. M. N. H.	L	×	..	..	..	×	..	7	6.5	.6	5.5	264	..		......	..	111	7
	Cathartes aura (turkey-buzzard)............C. M. C.	R	×	..	..	..	×	..	9.5	8	7.5	7	219	..	×	......	..	112	7
	Average diameters and medullary index..............	..	..	..	..	..	..	..	9.6	8.9	7.2	6.8	158.9	..	..	......	..	..	..

SYNOPTIC TABLE IV

Class Mammals			Right or left femur	Types and type combinations						Measurements					Medullary canal			Reference		
						III				Bone		Medullary canal								
						Incomplete differentiation			Complete differentiation											
				I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special	Senility	Figure	Plate
Bats.	Mormoops	No. 102231 U. S. N. M.	R	×	..	..	..	..	..	1	0.8	0.6	0.5	59	×	..	......	..	113	8
	Rhinolophus mehelyi	" 84768 "	"	×	..	..	..	..	..	0.8	0.8	0.5	0.5	64	×	..	......	..	114	8
	Sturnira lilium	" 115053 "	L	×	..	..	..	..	..	1	0.9	0.5	0.4	29	×	..	......	..	115	8
	Lonchorina	" 173849 "	R	×	..	..	..	..	..	0.9	0.8	0.5	0.5	55	×	..	......	..	116	8
	Rousettus amplexicaudatus	" 175844 "	L	×	..	..	..	..	..	2.5	2	1.5	1	44	×	..	......	..	117	8
	Hipposideros larvatus	" 152076 "	R	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	118	8
	Hemiderma	" 123744 "	L	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	119	8
	Desmodus rotundus	" 114977 "	"	×	..	..	..	..	..	1.5	2.5	1	2	129	×	..	......	..	120	8
	Leptonycteris	" 105129 "	"	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	121	8
	Rhinopoma (Palestine)	" 122140 "	R	×	..	..	..	..	..	1	0.9	0.5	0.4	29	×	..	......	..	122	8
	Erophylla bombifrons	" 86262 "	L	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	123	8
	Phyllostoma hastatum	" 102906 "	"	×	..	..	..	..	..	2.5	1.5	1.5	1	64	×	..	......	..	124	8
	Epomophorus wahlbergii	" 113451 "	"	×	..	..	..	..	..	2	1	1	0.5	33	×	..	......	..	125	8
	Glossophaga elongata	" 102107 "	"	×	..	..	..	..	..	0.9	0.8	0.4	0.4	28	×	..	......	..	126	8
	Nyctalus aviator	" 102098 "	"	×	..	..	..	..	..	1.5	1.5	0.5	0.5	12	×	..	......	..	127	8
	Scotophilus heathii	" 13692 "	"	×	..	..	..	..	..	2	1.5	1.2	1	65	×	..	......	..	128	8
	Miniopterus schreibersii	" 152610 "	R	×	..	..	..	..	..	0.8	0.7	0.3	0.4	64	×	..	......	..	129	8
	Promops fosteri	" 105676 "	L	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	130	8
	Vespertilio murinus	" 5333 "	"	×	..	..	..	..	..	1.5	1.5	0.5	0.5	12	×	..	......	..	131	8
	Molossus nigricans	" 8268 "	R	×	..	..	..	..	..	1.5	1	0.7	0.8	56	×	..	......	..	132	8
	Dasypterus intermedius	" 22408 "	"	×	..	..	..	..	..	1	0.9	0.5	0.4	29	×	..	......	..	133	8
	Molossus major	" 101893 "	L	×	..	..	..	..	..	0.6	0.6	0.4	0.4	80	×	..	......	..	134	8
	Antrozous pallidus	" 63386 "	"	×	..	..	..	..	..	1	1	0.8	0.8	178	×	..	......	..	135	8
	Eumops californicus	" 61387 "	"	×	..	..	..	..	..	1.5	1.5	0.9	0.9	56	×	..	......	..	136	8
	Plecotus auritus	" 152597 "	R	×	..	..	..	..	..	0.8	0.7	0.5	0.4	56	×	..	......	..	137	8
	Nycticeius humeralis	" 115141 "	L	×	..	..	..	..	..	0.8	0.7	0.6	0.5	116	×	..	......	..	138	8
	Myotis myotis	" 86500 "	R	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	139	8
	Eptesicus bahamensis	" 121929 "	L	×	..	..	..	..	..	0.8	0.7	0.5	0.4	56	×	..	......	..	140	8

SYNOPTIC TABLE IV—(Continued)

Class Mammals			Right or left femur	Types and type combinations I	II	III Incomplete differentiation 1a	1b	1c	Complete differentiation C	Measurements Bone Ant.-post. diam. in mm.	Bone Lat. diam. in mm.	Medullary canal Ant.-post. diam. in mm.	Medullary canal Lat. diam. in mm.	Medullary indices Per cent	Medullary canal Full	Empty	Special	Senility	Reference Figure	Plate
Bats.	Nycteris borealis	No. 101945 U. S. N. M.	L	×	..	..	..	..	..	0.8	0.8	0.4	0.4	33	×	..	......	..	141	8
	Glischropus tylopus	" 142385 "	R	×	..	..	..	..	..	0.5	0.4	0.3	0.2	45	×	..	......	..	142	8
	Nycteris cinerea	" ...... "	"	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	143	8
	Phyllonycteris	" 103501 "	L	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	144	8
	Megaderma spasma	" 114272 "	R	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	145	8
	Pteronotus	" 113570 "	"	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	146	8
	Balantiopteryx plicata	" 142606 "	L	×	..	..	..	..	..	0.5	0.5	0.3	0.3	56	×	..	......	..	147	8
	Saccopteryx	" 123800 "	R	×	..	..	..	..	..	1	0.8	0.4	0.3	18	×	..	......	..	148	8
	Petalia	" 154866 "	L	×	..	..	..	..	..	1	0.9	0.5	0.5	38	×	..	......	..	149	8
	Monophyllus	" 113677 "	"	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	150	8
	Vampyrops lineatus	" ...... "	"	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	151	8
	Chilonycteris	" 173842 "	R	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	152	8
	Cynopterus	" 141241 "	"	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	153	8
	Artibeus palmarum	" 102866 "	L	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	154	8
	Brachyphylla	" 102351 "	"	×	..	..	..	..	..	1.5	1	1	0.5	56	×	..	......	..	155	8
	Macroglossus minimus	" 171695 "	R	×	..	..	..	..	..	1	0.8	0.5	0.4	33	×	..	......	..	156	8
	Taphozous philippinensis	" 144851 "	L	×	..	..	..	..	..	1	1	0.5	0.5	33	×	..	......	..	157	8
	Cheiromeles torquatus	" 102462 "	R	×	..	..	..	..	..	3.5	2	1.5	1	27	×	..	......	..	158	8
	Noctilio	" 49540 "	"	×	..	×	..	..	..	2	1.5	1.5	0.9	82	×	..	......	..	159	8
	Pteropus molossinus (small)	" 151561 "	L	×	..	..	..	..	..	2.5	2.5	1.5	1.5	56	×	..	......	..	160	8
	Pteropus molossinus (large)	" ...... "	R	×	..	×	..	..	..	3	3.5	2.5	2.5	147	×	..	......	..	161	8
	Pteropus aldabrensis	" 20989 "	"	×	..	×	..	..	..	2	2.5	1	1.5	43	×	..	......	..	162	8
	Pteropus (Celebes)	" 172460 "	"	×	..	×	..	..	..	4	3.5	2.5	2	55	×	..	......	..	163	8
	Pteropus (Java)	" 12616 "	"	×	..	×	..	..	..	3	3.5	2.5	2	91	×	..	......	..	164	8
	Pteropus lepidus	" 112404 "	"	×	..	×	..	..	..	2.5	2	1.5	1	45	×	..	......	..	165	8
	Pteropus (Tongatabu)	" 173884 "	"	×	..	×	..	..	..	3	3	1.5	1.5	33	×	..	......	..	166	8
	Pteropus poliocephalus	" 35102 "	"	×	..	×	..	..	..	3.5	3.5	2	2	49	×	..	......	..	167	9
	Average diameters and medullary index		..	..	..	..	..	..	..	1.4	1.3	0.8	0.7	48.6	..	..	......	..	..	..

SYNOPTIC TABLE V

Class			Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
						III				Bone		Medullary canal								
						Incomplete differentiation			Complete differentiation											
				I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
Mammals.	Tupaia (tree-shrew)	A. M. N. H.	L	×	..	..	..	..	..	3	2.5	2	1.5	67	×	..	......	..	168	9
	Echidna (egg-laying mammal)...No. 17355	“	R	×	..	..	..	..	..	6	11.5	3.5	6.5	49	×	..	cancellous	..	169	9
	Ornithorhynchus (egg-laying mammal)	U. S. N. M.	L	×	..	..	×	..	..	4	5	2.5	3.5	79	×	..	“	..	170	9
	Cavia cutleri (guinea pig)	A. M. N. H.	“	×	..	×	..	..	..	6	4	4	3	100	×	..	......	..	171	9
	Scalopus aquaticus (mole)	“	“	×	..	..	×	..	..	1.5	1.5	1	1	80	×	..	......	..	172	9
	Sorex (shrew)	“	R	×	..	..	×	..	..	3	3.3	1.2	1.5	22	×	..	......	..	173	9
	Macropus (wallaby)	“	“	×	..	×	..	..	..	14	14	10	10.5	115	×	..	......	..	174	9
	Solenodon paradoxus (young)	“	L	×	..	×	×	..	..	5	4.5	4	3.5	165	×	..	cancellous	..	175	9
	Solenodon paradoxus (adult)	“	R	×	..	×	×	..	..	6.5	5	4.5	3.5	94	×	..	“	..	176	9
	Lemur mongoz	U. S. N. M.	..	×	..	..	×	..	..	9	7	7	4.5	100	×	..	......	..	177	9
	Colobus abyssinicus caudatus	A. M. N. H.	L	×	..	×	×	..	×	12.5	13	7	7	43	×	..	......	..	178	9
	Putorius vulgaris (weasel)	C. M. C.	..	×	..	..	..	..	..	1.5	2	1	1.5	62	×	..	......	..	179	9
	Mus rattus (black rat)	“	..	×	..	..	×	..	..	2.5	3.5	1.5	2.5	75	×	..	......	..	180	9
	Heteromys (spiny pocket rat)	A. M. N. H.	L	×	..	×	×	..	..	4.5	2.5	3.5	2	153	×	..	......	..	181	9
	Myogale moschata (desman)	C. M. C.	R	×	×	..	×	..	..	5	6.5	2.5	3	30	..	..	......	..	182	9
	Cynomys ludovicianus (prairie dog)	“	..	×	..	..	×	..	..	4.5	5	2.5	3	50	..	×	......	..	183	9
	Trichosurus vulpecula (phalanger)	A. M. N. H.	L	×	..	×	×	..	..	7	7.5	4	5	61	×	..	......	..	184	9
	Phascolomys ursinus (wombat)	“	“	×	..	×	×	..	..	11.5	13	4	6	11	×	..	cancellous	..	185	9
	Lasiopyga kolbi (African monkey)	“	R	×	..	×	×	..	..	8.5	10	6	7	98	×	..	......	..	186	9
	Tragulus javanicus (mouse-deer)	“	“	..	×	×	..	..	×	7.5	7	6.5	6	289	×	..	......	..	187	10
	Mus sylvaticus (wood mouse)	C. M. C.	“	×	..	..	×	..	..	2	3	1	2	50	×	..	......	..	188	10
	Erinaceus europæus (hedgehog)	A. M. N. H.	L	×	..	..	×	..	..	3	6	2	2.5	38	×	..	......	..	189	10
	Viverra (civet)	“	R	×	..	×	×	..	..	8	7	5	4	55	×	..	......	..	190	10
	Ratufa maxima (giant squirrel)	“	“	×	..	×	×	..	..	5.5	6.5	3.5	4.5	80	×	..	......	..	191	10
	Galeopithecus (flying lemur)	“	..	×	..	×	×	..	..	6.5	5.5	4	3.5	64	×	..	cancellous	..	192	10
	Manis (scaly ant-eater)	“	L	×	..	×	×	..	..	7.5	11	5	7	74	×	..	......	..	193	10
	Procavia capensis (coney)	“	R	×	..	×	..	..	×	7.5	5	3	2.5	25	×	..	......	..	194	10
	Helictis orientalis (Asiatic badger)	“	L	×	..	..	..	..	×	5.5	4.5	3.2	2.5	129	×	..	......	..	195	10
	Cynocephalus (baboon)	“	R	×	..	×	×	..	..	16	16	10	10	64	×	..	cancellous	..	196	10
	Cynocephalus maimon (mandrill)	“	“	×	..	×	×	..	..	13	11.5	8	8	75	×	..	“	..	197	10
	Hydrochœrus capybara (capybara)	“	“	×	..	×	×	..	..	22	20	13	11	48	×	..	......	..	198	10
	Fetal sheep (half time)	C. M. C.	“	..	×	..	×	..	..	3.5	4	1	1	8	×	..	......	..	199	11
	Fetal calf (half time)	“	“	..	×	..	×	..	..	12	11	5	4	18	×	..	......	..	200	11
	Fetal pig (half time)	“	“	..	×	..	..	..	..	3.5	3	1.5	1	17	×	..	......	..	201	11
	Cariacus macrotis (deer)	“	..	..	×	..	..	..	×	25	24	17	16.5	88	×	..	......	..	202	11
	Sus (domestic pig, adult)	“	..	..	×	..	..	..	×	21.5	18.5	16.5	12.5	108	×	..	cancellous	..	203	11
	Sus scrofa (wild boar)	“	R	..	×	..	..	..	×	23	20	15	13	74	×	..	“	..	204	11
	Alces machlis (elk)	“	..	..	×	..	..	..	×	35	33	23	20	66	×	..	“	..	205	11
	Camelus (camel)	A. M. N. H.	R	..	×	..	×	..	..	51	50	35	35	93	×	..	“	..	206	11
	Auchenia glama (llama)	“	“	..	×	..	×	..	..	25	25	17	15	69	×	..	“	..	207	11
	Rangifer (reindeer)	U. S. N. M.	“	..	×	×	×	..	..	26	23	16	14	60	×	..	“	..	208	11
	Ursus americanus (black bear)	C. M. C.	L	..	×	..	..	..	..	31	29	22	21	105	×	..	“	..	209	12
	Taurotragus oryx (eland)	A. M. N. H.	R	..	×	..	..	..	..	55	44	35	30	73	×	..	“	..	210	12
	Connochætes taurinus albojubatus (gnu)	“	L	..	×	..	..	..	..	33.5	30	20	17.5	53	×	..	“	..	211	12
	Ovibos moschatus wardi (musk ox)	“	R	..	×	..	×	..	..	36	34	30	28	219	×	..	“	..	212	12
	Mexican burro	C. M. C.	“	..	×	..	..	..	..	30	23	15	11	31	×	..	“	..	213	12

SYNOPTIC TABLE VI

Class		Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
					III				Bone		Medullary canal								
					Incomplete differentiation			Complete differentiation	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
			I	II	Ia	Ib	Ic	C											
Mammals.	Tapirus (tapir) A. M. N. H.	R	..	×	..	..	..	×	32	35	21	25	98	×	..	cancellous	..	214	12
	Equus hemionus (wild ass of Asia) U. S. N. M.	L	..	×	..	..	..	×	46	31	26	19	55	×	..	"	..	215	12
	Elephas africanus A. M. N. H.	R	..	..	..	..	..	×	108	83	65	49	55	×	..	"	..	216	12
	Cholœpus didactylus (two-toed sloth) "	..	..	..	..	..	..	×	16	11	4	4	9	×	..	"	×	217	12
	Potos caudivolvulus (kinkajou) "	R	..	..	..	..	..	×	7	8	4.5	5.5	80	×	..	"	..	218	12
	Lutra canadensis (otter) "	"	..	..	..	..	..	×	14.5	11	7	5	28	×	..	"	..	219	12
	Simia satyrus (orang-utan) U. S. N. M.	"	×	..	×	..	..	×	20	30	11	16	41	×	..	"	..	220	13
	Felis tigris (tiger) "	L	×	..	×	..	..	×	28	22	15	12	41	×	..	......	..	221	13
	Hemigalus hardwicki (civet cat) A. M. N. H.	R	×	..	×	..	..	×	7	5.5	4.5	3	54	×	..	......	..	222	13
	Tatu novemcinctus (armadillo) "	"	×	..	..	×	..	..	7.5	16	5	6	33	×	..	cancellous	..	223	13
	Tamandua tetradactyla (ant-eater) "	"	×	..	×	×	..	..	7	12	3	4	17	×	..	"	..	224	13
	Gorilla (gorilla) "	L	×	..	×	..	..	×	16.5	19.5	7.5	9	15	×	..	......	..	225	13
	Presbytis rubicunda U. S. N. M.	..	×	..	×	..	..	×	11	11	6	6.5	48	×	..	......	..	226	13
	Hylobates (gibbon) "	R	×	..	×	..	..	×	11	11.5	6	6.5	44	×	..	......	..	227	13
	Anthropopithecus troglodytes (chimpanzee) A. M. N. H.	L	×	..	×	..	..	×	13	16	6	8	30	×	..	......	..	228	13
	Macacus rhesus (Indian monkey) R. I.	R	×	..	..	×	..	×	8	8.5	5	5.5	68	×	..	......	..	229	14
	Sciurus Sp. (large red squirrel) C. M. C.	"	×	..	..	×	..	×	4.5	6	3.5	5	18	×	..	......	..	230	14
	Felis (domestic cat) "	"	×	×	..	..	..	×	7.5	9.5	4	5.5	45	×	..	......	..	231	14
	Felis catus (wild cat) "	L	×	..	..	×	..	×	13.5	11	8	5.5	42	×	..	......	..	232	14
	Mephitis mephitica (skunk) "	..	×	..	..	..	..	×	5	5	3.5	4	127	×	..	......	..	233	14
	Putorius vison (mink) "	..	×	..	..	..	..	×	3.5	4.5	1.5	2	23	×	..	......	..	234	14
	Cryptoprocta ferox (cat-like civet) A. M. N. H.	L	×	..	×	..	..	×	8.5	8	4.5	4.5	42	×	..	......	..	235	14
	Hyæna crocuta (hyæna) "	R	×	..	×	..	..	×	14	18	9	13.5	98	×	..	......	..	236	14
	Thylacinus cynocephalus (Tasmanian wolf) "	"	×	..	×	..	..	×	19.5	15	8	8.5	28	×	..	cancellous	..	237	14
	Dasyprocta agouti (agouti) "	"	×	..	×	..	..	×	10	8	6.5	5	93	×	..	......	..	238	14
	Lasiopyga centralis johnstoni (monkey) "	L	×	..	×	..	..	×	9	8	5.5	5	62	×	..	......	..	239	14
	Felis canadensis (Canada lynx) C. M. C.	R	×	..	×	..	..	×	13	12	9.5	9	121	×	..	......	..	240	15
	Lasiopyga Sp. (African monkey) U. S. N. M.	"	×	..	×	..	..	×	5.5	5	3	2.5	38	×	..	......	..	241	15
	Midas rufoniger (South American monkey) "	..	×	..	×	..	..	×	4.5	4	3	2.5	74	×	..	......	..	242	15
	Lemur variegatus "	L	×	..	×	..	..	×	10	8.5	5.5	4.5	41	×	..	......	..	243	15
	Lemur catta (ring-tailed lemur) "	R	×	..	×	×	..	×	8.5	7	7	4.5	122	×	..	cancellous	..	244	15
	Ateles (Tehuantepec) (spider-monkey) "	L	×	..	×	..	..	×	12.5	10.5	7	5.5	42	×	..	......	..	245	15
	Callicebus torquatus (squirrel-monkey) "	R	×	..	×	..	..	×	5.5	5	4	3.5	104	×	..	......	..	246	15
	Genetta (genet) "	L	×	..	×	..	..	×	9	7	6.5	5	107	×	..	......	..	247	15
	Pedetes (jumping hare) "	"	×	..	×	..	..	×	10.9	9	7.5	6	85	×	..	......	..	248	15
	Bradypus tridactylus (three-toed sloth) A. M. N. H.	R	×	..	×	..	..	×	8.5	13	3	4	12	×	..	cancellous	×	249	15
	Castor canadensis (beaver) U. S. N. M.	"	×	×	×	×	..	×	25	11	6	4	10	×	..	"	..	250	16
	Felis pardus (leopard) "	L	×	..	..	..	..	×	18	17	10	9	37	×	..	"	×	251	16
	Bos (domestic ox) C. M. C.	"	..	×	..	..	..	×	44	39	23	21	40	×	..	"	..	252	16
	Equus caballus (domestic horse) "	"	..	×	..	..	..	×	57.5	41.5	32	22.5	43	×	..	"	..	253	16
	Ovis (domestic sheep) A. M. N. H.	R	..	×	..	..	..	×	18	14	10.7	7	44	×	..	"	..	254	16
	Bison americanus "	"	..	×	..	..	..	×	56	46	39	33	100	×	..	"	..	255	16
	Mule C. M. C.	"	..	×	..	..	..	×	60	55	47	45	179	×	..	"	×	256	16
	Mule "	L	..	×	..	..	..	×	68	50	40	37	77	×	..	"	×	257	16
	Mule "	"	..	×	..	..	..	×	65	51	38	40	85	×	..	"	×	258	16
	Mule "	"	..	×	..	..	..	×	61	50	40	38	100	×	..	"	..	259	16

SYNOPTIC TABLE VII

Class		Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
					III				Bone		Medullary canal								
					Incomplete differentiation			Complete differentiation											
			I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
Mammals.	Elephas indicus (Asiatic elephant)........A. M. N. H.	L	..	×	..	..	..	×	121	77	50	38	25	×	..	cancellous	×	260	17
	Hippopotamus amphibius (hippopotamus). “	R	..	×	×	..	..	×	70	70	26	30	19	×	..	“	..	261	17
	Giraffa camelopardalis (giraffe)........... “	L	..	×	..	..	..	×	72	59	35	30	33	×	..	“	..	262	17
	Rhinoceros bicornis (rhinoceros).......... “	“	..	×	..	..	..	×	47.5	130	14	23	55	×	..	“	×	263	17
	Equus burchelli (zebra).................. “	R	..	×	..	..	..	×	43	37	20	22	38	×	..	“	..	264	17
	Ursus maritimus (polar bear)............ “	L	..	×	..	..	..	×	31	38	18	22	51	×	..	“	..	265	17
	Bubalis jacksoni (hartebeest)............ “	R	..	×	..	..	..	×	32.5	30	17	16	39	×	..	“	..	266	17
	Phacochœrus africanus (warthog)........ “	L	..	×	..	×	..	×	24	20.5	14	12	52	×	..	“	..	267	17
	Felis concolor (panther).................. “	“	×	×	..	..	..	×	16	19	11	12	76	×	..	“	..	268	18
	Gulo luscus (wolverene).................. “	“	×	×	..	..	..	×	10	11.5	5.5	6	31	×	..	“	..	269	18
	Erignathus barbatus (seal)............... “	“	..	×	..	..	..	×	19.5	39	10	25	50	×	..	“	..	270	18
	Bos bubalis (water buffalo)............... “	“	..	×	..	×	..	×	48	45	24	25	38	×	..	“	..	271	18
	Ovis montana (mountain sheep)..............C. M. C.	“	..	×	..	..	..	×	20	25	12.5	15	60	×	..	“	..	272	18
	Cephalophus (African antelope)...........U. S. N. M.	..	..	×	..	..	..	×	15	13.5	9	9	67	×	..	“	..	273	18
	Raphiceros (steinbok).................... “	..	..	×	×	..	..	×	12	12.5	6.5	7	43	×	..	“	..	274	18
	Gazella granti (Grant's gazelle)...........A. M. N. H.	L	..	×	..	..	..	×	19	19.5	10.5	11	45	×	..	“	..	275	18
	Kobus ellipsiprymnus (water buck)...... “	“	×	×	×	..	..	×	28	25	18	16	70	×	..	“	..	276	18
	Arctomys monax (woodchuck)...............C. M. C.	..	..	×	×	..	..	×	6	7	4	4.5	74	×	..	“	..	277	19
	Canis latrans (coyote)....................... “	R	..	×	..	..	..	×	12	11.5	8	7	68	×	..	“	..	278	19
	Capra (goat) .... “	“	..	×	..	×	..	×	4.5	5	2.5	3	50	×	..	“	..	279	19
	Bull dog (not a pure blood).................. “	“	×	×	..	..	..	×	14.5	12.5	10.5	9	109	×	..	“	..	279½	19
	Shepherd dog (not a pure blood)............ “	L	..	×	..	..	..	×	11	10.5	6.5	5.5	45	×	..	“	..	280	19
	Dog (mongrel) .... “	R	×	×	×	..	..	×	16	17	11	10	68	×	..	“	..	280½	19
	Fox terrier (not a pure blood).............. “	..	..	×	..	..	..	×	11	9.5	6.5	6	59	×	..	“	..	281	19
	Dog (mongrel) .... “	R	..	×	..	..	..	×	12.5	13	8.5	9	90	×	..	“	..	282	19
	Bull dog (not a pure blood).................. “	“	..	×	..	..	..	×	13	12	7	6.5	41	×	..	“	..	283	19
	Collie dog (not a pure blood)................ “	“	×	×	..	..	..	×	13.5	13	8	7.5	50	×	..	“	..	284	19
	Spaniel (not a pure blood).................. “	“	..	×	..	..	..	×	13	13.5	8.5	8.5	70	×	..	“	..	285	19
	Dog (mongrel) .... “	“	×	..	..	×	..	×	12.5	10.5	8	7	74	×	..	“	..	..	..
	Lepus cuniculus (rabbit).................... “	L	×	×	..	..	..	×	5.5	7.5	3.5	5	74	×	..	......	..	286	19
	Procyon lotor (raccoon)..................... “	R	×	×	×	..	..	×	9	10	6.5	7	100	×	..	cancellous	..	287	20
	Os penis of raccoon......................... “	..	×	..	..	..	..	×	4	4	0.8	0.8	4	×	..	......	..	288	20
	Canis lupus (wolf)........................... “	..	..	×	×	..	..	×	16.5	7	10	5	77	×	..	cancellous	..	289	20
	Felis leo (lion)..........................A. M. N. H.	R	×	×	×	..	..	×	26	25.5	13	11.5	28	×	..	“	..	290	20
	Canis (small grey fox).......................C. M. C.	..	×	×	×	..	..	×	8	9	5	6.5	80	×	..	......	..	291	20
	Taxidea americana (American badger)....A. M. N. H.	L	×	×	..	..	..	×	7	8	4	4	40	×	..	......	..	292	20
	Melursus labiatus (sloth bear)............ “	R	×	×	×	..	..	×	24	24	10	10	21	×	..	cancellous	..	293	20
	Canis aureus (jackal)....................U. S. N. M.	L	×	×	×	..	..	×	10	8.5	6.5	6	85	×	..	......	..	294	20
	Didelphis virginiana (opossum).............C. M. C.	R	×	..	..	×	..	..	7	8.5	3.5	5	42	×	..	......	..	295	20
	Manis (ant-eater) ....U. S. N. M.	L	..	×	×	×	..	..	9	12.5	4	5.5	24	×	..	cancellous	..	296	20
	Haplodontia olympica (sewellel, mount. beaver) C. M. C.	R	×	×	×	×	..	..	5.5	4	3	1.5	26	×	..	......	..	297	20
	Erethizon (porcupine) .... “	L	×	..	×	×	..	×	9.5	7.5	3	2.5	12	×	..	cancellous	..	298	20
	Average diameters and medullary index of mammals.	..	..	..	..	..	..	..	19	18.6	10.9	10.4	63.3	..	..	......	..	..	..

SYNOPTIC TABLE VIII

Class Mammal Man		Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
					III				Bone		Medullary canal								
			1	II	Incomplete differentiation 1a	1b	1c	Complete differentiation C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
Fetal.	White fetus, 2-2½ months ...... C. M. C.	R	×	..	..	..	..	..	1.8	1.5	0.5	0.4	8	×	..	cancellous	..	299	21
	" " 3-3½ " ...... "	"	..	×	×	..	..	..	2.5	2	0.5	0.5	5	×	..	"	..	300	21
	" " 4-4½ " ...... "	"	..	×	..	×	..	..	3.5	2.5	0.6	0.5	3	×	..	"	..	301	21
	" " 5-7 " ...... U. S. N. M.	"	..	×	..	×	..	..	3.5	3	0.5	0.5	2	×	..	"	..	302	21
	" " 8-9 " ...... "	"	..	×	..	×	..	..	4.5	5	1	1	4	×	..	"	..	303	21
	Negro " 8-9 " ...... "	"	..	×	..	×	..	..	4.5	5.5	1.5	2.5	15	×	..	"	..	304	21
	White " 8½ " (craniorrhachischisis) C. M. C.	"	..	×	..	×	..	..	6	6	3	2.5	26	×	..	"	..	305	21
Adult black race.	Negro ...... No. 228481 U. S. N. M.	L	..	..	..	..	..	×	29	30	16	15	38	×	..	"	..	306	21
	" (mixed black and white) .. " 247368 "	..	..	..	..	..	..	×	22	27	12	11	30	×	..	"	×	307	21
	" ...... " 3 M. D. T. U.	L	..	..	..	..	..	×	30	24	15	14	41	×	..	"	×	308	21
	" ...... " 87 "	"	..	..	..	..	..	×	27.5	30	17	17	54	×	..	"	×	309	22
	" ...... " 7 "	R	..	..	..	..	..	×	27	30	19	18	74	×	..	"	×	310	22
	" ...... " 4 "	L	..	..	..	..	..	×	30	23	21	13	65	×	..	"	..	311	22
	" ...... " 84 "	"	..	..	..	..	..	×	24	25	15	13	48	×	..	"	..	312	22
	" ...... " 10 "	"	×	..	..	..	..	×	26	29	14	15	38	×	..	"	..	313	22
	Negress ...... " 123 "	R	..	..	..	..	..	×	28	27	14	11	25	×	..	"	×	314	22
	Negro ...... " 79 "	L	..	..	..	..	..	×	30.5	26.5	17	15	46	×	..	"	×	315	22
	" ...... " 224714 U. S. N. M.	"	×	..	..	..	..	×	34	36	21	21	56	×	..	"	×	316	22
	" ...... " 11 M. D. T. U.	"	×	..	×	..	..	×	32	26.5	13	12	22	×	..	"	..	317	22
	" ...... " 2 "	R	×	×	..	..	..	×	30	29	16	14	36	×	..	"	..	318	23
	" ...... " 56 "	L	×	..	..	..	..	×	27.5	27	16	14	43	×	..	"	×	319	23
	Negress ...... " 220 C. M. C.	"	×	..	×	..	..	×	30	25	18	14	50	×	..	"	×	320	23
	" (amputated lower ⅓) ...... " 220 "	R	×	..	×	..	..	×	30	25	24	15	92	×	..	"	××	321	23
	" (age 14, mixed black and white) ...... " 226 "	L	×	..	..	..	..	×	24	18	12	9	34	×	..	"	..	322	23
	Negro ...... " 1 M. D. T. U.	..	×	×	×	..	..	×	23	25	11	10	24	×	..	"	..	323	23
	Negro (kaffir) ...... U. S. N. M.	R	×	..	..	..	..	×	27	23	14	11.5	32	×	..	"	..	324	23
	" ...... " 248674 "	"	×	×	×	..	..	×	30	26	15	12.5	32	×	..	"	..	325	23
	" ...... " " "	L	×	×	×	..	..	×	29	27	17	14	42	×	..	"	..	326	24
	Tibia of negro ...... " " "	..	×	×	×	..	..	×	...... Control					×	..	......	..	327	24
	Fibula " " ...... " " "	..	×	×	×	..	..	×						×	..	......	..	328	24
	Ulna " " ...... " " "	..	×	×	×	..	..	×						×	..	......	..	329	24
	Radius " " ...... " " "	..	×	..	×	..	..	×						×	..	......	..	330	24
	Humerus " " ...... " " "	..	×	..	×	..	..	×						×	..	......	..	331	24
	Clavicle " " ...... " " "	..	×	×	..	..	..	×						×	..	......	..	332	24
	Metatarsal bone of great toe ...... " " "	..	×	..	×	..	..	×						×	..	......	..	333	24
	Negro ...... " 224713 "	L	×	×	×	..	..	×	35	24	20	12	40	×	..	cancellous	..	334	24
	" ...... " 83 M. D. T. U.	R	×	×	×	..	..	×	30	25	12	10	19	×	..	"	..	335	25
	" ...... " 6 "	"	×	×	×	..	..	×	33.5	27	13	10	17	×	..	"	..	336	25
	" ...... " 63 "	"	×	×	×	..	..	×	32	28	20	14	45	×	..	"	..	337	25
	" ...... " 5 "	L	×	×	×	..	..	×	25	24	16	15	67	×	..	"	..	338	25
	" ...... " 8 "	R	×	..	×	..	..	×	27	25	12.5	9	20	×	..	"	..	339	25
	Average diameters and medullary index	..	..	..	..	..	..	..	22.7	20.9	12.7	10.6	41.9	..	..	......	..	..	..

SYNOPTIC TABLE IX

Class Mammal Man				Right or left femur	Types and type combinations: I	Types and type combinations: II	III: Incomplete differentiation: 1a	III: Incomplete differentiation: 1b	III: Incomplete differentiation: 1c	III: Complete differentiation: C	Measurements: Bone: Ant.-post. diam. in mm.	Measurements: Bone: Lat. diam. in mm.	Measurements: Medullary canal: Ant.-post. diam. in mm.	Measurements: Medullary canal: Lat. diam. in mm.	Measurements: Medullary canal: Medullary indices Per cent	Medullary canal: Full	Medullary canal: Empty	Medullary canal: Special	Senility	Reference: Figure	Reference: Plate
Black.	Negro ....No.	7	M. D. T. U.	L	..	..	..	..	..	×	30	26	17	15	50	×	..	cancellous	×	340	25
Yellow-brown races.	Pueblo Indian, child, 1 year old	" 258675(z)	U. S. N. M.	R	..	×	..	×	..	..	8	7.5	4.5	4	43	×	..	......	..	341	25
	Pueblo Indian, child, 6 years old	" 258675(L)	"	R	×	×	×	..	..	×	12	10.5	8	6	61	×	..	......	..	342	25
	Pueblo Indian, youth.......	" 258675(S2)	"	L	×	×	×	..	..	×	17	16	9	9	42	×	..	......	..	342½	25
	Pueblo Indian, adult.......	" 258675(x)	"	..	×	×	×	..	..	×	20	20	8	9	22	×	..	......	..	343	26
	Pueblo Indian, "	" 227339	"	R	..	..	..	..	..	×	25	23	14	11	37	×	..	......	..	344	26
	Peruvian Indian	" 266469(b)	"	L	×	×	..	..	..	×	27	31	21	19	91	×	..	......	×	345	26
	Peruvian Indian	" 266469(a)	"	"	..	..	..	..	..	×	22	27	13	12	36	×	..	......	..	346	26
	Chicama Indian (Peru)....	" 2	"	"	×	..	×	..	..	×	31	30	13	13	22	×	..	......	×	347	26
	" " "	" 3	"	R	×	..	..	..	..	×	27	25	16	11	35	×	..	......	..	348	26
	" " "	" 1	"	"	..	..	..	..	..	×	26.5	31	11	16	27	×	..	......	..	349	26
	" " "	" 4	"	L	×	..	..	..	..	×	30	28	18	16	52	×	..	......	×	350	26
	" " "	" 7	"	"	×	×	..	..	..	×	18.5	19	10.5	9	37	×	..	......	..	351	27
	* " " "	" 9	"	"	×	×	×	..	..	×	22	23.5	11	11	30	×	..	......	..	..	..
	*Pachacamac Indian (Peru)	" 14	"	R	×	×	×	..	..	×	24	21	14	10	38	×	..	......	..	..	..
	* " " " "	13	"	"	..	×	×	..	..	×	16	15	8	7	30	×	..	......	..	..	..
	* " " " "	8	"	L	..	×	..	..	..	×	22.5	18	9	7	19	×	..	......	..	..	..
	* " " " "	11	"	R	..	×	×	×	..	..	10	9	7	6.5	100	×	..	......	..	..	..
	" " " "	12	"	L	..	×	..	×	..	..	10	12.5	7	7.5	72	×	..	......	..	357	27
	* " " " "	10	"	R	×	..	×	..	..	×	21.5	20	10.5	8.5	23	×	..	......	..	..	..
	* " " " "	5	"	L	×	..	×	..	..	×	20	21	11	9	31	×	..	......	..	..	..
	" " " "	15	"	R	×	..	×	..	..	×	24	20	12	9	27	×	..	......	..	360	27
	" " " "	6	"	L	×	..	..	..	..	×	20.5	18.5	9	7	20	×	..	......	..	361	27
	Japanese, male	" 245	C. M. C.	R	×	..	×	..	..	×	30	30	20	18	65	×	..	......	×	362	27
	Average diameters and medullary index..............			..	..	..	..	..	..	..	21.1	20.7	11.5	10.5	43.8	..	..	......	..	..	..
Ancient Egyptian, Twelfth Dynasty.	Egyptian child, about 1 year old	No. 256479(de)	U. S. N. M.	..	..	..	×	×	..	..	9	11.5	7	8	111	×	..	......	..	363	27
	Diagram of the vascular origin of Haversian system..			..	..	..	..	..	..	..	..	..	..	..	..	..	..	......	..	363a	27
	Egyptian child	No. 256479(d)	U. S. N. M.	..	×	×	×	×	..	..	9.5	10	4	5	27	×	..	......	..	364	27
	" adolescent	" 256479(a3)	"	R	×	..	×	..	..	×	12	12.5	5.5	7	35	×	..	......	..	365	27
	" "	" 258675(a)	"	..	×	..	×	..	..	×	18	16.5	10	9	44	×	..	......	..	366	27
	" adult	" 256481(d)	"	R	×	×	×	..	..	×	18.5	17.5	9	8	28	×	..	......	..	367	28
	" "	" 256481(a)	"	L	×	..	..	×	..	×	18	16	8	7	24	×	..	......	×	368	28
	" "	" 258675(e)	"	R	×	..	..	..	..	×	26	21.5	14	10	44	×	..	......	..	369	28
	" "	" 256478(23)	"	..	..	..	..	..	..	×	24	30	10	10	16	×	..	......	..	370	28
	" "	" 256478(x)	"	R	×	..	..	..	..	×	23	27	12	11	27	×	..	......	..	371	28
	Average diameters and medullary index..............			..	..	..	..	..	..	..	17.6	18.1	8.8	8.3	39.5	..	..	......	..	..	..

* The femora marked with (*) have been described but not drawn.

SYNOPTIC TABLE X

Class Mammal Man			Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
						III				Bone		Medullary canal								
						Incomplete differentiation			Complete differentiation											
				I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
White race.	Male, white	No. 1629 U. S. N. M.	..	..	..	..	..	..	×	28	28	18	17	64	×	..	cancellous	..	372	28
	Female, “	“ 147 M. D. N. U.	R	..	..	..	..	..	×	33.5	32	19	18.5	49	×	..	“	×	373	28
	Child, “ (less than 1 yr. old) .	“ 249588 U. S. N. M.	“	..	×	×	×	..	..	6.5	7.5	4	5	70	×	..	“	..	374	29
	Male, “	“ 53 C. M. C.	..	..	..	..	..	..	×	28	30	16	17	48	×	..	“	..	375	29
	“ “	“ 171 M. D. N. U.	R	..	..	..	..	..	×	30	33	17	15	35	×	..	“	×	376	29
	“ “	“ 95 C. M. C.	L	..	..	..	..	..	×	30	27.5	17	16	42	×	..	“	×	377	29
	“ “	“ 96 “	“	..	..	..	..	..	×	29.5	30	14.5	12	24	×	..	“	×	378	29
	“ “	“ 168 M. D. N. U.	“	..	..	..	..	..	×	30	30	15	17	40	×	..	“	×	379	29
	“ “ (age 50)	“ 10 “	“	..	..	..	..	..	×	30	31.5	13	12	20	×	..	“	×	380	29
	Female, “ (“ 52)	“ 227876 U. S. N. M.	..	..	..	..	..	..	×	22	25	13.5	12	42	×	..	“	×	381	29
	“ “ (“ 62)	“ 227880 “	..	..	..	..	..	..	×	24	25	16	16	74	×	..	“	××	382	29
	Male, “	“ 162 “	L	..	..	..	..	..	×	25	29	13	15	35	×	..	“	×	384	30
	“ “	“ 244 “	R	..	..	..	..	..	×	35	30	17	15	32	×	..	“	×	385	30
	“ East Indian	“ 223 C. M. C.	“	..	..	×	..	..	×	29	24	16	12	38	×	..	“	×	386	30
	“ “ “ (same as above) amputated	“	L	..	..	×	..	..	×	28	22	17	12	49	×	..	“	×	387	30
	“ white	“ 228479 U. S. N. M.	R	..	..	..	..	..	×	32	28	14	17	36	×	..	“	×	388	30
	“ “ (age 45)	“ 154 M. D. N. U.	“	..	..	..	..	..	×	30	29	15	14	26	×	..	“	×	389	30
	“ “	“ 146 “	L	..	..	..	..	..	×	28	24	13	10	24	×	..	“	×	390	30
	“ “	“ 159 “	“	..	..	..	..	..	×	32	31.5	17.5	18	45	×	..	“	×	391	30
	“ “	“ 167 “	R	..	..	..	..	..	×	27	25	14	11	30	×	..	“	×	392	30
	“ “	“ 172 “	“	..	..	..	..	..	×	32	31.5	17.5	18	45	×	..	“	×	393	30
	“ “	“ 242 C. M. C.	“	..	..	..	..	..	×	32	27	19	15	49	×	..	“	×	394	31
	“ “ (age 60)	“ 145 M. D. N. U.	“	..	..	..	..	..	×	30	29	16	18	49	×	..	“	×	395	31
	Female, white	“ 174 “	L	×	..	..	..	..	×	27	26	14	13	35	×	..	“	×	396	31
	Male, “	“ 157 “	R	×	×	..	..	..	×	30	29	16.5	16	44	×	..	“	×	397	31
	“ “	“ 161 “	L	..	..	..	..	..	×	28	31	12	15	26	×	..	“	×	398	31
	“ “	“ 153 “	R	×	..	×	..	..	×	27.5	26	14	11	27	×	..	“	×	399	31
	“ “	“ 243 C. M. C.	“	×	..	×	..	..	×	30	27	16	14	23	×	..	“	×	400	31
	“ “	“ 148 M. D. N. U.	L	×	..	..	..	..	×	24	33	13.5	14	30	×	..	“	×	401	31
	“ “	“ 230 C. M. C.	“	×	..	..	..	..	×	31	29	17	14	33	×	..	“	×	402	31
	“ “	“ 97 “	“	×	×	×	..	..	×	28.5	27	16	15	45	×	..	“	..	403	32
	“ “	“ 99 “	L	×	×	×	..	..	×	30	27.5	14	10	20	×	..	“	..	404	32
	“ “	“ 160 M. D. N. U.	R	×	..	..	..	..	×	28	28.5	15	15	38	×	..	“	×	405	32
	“ “	“ 163 “	L	×	..	×	..	..	×	28	25	15	11.5	32	×	..	“	×	406	32
	“ “	“ 156 “	R	×	..	..	..	..	×	31	23.5	11	11	20	×	..	“	×	407	32
	“ “	“ 169 “	L	×	..	..	..	..	×	31	29	16	15	37	×	..	“	×	408	32
	“ “ (age 35)	“ 151 “	R	×	×	×	..	..	×	28	31	11.5	12	19	×	..	“	×	409	32
	“ “	“ 100 C. M. C.	L	×	×	..	..	..	×	24	31	17.5	13.5	46	×	..	“	×	410	32
	Female, “	“ 150 M. D. N. U.	R	×	..	..	..	..	×	26	26	20	21	16	×	..	“	××	411	32

SYNOPTIC TABLE XI

Class Mammal Man				Right or left femur	Types and type combinations						Measurements					Medullary canal			Senility	Reference	
							III				Bone		Medullary canal								
							Incomplete differentiation			Complete differentiation											
					I	II	Ia	Ib	Ic	C	Ant.-post. diam. in mm.	Lat. diam. in mm.	Ant.-post. diam. in mm.	Lat. diam. in mm.	Medullary indices Per cent	Full	Empty	Special		Figure	Plate
White race.	Male, white (double femur).....No.	152	M. D. N. U.	L	×	..	..	×	..	×	26	37	14	16	30	×	..	caucellous	×	412	33
	" " (33 mm. below above	"	" {	..	..	..	..	..	..	..	27	25	16	17	67	..	..	"	..	..	..
	sect.) .... "			"	×	..	..	×	..	×	23	18	10	10	31	×	..	"	×	413	33
	Female, white .... "	164	"	"	×	..	..	..	..	×	28	27.5	20	20	55	×	..	"	××	414	33
	" " .... "	166	"	"	×	..	..	..	..	×	26.5	26	14	13	34	×	..	"	×	415	33
	Male, white (age 22, suicide).... "	175	C. M. C.	"	×	×	×	×	..	×	27	29	14	19	53	×	..	"	..	416	33
	" " .... "	98	"	L	×	×	..	..	..	×	30	30	17	15	39	×	..	"	×	417	33
	" " .... "	91	"	"	×	×	..	..	..	×	30	27	17	13	39	×	..	"	..	418	33
	" Australian .... "	227420	U. S. N. M.	..	×	..	..	..	..	×	28	23	12	11	25	×	..	"	..	419	34
	" white ...."	94	C. M. C.	L	×	..	..	..	..	×	30	29	17	14	38	×	..	"	..	420	34
	" " (age 40)........... "	142	M. D. N. U.	R	×	..	×	..	..	×	30	27.5	13	11.5	22	×	..	"	×	421	34
	Single Haversian system showing lamellæ...........			..	..	..	..	..	..	..	..	..	..	..	..	..	..	......	..	423	34
	" " " " early stage of senility			..	..	..	..	..	..	..	..	..	..	..	..	..	..	......	..	424	34
	" " " " later " " "			..	..	..	..	..	..	..	..	..	..	..	..	..	..	......	..	425	34
	" " " " latest " " "			..	..	..	..	..	..	..	..	..	..	..	..	..	..	......	..	426	34
	Male, white (convict)...........No.	2	M. D. N. U.	R	..	..	..	..	..	×	32	27.5	15	10	21	×	..	cancellous	×	428	35
	" " " .... "	3	"	"	..	..	..	..	..	×	26.5	25	15	12	39	×	..	"	×	429	35
	* " " (age 50) .... "	268	C. M. C.	L	..	..	..	..	..	×	30	30	13	12	21	×	..	"	×	..	..
	* " " (amputated) .... "	269	"	R	×	×	×	..	..	×	29	33.5	17	20	54	×	..	"	×	..	..
	* " " .... "	270	"	"	..	..	..	..	..	×	31	25	14	13	29	×	..	"	×	..	..
	* " " .... "	271	"	"	..	..	..	..	..	×	31	32	17	15	35	×	..	"	×	..	..
	* " " .... "	272	"	"	..	..	..	..	..	×	33	28	27	25	26	×	..	"	..	..	..
	* " " .... "	273	"	"	..	..	..	..	..	×	28	29	15	12	29	×	..	"	×	..	..
	" " .... "	274	"	"	..	..	..	..	..	×	30	35	15	16	30	×	..	"	×	436	35
	" " .... "	275	"	"	×	..	×	..	..	×	30	27	19	14	50	×	..	"	×	437	35
	* " " .... "	276	"	L	..	..	..	..	..	×	28	33.5	26	17.5	100	×	..	"	×	..	..
	" " .... "	277	"	R	×	..	..	..	..	×	32	28	17	11	28	×	..	"	×	439	35
	* " " .... "	278	"	"	..	..	..	..	..	×	29	34	17	15	35	×	..	"	..	..	..
	* " " .... "	279	"	"	..	..	..	..	..	×	30	27	16	14	38	×	..	"	×	..	..
	* " " .... "	280	"	"	..	..	..	..	..	×	30	24.5	15	11	29	×	..	"	..	..	..
	* " " .... "	281	"	L	..	..	..	..	..	×	31	27	13	10	19	×	..	"	×	..	..
	* " " .... "	282	"	R	..	..	..	..	..	×	30	31.5	16	13.5	30	×	..	"	×	..	..
	" " .... "	284	"	"	×	×	×	..	..	×	26.5	26	13	12.5	31	×	..	"	×	445	35
	* " " .... "	285	"	"	..	..	..	..	..	×	29	28	15	14	35	×	..	"	×	..	..
	* " " .... "	286	"	"	..	..	..	..	..	×	32	27.5	17	14	36	×	..	"	×	..	..
	* " " .... "	287	"	"	×	..	×	..	..	×	25	25	12	9	21	×	..	"	×	..	..
	* " " .... "	288	"	"	..	..	..	..	..	×	30	31	17	15	38	×	..	"	×	..	..
	" " .... "	289	"	"	×	..	×	..	..	×	30	33	14	15	27	×	..	"	×	451	35
	" " .... "	296	"	L	×	..	×	..	..	×	27.5	23	12	10	23	×	..	"	×	452	35
	Average diameters and medullary index of white race.			..	..	..	..	..	..	..	28.7	28.1	15.5	14.1	35.8	..	..	......	..	..	..
	Male, white, idiopathic epileptic..............N. S. H.			L	..	..	..	..	..	×	27	22	24	18	277	×	..	......	..	453	35

* Described, not drawn.

INDEX

Femora marked with (*) described, but not drawn.


FIG. A
Round lacuna with short, bushy canaliculi.
Early stage


FIG. B
Oval lacuna with short, bushy canaliculi.
Later stage

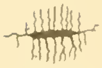
FIG. C
Long, narrow lacuna with long, straight canaliculi. Latest stage

THREE STAGES IN THE DIFFERENTIATION OF LACUNÆ


FIG. D
Basic or undifferentiated bone. Amblystoma tigrinum


FIG. E
Differentiated bone. Frog. Concentric lacunæ


FIG. F
Differentiated bone. Haversian system of man. Concentric lamellæ

FIRST DIFFERENTIATION


FIG. H
Early stage in the differentiation of laminæ.
Aztec jay


FIG. I
Later stage in the differentiation of laminæ.
Chinese pheasant


FIG. J
Latest stage in the differentiation of laminæ.
Pig

SECOND DIFFERENTIATION

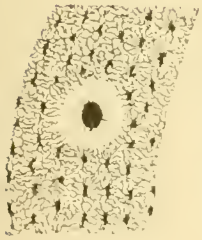
FIG. K
Stage Ia. Amphibian

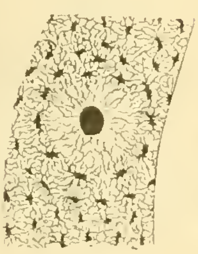
FIG. L
Stage Ib. Reptile

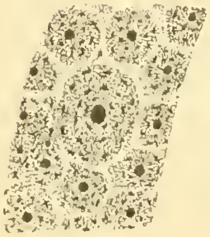
FIG. M
Stage Ic. Bird

Incomplete differentiation of Haversian systems

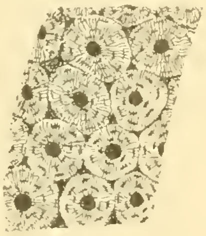
FIG. N
Stage C. Mammal. Man.
Complete differentiation of Haversian systems

THIRD DIFFERENTIATION

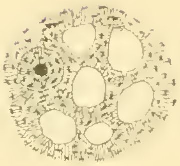
FIG. O
Haversian system formed in the mesh of cancellous bone


FIG. P
Haversian systems formed in the canals of a second type bone

ABERRANT FORMS


FIG. 1
First type. Frog


FIG. 2
Second type. Turkey

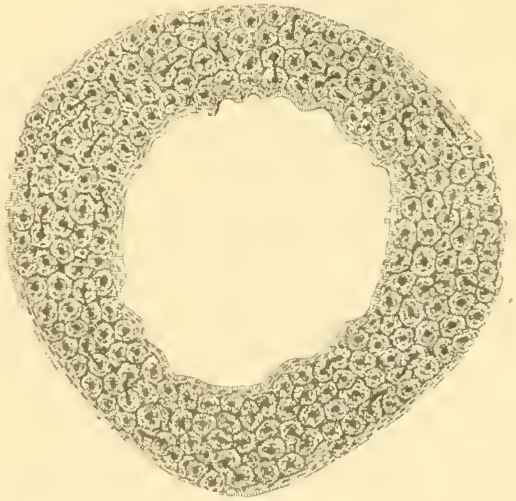
FIG. 3
Third type. Man

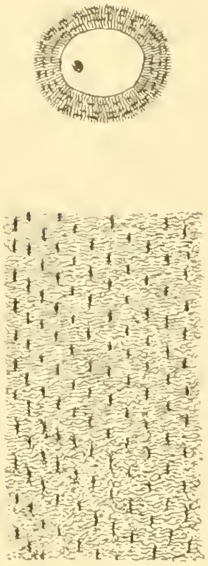

Fig. 1
Cross and longitudinal sections of a femur of the first type

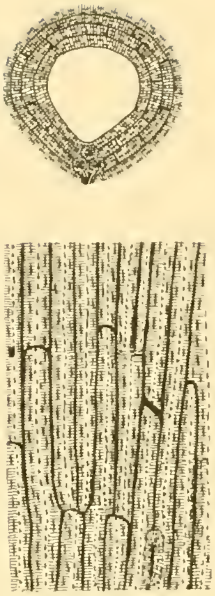

Fig. 2
Cross and longitudinal sections of a femur of the second type

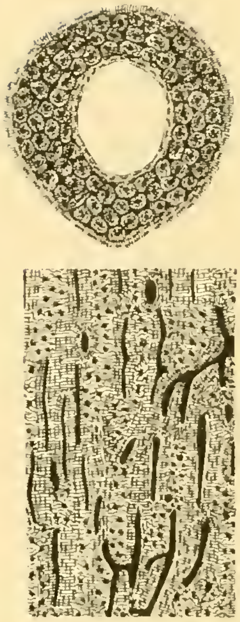

Fig. 3
Cross and longitudinal sections of a femur of the third type

Fig. 4
Diagram illustrating a first type femur

Fig. 5
Diagram illustrating a second type femur

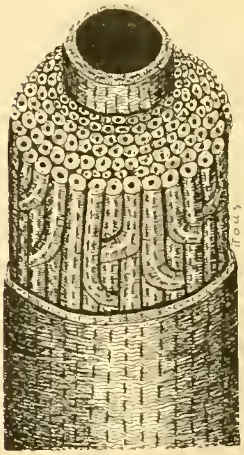

Fig. 6
Diagram illustrating a third type femur

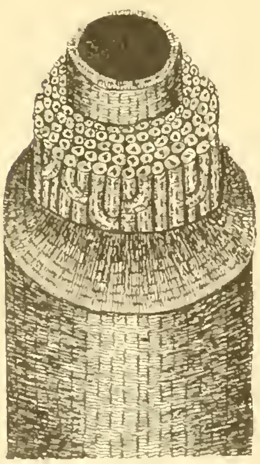

Fig. 7
Diagram illustrating a femur of the first and third type combination

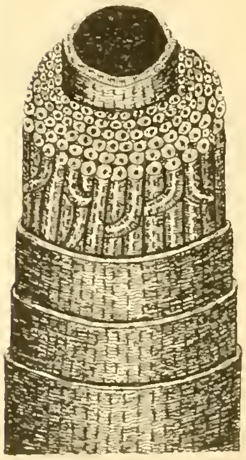

Fig. 8
Diagram illustrating a femur of the second and third type combination

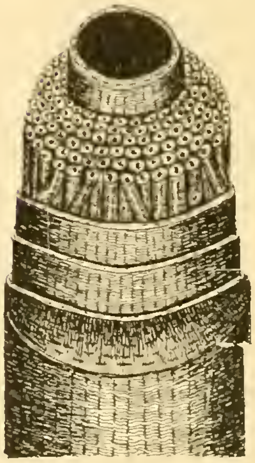

Fig. 9
Diagram illustrating a femur of the first, second and third type combination

CROSS AND LONGITUDINAL SECTIONS OF TYPES OF FEMORA, AND DIAGRAMS ILLUSTRATING THE CONSTRUCTION OF FEMORA

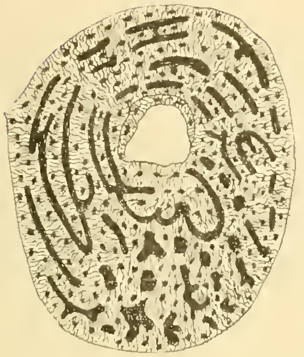

FIG. 1
I-II. Human fetus

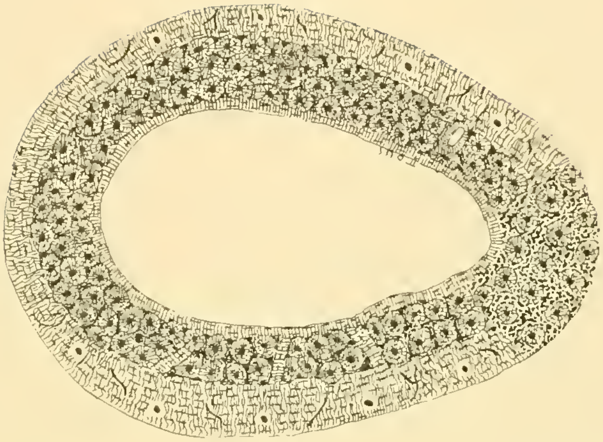

FIG. 2
I-III. Hyæna crocuta

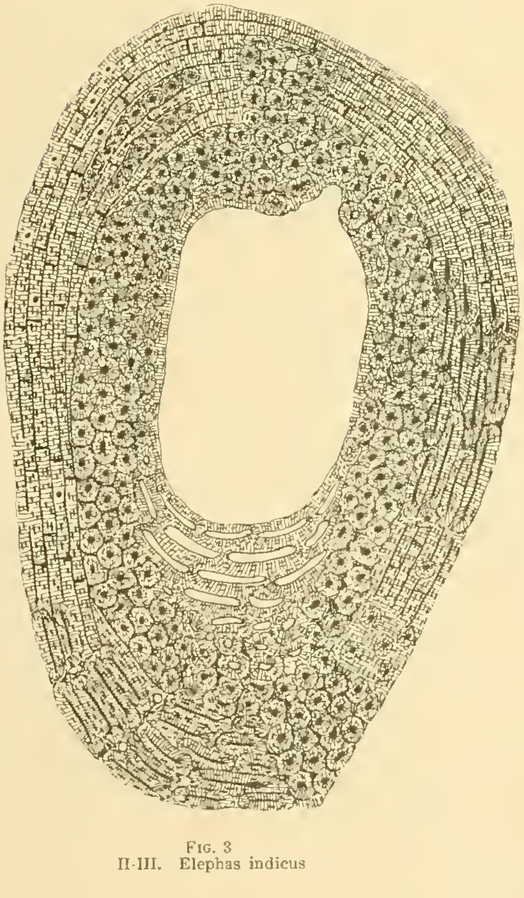

FIG. 3
II-III. Elephas indicus

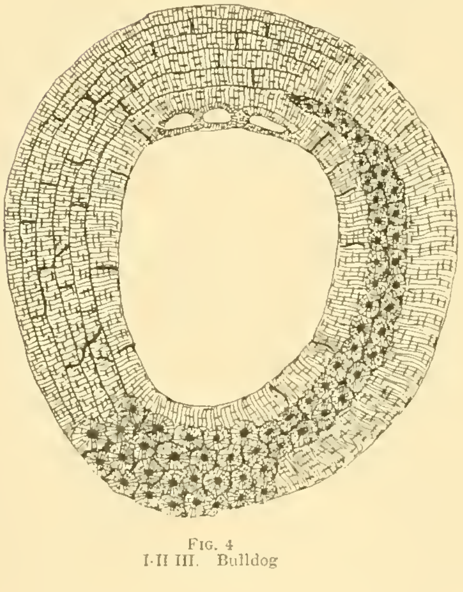

FIG. 4
I-II III. Bulldog

COMBINATIONS OF TYPES

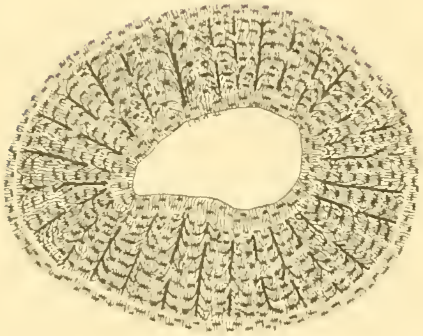

FIG. 1
Right femur of a large bull frog (Rana catesbiana), showing radiating bush-like canals

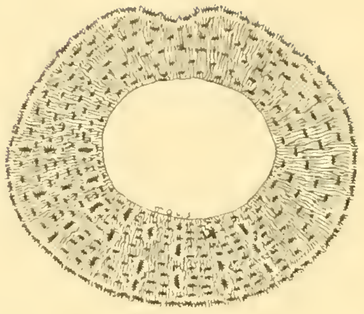

FIG. 2
Right femur of a medium-sized bull frog (Rana catesbiana), the radiating canals disappearing

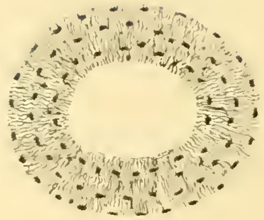

FIG. 3
Right femur of a small bull frog (Rana catesbiana), in which radiating canals are displaced by lamellæ

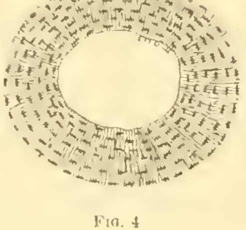

FIG. 4
Right femur of a bull frog showing the first type of structure

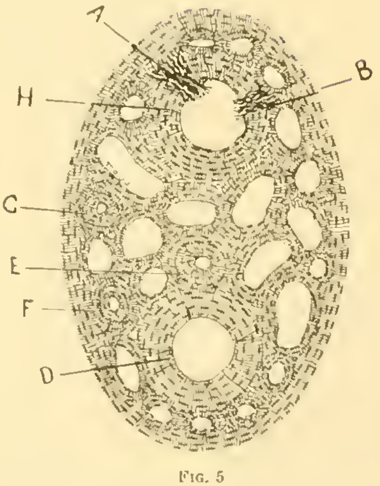

FIG. 5
Fractured and repaired femur of a bull frog (Rana catesbiana), showing new cancellous bone of repair

AMPHIBIANS

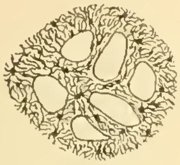

FIG. 6
Right femur of
Amblystoma tigrinum
(most primitive amphibian)

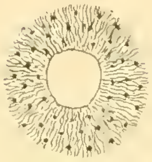

FIG. 7
Right femur of
Hyla versicolor
(tree frog)

FIG. 8
Right femur of Hyla
arenicolor

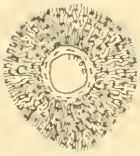

FIG. 9
Right femur of Hyla
femoralis

FIG. 10
Right femur of Hyla
evittata

FIG. 11
Right femur of Hyla
cinerea

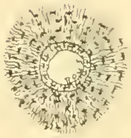

FIG. 12
Right femur of Hyla
regilla

FIG. 13
Right femur of Hyla
squirella

FIG. 14
Right femur of Hyla
gratiosa

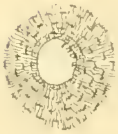

FIG. 15
Right femur of
Dendrobates tinctorius

FIG. 16
Right femur of
Leptodactylus albilabris

FIG. 17
Right femur of Chorophilus
feriarum

FIG. 18
Right femur of Acris
gryllus

FIG. 19
Right femur of Rana
catesbiana

FIG. 20
Right femur of Rana
palustris

FIG. 21
Right femur of Rana
areolata circulosa

FIG. 22
Right femur of Rana
aurora

FIG. 23
Right femur of Rana
pretiosa

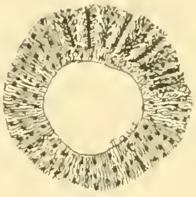

FIG. 24
Right femur of Rana
draytonii

FIG. 25
Right femur of
Spelerpes ruber

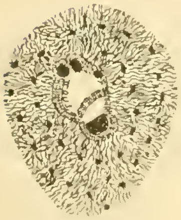

FIG. 26
Right femur of Cryptobranchus alleghenicnsis

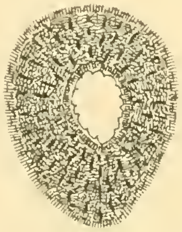

FIG. 27
Right femur of Necturus
maculatus

FIG. 28
Right femur of Scaphiopus
holbrookii

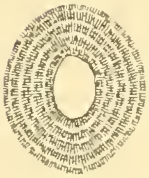

FIG. 29
Right femur of Scaphiopus
couchii

FIG. 30
Right femur of Scaphiopus
hammondii

AMPHIBIANS

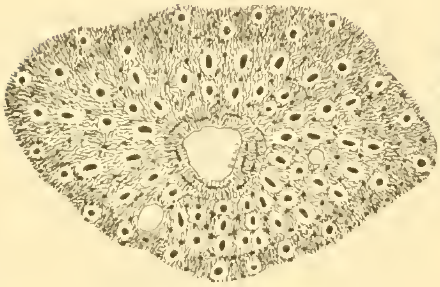
FIG. 31
Right femur of Pipa americana (Surinam toad)


FIG. 32
Right femur of Bufo agua (Bermuda toad)


FIG. 33
Right femur of Bufo halophilus


FIG. 34
Right femur of Bufo columbiensis


FIG. 35
Right femur of Bufo lentiginosus woodhousii

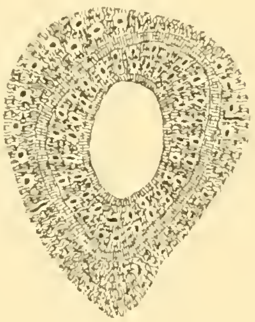
FIG. 36
Right femur of Bufo americana


FIG. 37
Right femur of Bufo lentiginosus cognatus


FIG. 38
Right femur of Bufo valliceps


FIG. 39
Right femur of Rana boylii

REPTILES


FIG. 40
Right femur of Sphenodon punctatus (most primitive reptile)


FIG. 41
Right femur of Phrynosoma cornutum


FIG. 42
Left femur of Chamæleo vulgaris


FIG. 43
Right femur of Phrynosoma douglassii


FIG. 44
Right femur of Ptychozoon homalocephalum

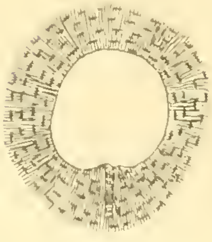
FIG. 45
Right femur of Iguana tuberculata


FIG. 46
Left femur of Varanus salvator

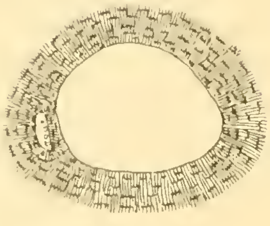
FIG. 47
Right femur of Amphibolurus barbatus

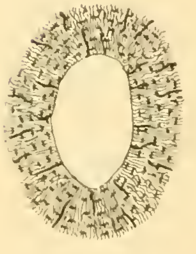
FIG. 48
Left femur of Varanus arenarius


FIG. 49
Right femur of Varanus nuchalis

AMPHIBIANS AND REPTILES

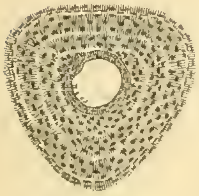
Fig. 50
Right femur of Heloderma suspectum

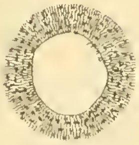
Fig. 51
Right femur of Sceloporus clarkii


Fig. 52
Right femur of Sceloporus spinosus floridanus


Fig. 53
Right femur of Sceloporus occidentalis.

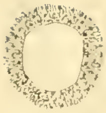
Fig. 54
Right femur of Sceloporus magister


Fig. 55
Right femur of Cyclura carinata


Fig. 56
Right femur of Anolis cristatellus

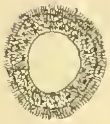
Fig. 57
Right femur of Crotaphytus collaris


Fig. 58
Left femur of Crotaphytus collaris

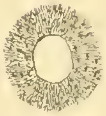
Fig. 59
Right femur of Ameiva exul


Fig. 60
Right femur of Eumeces fasciatus


Fig. 61
Right femur of Sauromalus


Fig. 62
Right femur of Gerrhonotus grandis


Fig. 63
Right femur of Python regius


Fig. 64
Left femur of Python regius

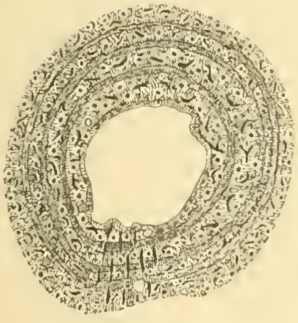
Fig. 65
Left femur of Alligator mississippiensis

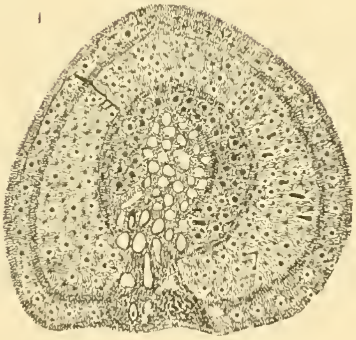
Fig. 66
Femur of Chelydra serpentina (snapping turtle)

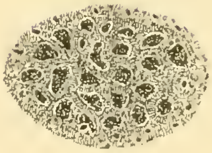
Fig. 67
Right femur of Trionyx spinifer (soft-shelled turtle)

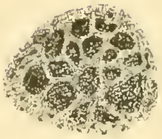
Fig. 68
Right femur of Cinosternum pennsylvanicum

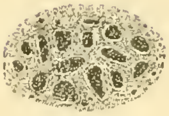
Fig. 69
Right femur of Chelopus guttatus (spotted turtle)

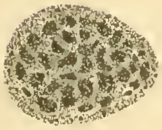
Fig. 70
Left femur of Chrysemys picta (painted turtle)


Fig. 71
Right femur of Aromochelys odoratus (musk turtle)

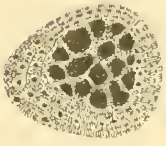
Fig. 72
Right femur of Pseudemys floridana

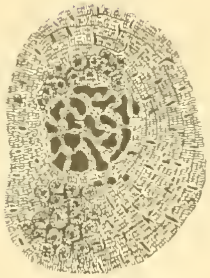
Fig. 73
Right femur of Testudo (Gopherus) polyphemus

REPTILES


Fig. 74
Right femur of Cyanocitta stelleri azteca (Aztec jay)


Fig. 75
Left femur of Mergus serrator (red-breasted merganser)


Fig. 76
Right femur of Ajaia ajaja (roseate spoonbill)


Fig. 77
Right femur of Tympanuchus americanus (prairie chicken)


Fig. 77½
Right femur of Numida meleagris (guinea-fowl)

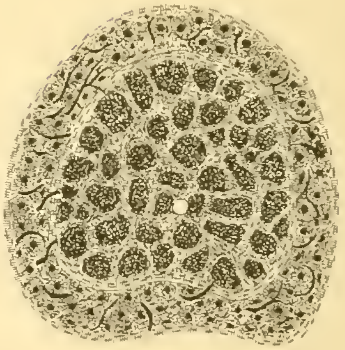
Fig. 83
Femur of Pelecanus erythrorhynchus (white pelican)

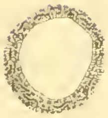
Fig. 78
Right femur of Cyanocitta cristata (blue jay)


Fig. 79
Left femur of Pteroglossus torquatus (banded toucan)


Fig. 80
Left femur of Charadrius pluvialis (golden plover)


Fig. 81
Left femur of Amazona oratrix (Mexican parrot)

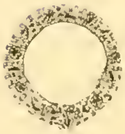
Fig. 82
Right femur of Turdus migratorius (robin)


Fig. 84
Right femur of Ara macao (macaw)


Fig. 85
Right femur of Nyctherodius violaceus (night heron)

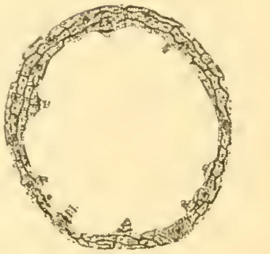
Fig. 86
Femur of Pavo cristatus (peafowl)

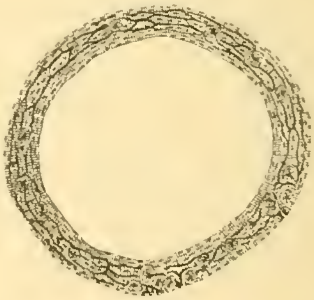
Fig. 87
Femur of Haliætus leucocephalus (eagle)


Fig. 88
Left femur of Aramus vociferus (courlan)


Fig. 89
Left femur of Centrocercus urophasianus (sage grouse)

BIRDS


FIG. 90
Left femur of Meleagris gallipavo
(wild turkey)

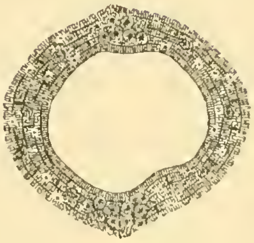
FIG. 91
Left femur of Meleagris gallipavo
(domestic turkey, 16 lbs. weight)


FIG. 91½
Left femur of Meleagris gallipavo
(domestic turkey, 32 lbs. weight)

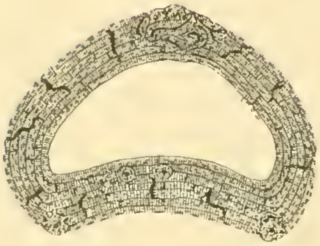
FIG. 92
Left femur of Dendragapus obscurus
(blue grouse)

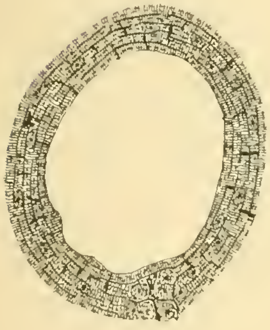
FIG. 93
Left femur of Rhea americana
(rhea)

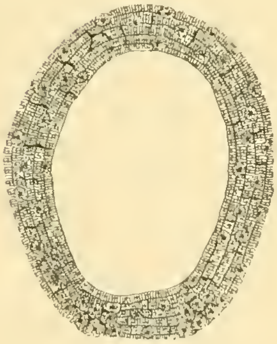
FIG. 94
Left femur of Struthio
(ostrich)

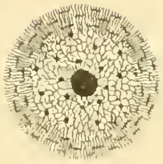
FIG. 95
Haversian system of
Fig. 94, showing early
central and late peripheral stages of
development


FIG. 95½
Left femur of Phasianus torquatus (Chinese pheasant)

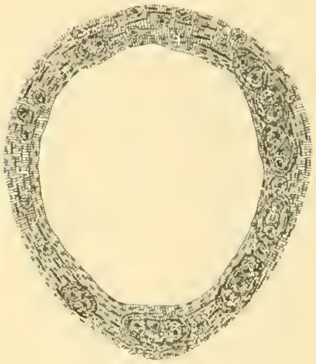
FIG. 96
Right femur of Dromæus novæ
hollandiæ (emu)


FIG. 97
Femur of Anas boscas (mallard duck)


FIG. 98
Femur of Emberiza citrinella
(yellow hammer)


FIG. 99
Right femur of Chauna cristata
(crested screamer)


FIG. 100
Left femur of Pandion carolinensis
(American osprey)

BIRDS

FIG. 101
Right femur of Sarcorhamphus gryphus (Andean condor)

FIG. 102
Right femur of Olor sp. (swan)

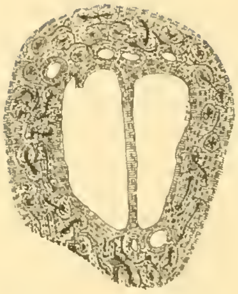

FIG. 103
Left femur of Gavia stellata (red-throated loon)

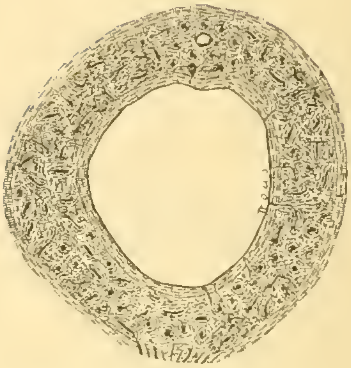

FIG. 104
Femur of Gallus (domestic chicken)

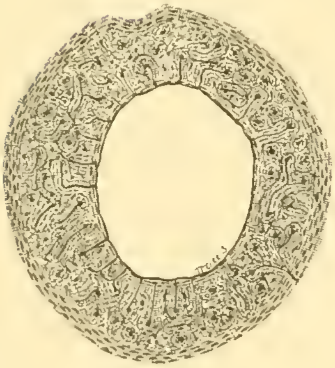

FIG. 105
Femur of Corvus americanus (American crow)

FIG. 106
Femur of Asio wilsonianus (long-eared owl)

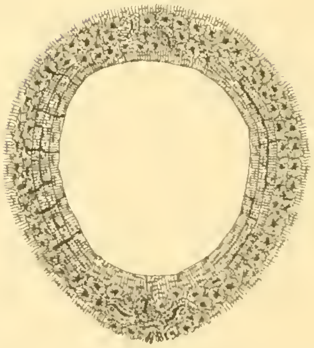

FIG. 107
Right femur of Bernicla canadensis (wild goose)

FIG. 108
Left femur of Leptoptilos sp. (stork)

FIG. 109
Right femur of Anthracoceros malabaricus (hornbill)

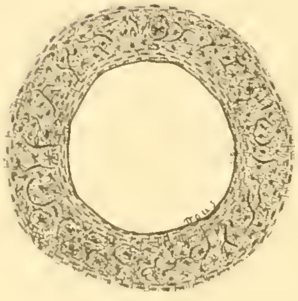

FIG. 110
Femur of Astur atricapillus (goshawk)

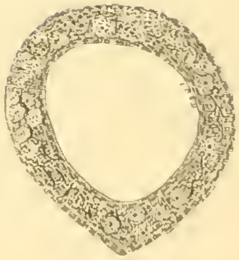

FIG. 111
Left femur of Inocotis papillosus (ibis)

FIG. 112
Right femur of Cathartes aura (turkey-buzzard)

BIRDS


FIG. 113
Right femur of
Mormoops


FIG. 114
Right femur of
Rhinolophus
mehelyi


FIG. 115
Left femur of
Sturnira lilium


FIG. 116
Right femur of
Lonchorhina


FIG. 117
Left femur of
Rousettus
amplexicaudatus

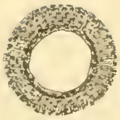
FIG. 118
Right femur of
Hipposideros
larvatus


FIG. 119
Left femur of
Hemiderma


FIG. 120
Left femur of
Desmodus
rotundus


FIG. 121
Left femur of
Leptonycteris


FIG. 122
Right femur of
Rhinopoma
(Palestine)


FIG. 123
Left femur of
Erophylla
bombifrons


FIG. 124
Left femur of
Phyllostoma
hastatum


FIG. 125
Left femur of
Epomophorus
wahlbergii


FIG. 126
Left femur of
Glossophaga
elongata


FIG. 127
Left femur of
Nyctalus
aviator


FIG. 128
Left femur of
Scotophilus
heathii


FIG. 129
Right femur of
Miniopterus
schreibersii


FIG. 130
Left femur of
Promops
fosteri


FIG. 131
Left femur of
Vespertilio
murinus


FIG. 132
Right femur of
Molossus
nigricans


FIG. 133
Right femur of
Dasypterus
intermedius

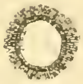
FIG. 134
Left femur of
Molossus
major

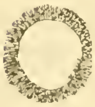
FIG. 135
Left femur of
Antrozous
pallidus


FIG. 136
Left femur of
Eumops
californicus


FIG. 137
Right femur of
Plecotus
auritus


FIG. 138
Left femur of
Nycticeius
humeralis


FIG. 139
Right femur of
Myotis
myotis


FIG. 140
Left femur of
Eptesicus
bahamensis


FIG. 141
Left femur of
Nycteris
borealis


FIG. 142
Right femur of
Glischropus
tylopus


FIG. 143
Right femur of
Nycteris
cinerea

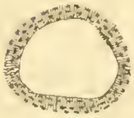
FIG. 144
Left femur of
Phyllonycteris


FIG. 145
Right femur of
Megaderma
spasma


FIG. 146
Right femur of
Pteronotus


FIG. 147
Left femur of
Balantiopteryx
plicata


FIG. 148
Right femur of
Saccopteryx


FIG. 149
Left femur of
Petalia


FIG. 150
Left femur of
Monophyllus


FIG. 151
Left femur of
Vampyrops
lineatus


FIG. 152
Right femur of
Chilonycteris


FIG. 153
Right femur of
Cynopterus


FIG. 154
Left femur of
Artibeus
palmarum


FIG. 155
Left femur of
Brachyphylla.


FIG. 156
Right femur of
Macroglossus
minimus


FIG. 157
Left femur of
Taphozous
philippinensis


FIG. 158
Right femur of
Cheiromeles
torquatus


FIG. 159
Right femur of
Noctilio.


FIG. 160
Left femur of
Pteropus
molossinus
(small)


FIG. 161
Right femur of
Pteropus
molossinus
(large)


FIG. 162
Right femur of
Pteropus
aldabrensis


FIG. 163
Right femur of
Pteropus
(Celebes)


FIG. 164
Right femur of
Pteropus
(Java)


FIG. 165
Right femur of
Pteropus
lepidus


FIG. 166
Right femur of
Pteropus
(Tongatabu)

FIFTY GENERA OF BATS

FIG. 167
Right femur of
Pteropus
poliocephalus
(fruit-eating bat)

FIG. 168
Left femur of
Tupaia. Tree
shrew

FIG. 169
Right femur of Echidna (egg-laying
mammal)

FIG. 170
Left femur of Ornithorhynchus.
(duckbill, egg-laying mammal)

FIG. 171
Left femur of
Cavia cutleri
(guinea-pig)

FIG. 172
Left femur of
Scalopus aquaticus
(mole)

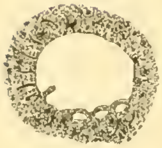

FIG. 173
Right femur of
Sorex (shrew)

FIG. 174
Right femur of
Macropus (wallaby)

FIG. 175
Left femur of
Solenodon paradoxus
(young)

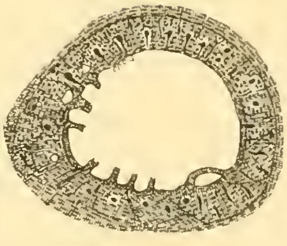

FIG. 176
Right femur of Solenodon
paradoxus (adult)

FIG. 177
Femur of Lemur mongoz

FIG. 178
Left femur of Colobus
abyssinicus caudatus
(African monkey)

FIG. 179
Femur of Putorius vulgaris (weasel)

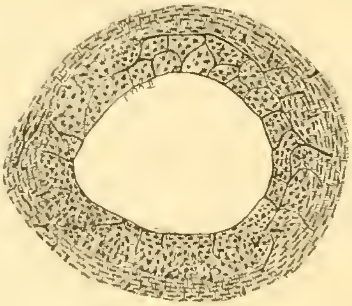

FIG. 180
Right femur of Mus rattus (black rat)

FIG. 181
Left femur of Heteromys
(Spiny pocket rat)

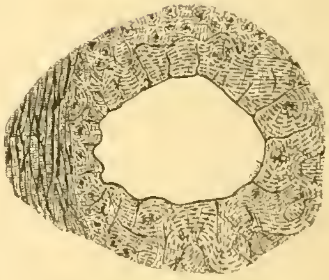

FIG. 182
Right femur of Myogale moschata
(desman)

FIG. 183
Femur of Cynomys ludovicianus
(prairie dog)

FIG. 184
Left femur of Trichosurus vulpecula
(phalanger)

FIG. 185
Left femur of Phascolomys ursinus
(wombat)

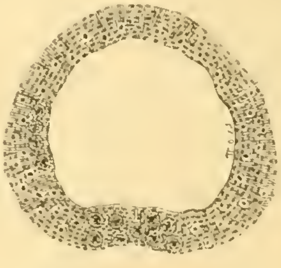

FIG. 186
Right femur of Lasiopyga
kolbi

MAMMALS

FIG. 187
Right femur of Tragulus javanicus (mouse-deer)

FIG. 188
Right femur of Mus sylvaticus (wood mouse)

FIG. 189
Left femur of Erinaceus europæus (hedgehog)

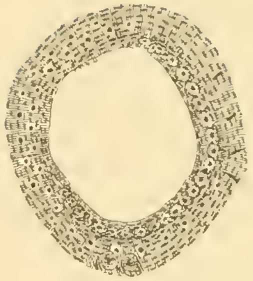

FIG. 190
Right femur of Viverra Civet

FIG. 191
Right femur of Ratufa maxima (giant squirrel)

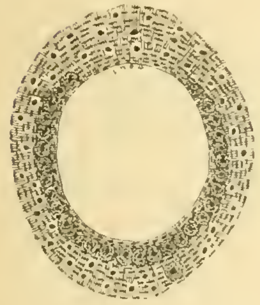

FIG. 192
Femur of Galeopithecus (flying lemur)

FIG. 193
Left femur of Manis (scaly ant-eater)

FIG. 194
Right femur of Procavia capensis (coney)

FIG. 195
Left femur of Helictis orientalis (asiatic badger)

FIG. 196
Right femur of Cynocephalus (baboon)

FIG. 197
Right femur of Cynocephalus maimon (mandrill)

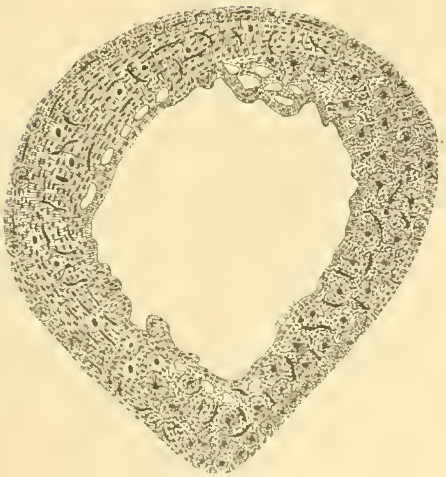

FIG. 198
Right femur of Hydrochœrus capybara

MAMMALS

Fig. 199
Right femur of a fetal sheep (eleven weeks)

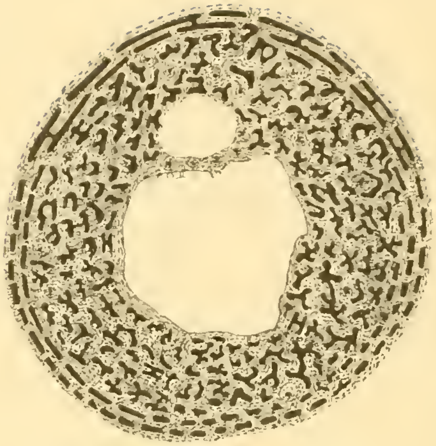

Fig. 200
Right femur of a fetal calf (eighteen weeks)

Fig. 201
Right femur of a fetal pig (eight and one-half weeks)

Fig. 202
Femur of Cariacus macrotis (deer)

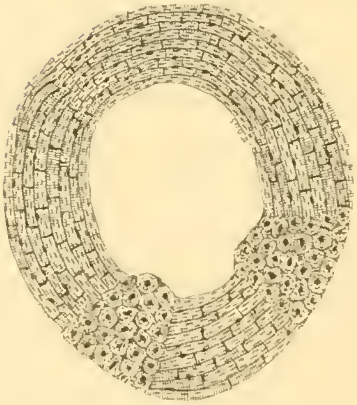

Fig. 203
Right femur of Sus (domestic pig)

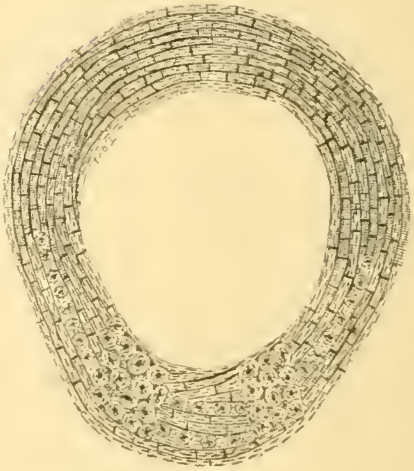

Fig. 204
Right femur of Sus scrofa (wild boar)

Fig. 205
Femur of Alces machlis (elk)

Fig. 206
Right femur of Camelus (camel)

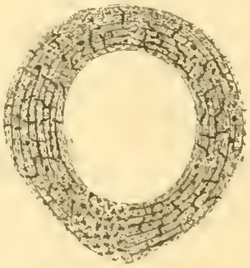

Fig. 207
Right femur of Auchenia glama (llama)

Fig. 208
Right femur of Rangifer (reindeer)

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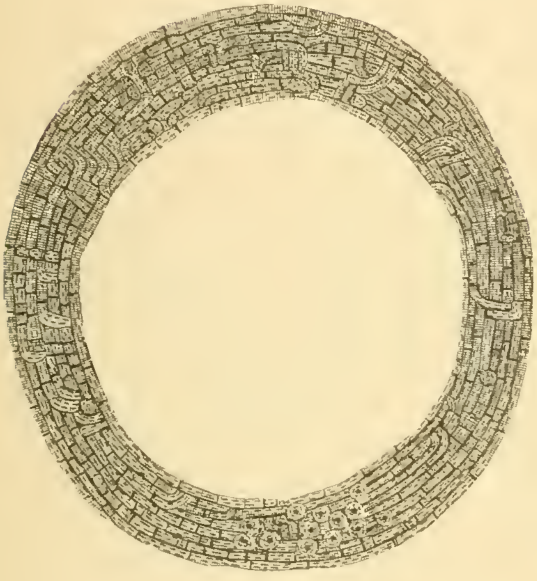
Fig. 209
Left femur of Ursus americanus (black bear)

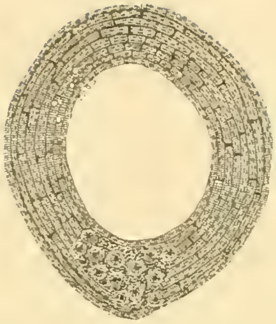
Fig. 210
Right femur of Taurotragus (eland)


Fig. 211
Left femur of Connochætes taurinus albojubatus (gnu)


Fig. 212
Right femur of Ovibos moschatus wardi (musk ox)

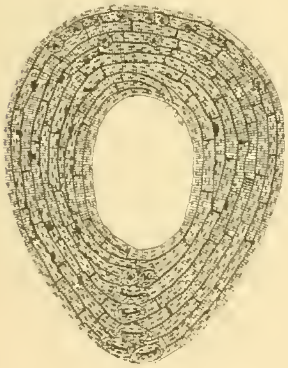
Fig. 213
Right femur of a Mexican burro


Fig. 214
Right femur of Tapirus (tapir)


Fig. 215
Right femur of Equus hemionus (wild ass of Asia)

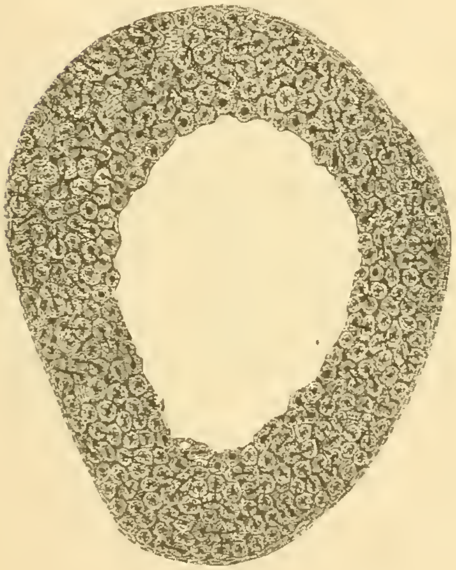
Fig. 216
Right femur of Elephas africanus (African elephant)


Fig. 217
Femur of Cholœpus didactylus (two-toed sloth)

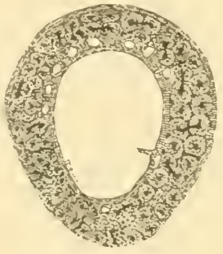
Fig. 218
Right femur of Potos caudivolvulus (kinkajou)

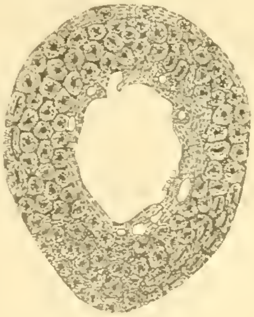
Fig. 219
Right femur of Lutra canadensis (otter)

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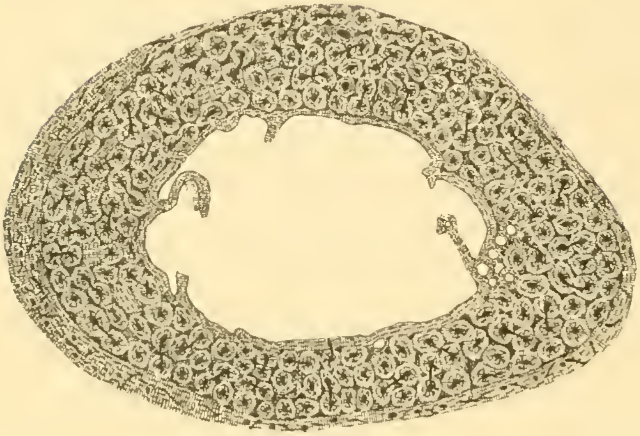

FIG. 220
Right femur of Simia satyrus (orang-utan)

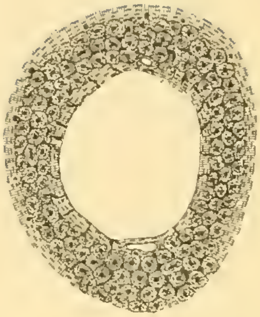

FIG. 221
Left femur of Felis tigris (tiger)

FIG. 222
Right femur of Hemigalus hardwickii

FIG. 223
Right femur of Tatu novemcinctus. Armadillo

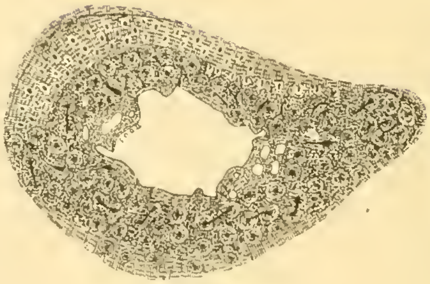

FIG. 224
Right femur of Tamandua tetradactyla (ant-eater)

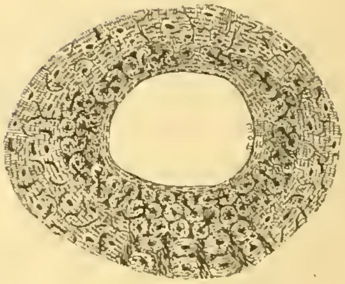

FIG. 225
Left femur of Gorilla (gorilla)

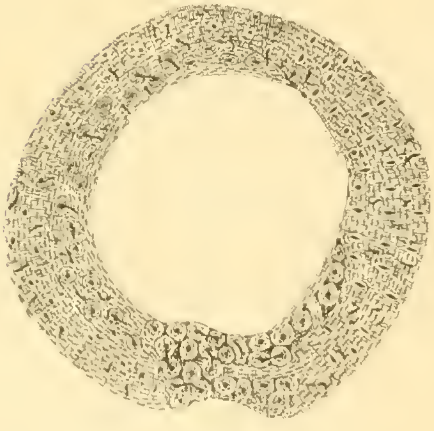

FIG. 226
Femur of Presbytis rubicunda (monkey)

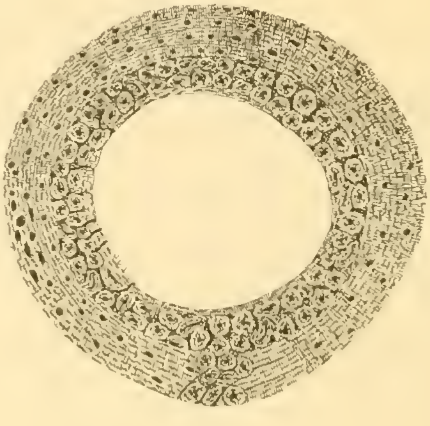

FIG. 227
Right femur of Hylobates (gibbon)

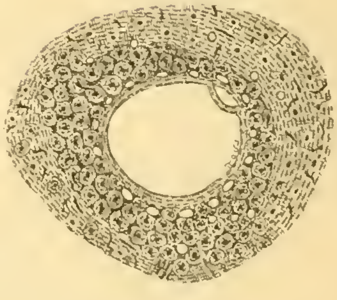

FIG. 228
Left femur of Anthropopithecus troglodytes (chimpanzee)

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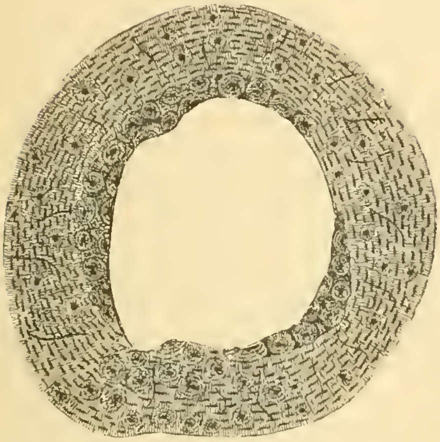

FIG. 229
Right femur of Macacus rhesus (Indian monkey)

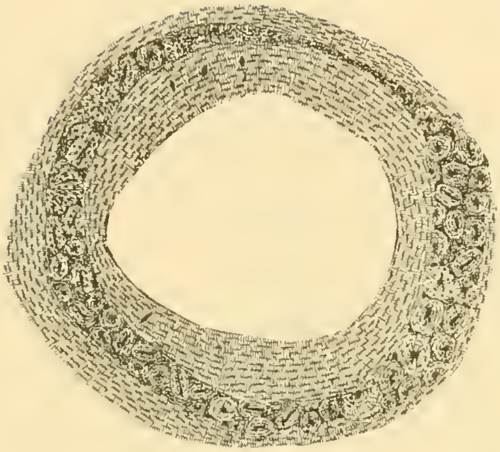

FIG. 230
Right femur of Sciurus sp. (large red squirrel)

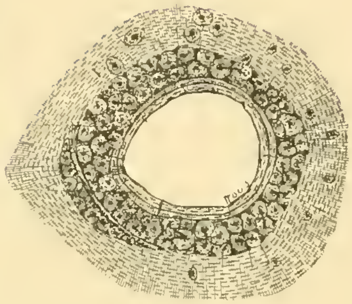

FIG. 231
Right femur of Felis (domestic cat)

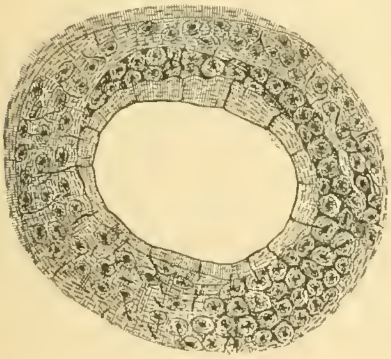

FIG. 232
Left femur of Felis catus (wildcat)

FIG. 233
Femur of Mephitis mephitica (skunk)

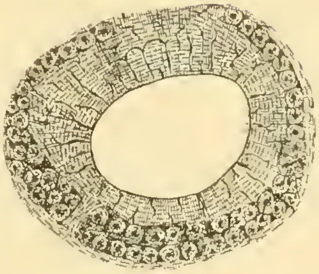

FIG. 234
Femur of Putorius vison (mink)

FIG. 235
Left femur of
Cryptoprocta ferox
(catlike civet)

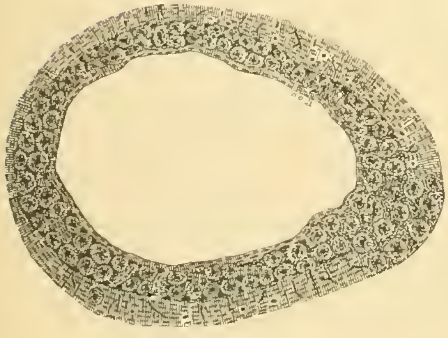

FIG. 236
Right femur of Hyæna crocuta (Hyæna)

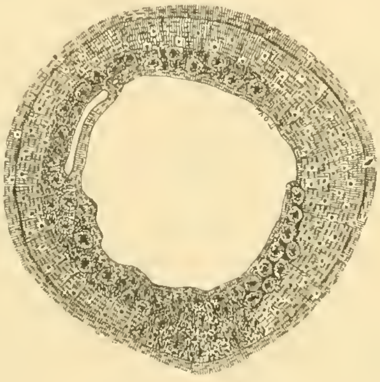

FIG. 237
Right femur of Thylacinus cynocephalus
(Tasmanian wolf)

FIG. 238
Right femur of Dasyprocta
agouti

FIG. 239
Left femur of Lasiopyga
centralis johnstoni (monkey)

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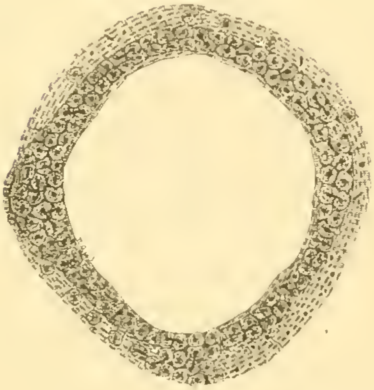

FIG. 240
Right femur of Felis canadensis (Canada lynx)

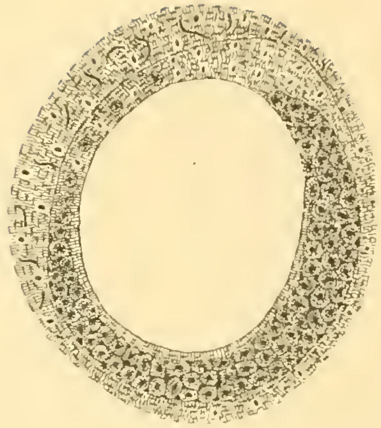

FIG. 241
Right femur of Lasiopyga sp. (African monkey)

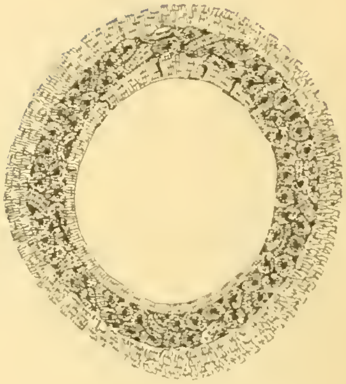

FIG. 242
Right femur of Midas rufoniger (South American monkey)

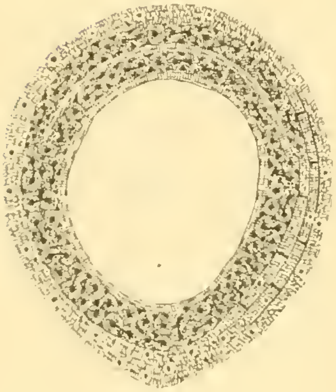

FIG. 243
Left femur of Lemur variegatus

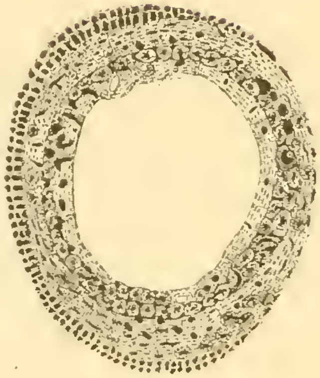

FIG. 244
Right femur of Lemur catta (ring-tailed lemur)

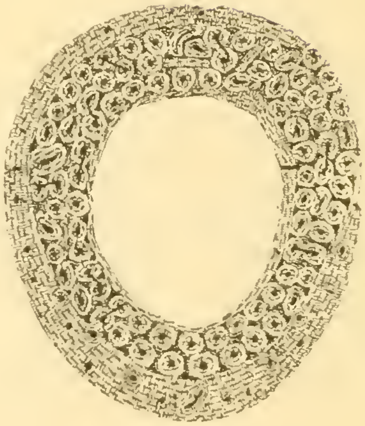

FIG. 245
Left femur of Ateles (spider-monkey) (Tehuantepec)

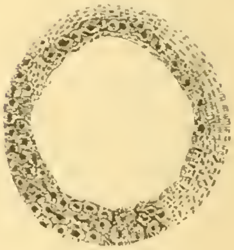

FIG. 246
Right femur of Callicebus torquatus (squirrel-monkey)

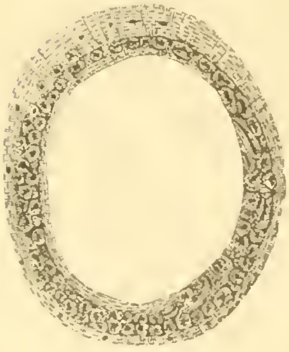

FIG. 247
Left femur of Genetta (genet)

FIG. 248
Left femur of Pedetes (jumping hare)

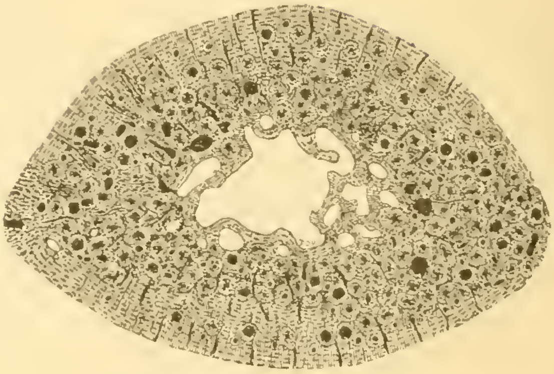

FIG. 249
Right femur of Bradypus tridactylus (three-toed sloth)

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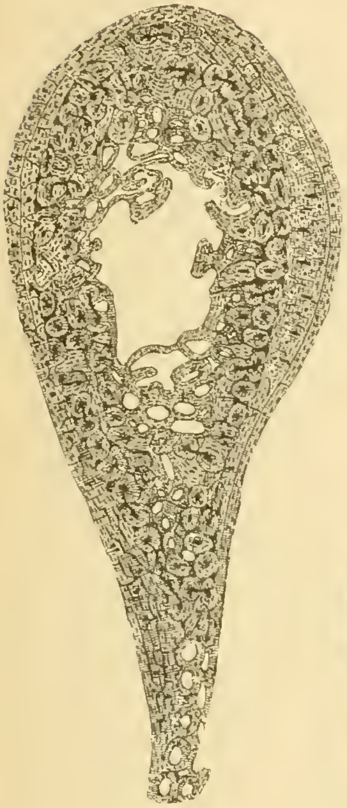

Fig. 250
Right femur of Castor canadensis (beaver)

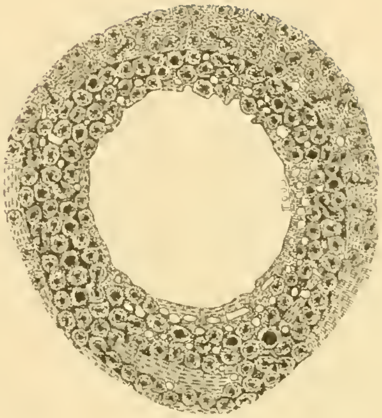

Fig. 251
Left femur of Felis pardus (leopard)

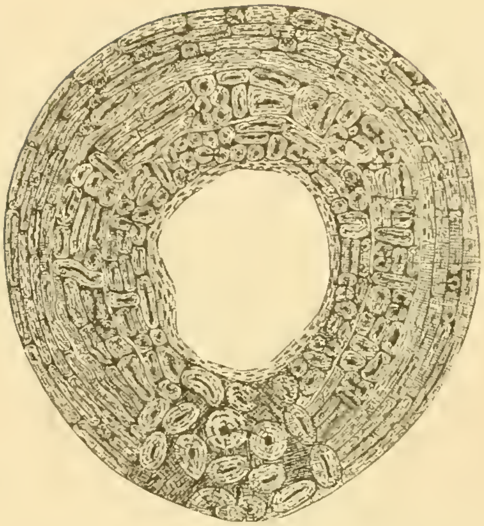

Fig. 252
Left femur of Bos (ox)

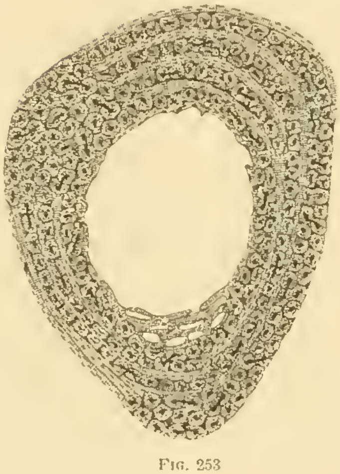

Fig. 253
Left femur of Equus caballus (horse)

Fig. 254
Right femur of Ovis (sheep)

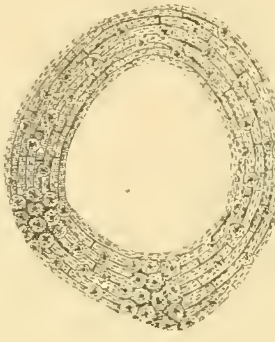

Fig. 255
Right femur of Bison americanus (bison)

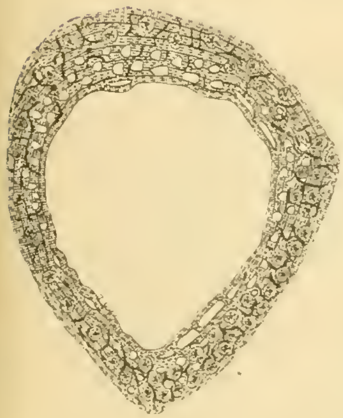

Fig. 256
Right femur of a mule.
No. 227, C. M. C.

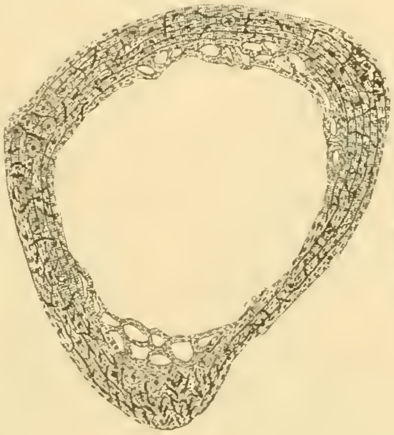

Fig. 257
Left femur of a mule. No. 229
C. M. C.

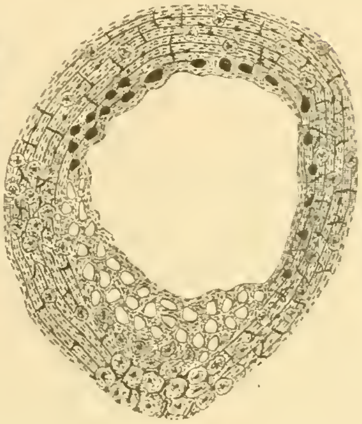

Fig. 258
Left femur of a mule. No. 235,
C. M. C.

Fig. 259
Left femur of a mule. No. 236,
C. M. C.

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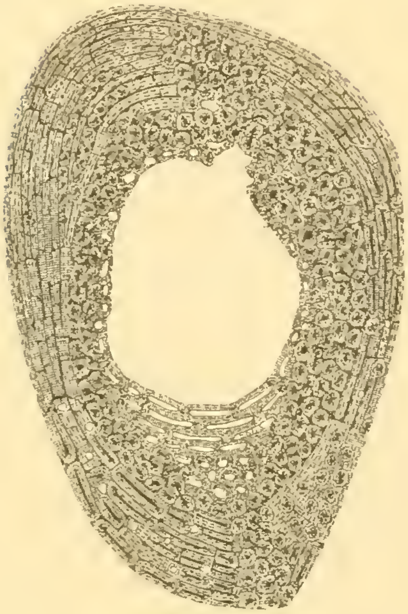

FIG. 260
Left femur of Elephas indicus (Asiatic elephant)

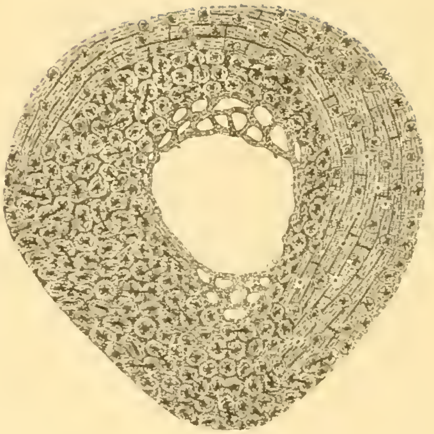

FIG. 261
Right femur of Hippopotamus amphibius (hippopotamus)

FIG. 262
Left femur of Giraffa camelopardalis (giraffe)

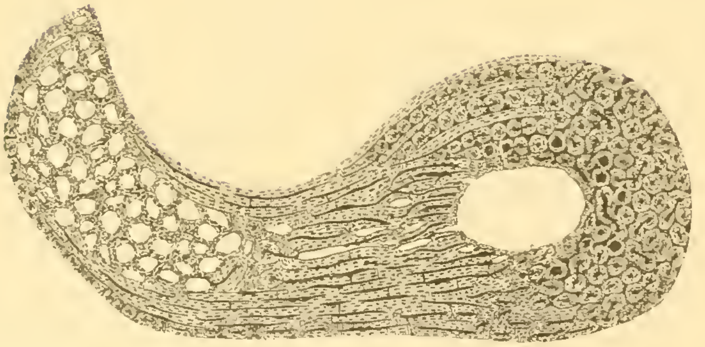

FIG. 263
Left femur of Rhinoceros bicornis (rhinoceros)

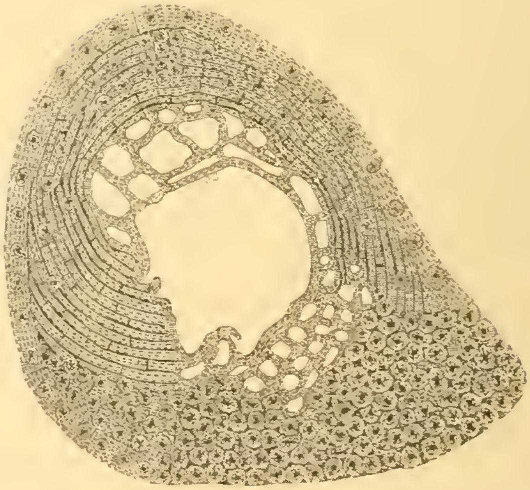

FIG. 264
Right femur of Equus burchelli (zebra)

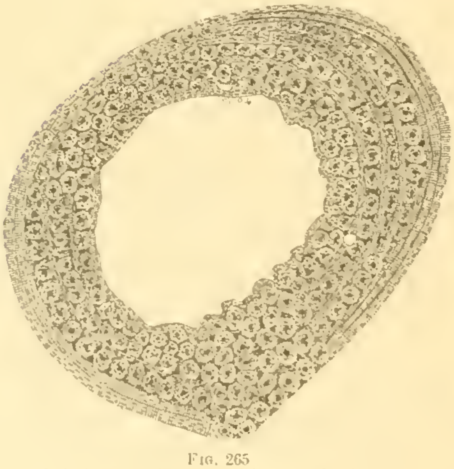

FIG. 265
Left femur of Ursus maritimus (polar bear)

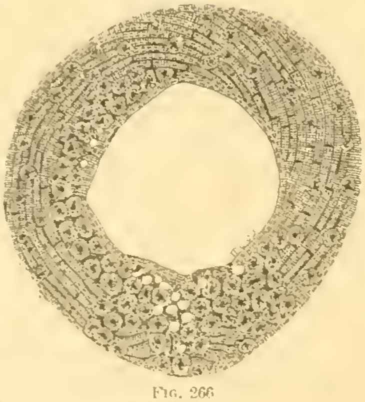

FIG. 266
Right femur of Bubalis jacksoni (Hartebeest)

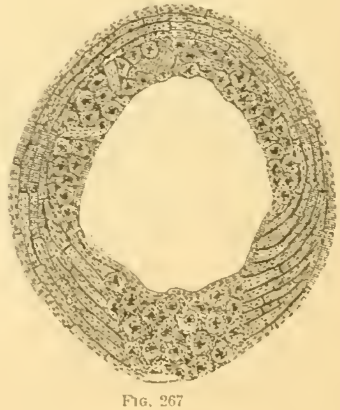

FIG. 267
Left femur of Phacochœrus (wart-hog)

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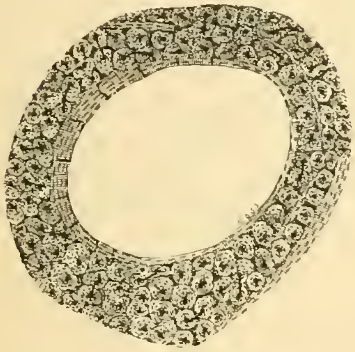

Fig. 268
Left femur of Felis concolor (panther)

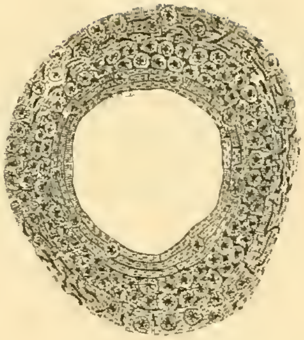

Fig. 269
Left femur of Gulo luscus
(wolverene)

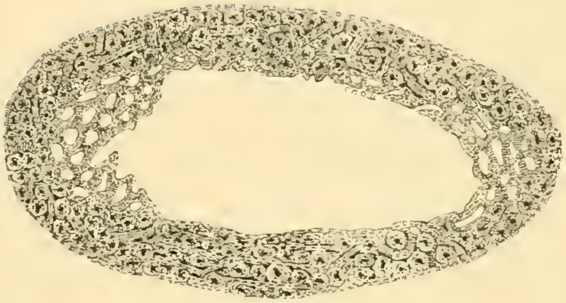

Fig. 270
Left femur of Erignathus barbatus (seal)

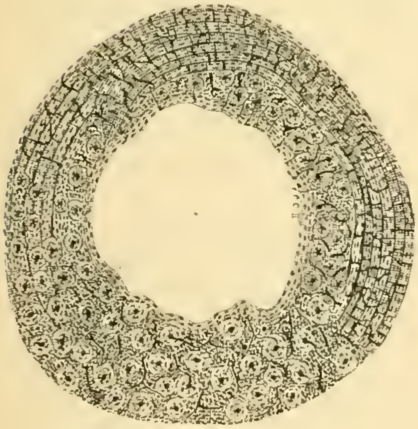

Fig. 271
Left femur of Bos bubalis (water buffalo)

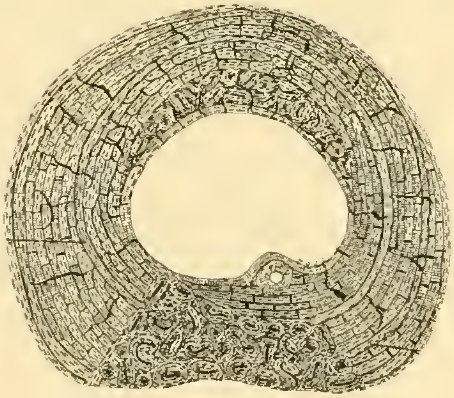

Fig. 272
Left femur of Ovis montana (mountain sheep)

Fig. 273
Femur of Cephalophus (African antelope)

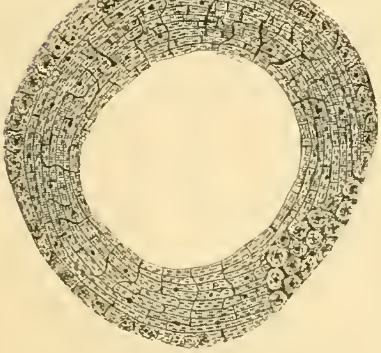

Fig. 274
Femur of Raphiceros (steinbok)

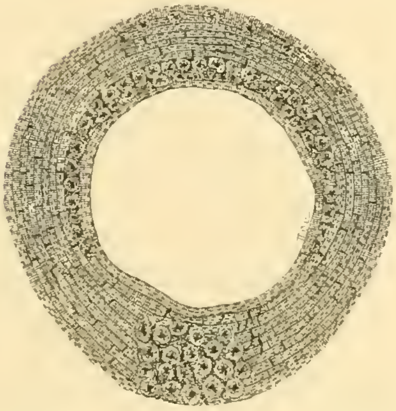

Fig. 275
Left femur of Gazella granti (Grant's gazelle)

Fig. 276
Left femur of Kobus ellipsiprymnus
(water buck)

MAMMALS

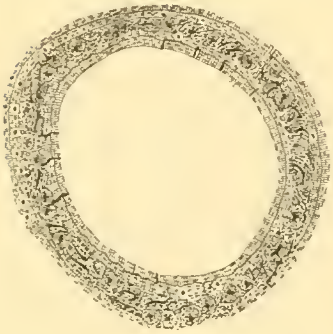

Fig. 277
Right femur of Arctomys monax
(woodchuck)

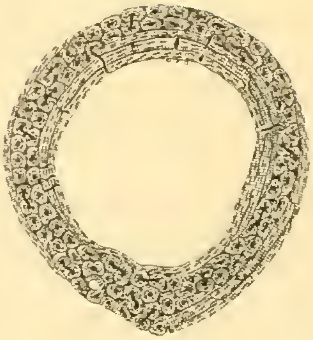

Fig. 278
Right femur of Canis latrans
(coyote)

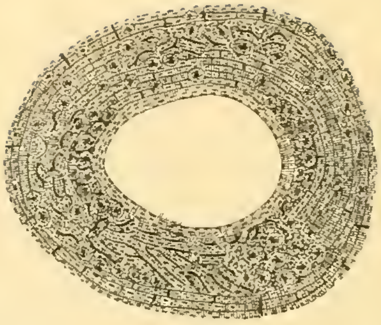

Fig. 279
Right femur of Capra (goat)

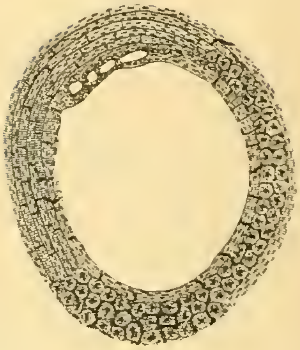

Fig. 279½
Right femur of a bull-dog (not a pure blood)

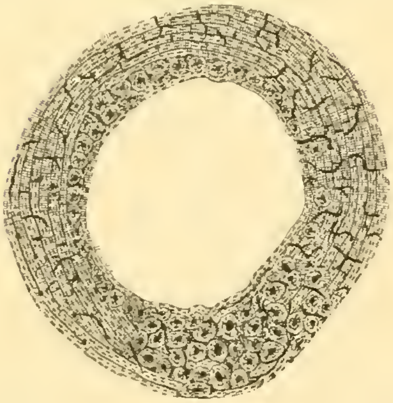

Fig. 280
Left femur of a shepherd dog (not a pure blood)

Fig. 280½
Right femur of a dog

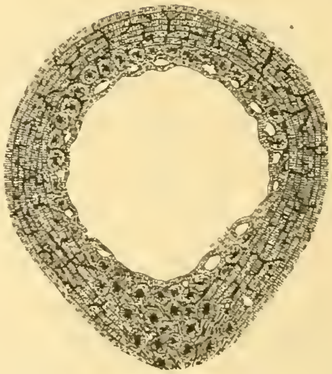

Fig. 281
Femur of a fox terrier (not a pure blood)

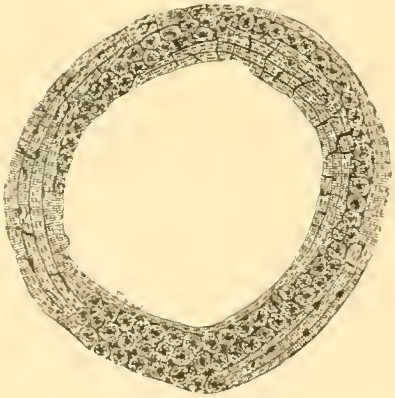

Fig. 282
Right femur of a mongrel dog

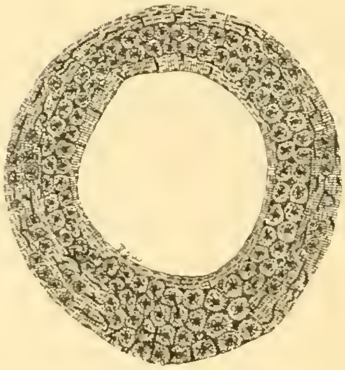

Fig. 283
Right femur of a bull dog (not a pure blood)

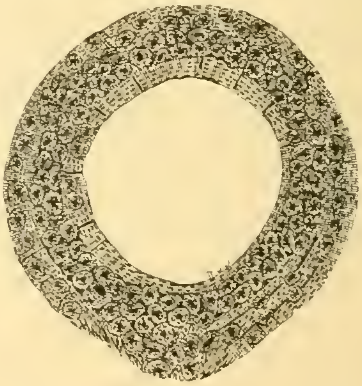

Fig. 284
Right femur of a collie dog (not a pure blood)

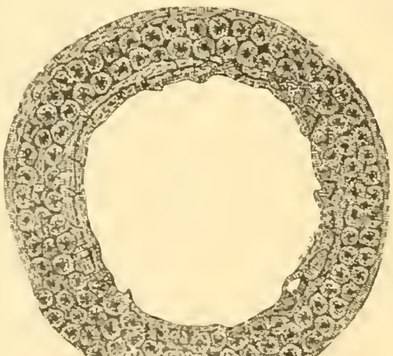

Fig. 285
Right femur of a spaniel (not a pure blood)

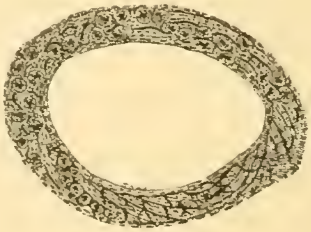

Fig. 286
Left femur of Lepus cuniculus (rabbit)

MAMMALS

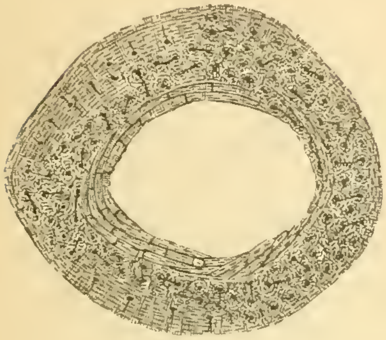

Fig. 287
Right femur of Procyon lotor (raccoon)

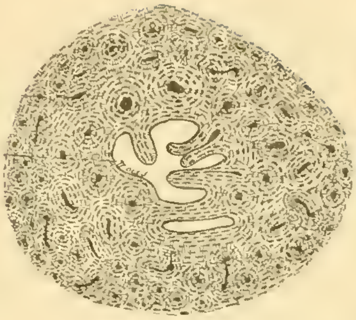

Fig. 288
Os penis of Raccoon

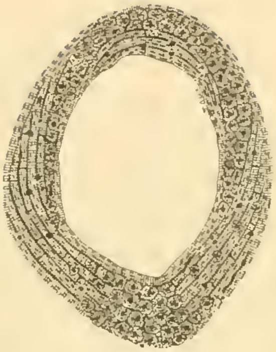

Fig. 289
Femur of Canis lupus
(grey wolf)

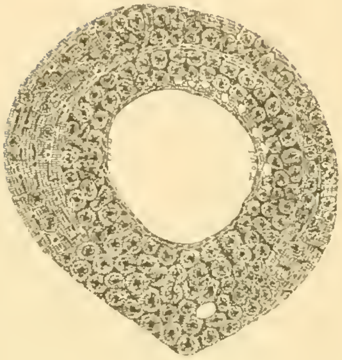

Fig. 290
Right femur of a Felis leo (lion)

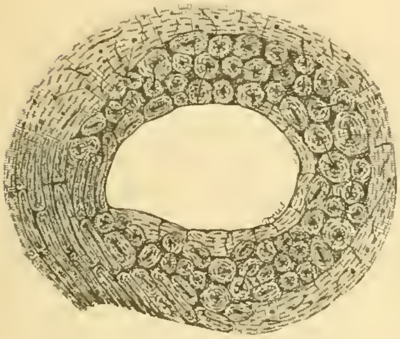

Fig. 291
Right femur of Canis (small grey fox)

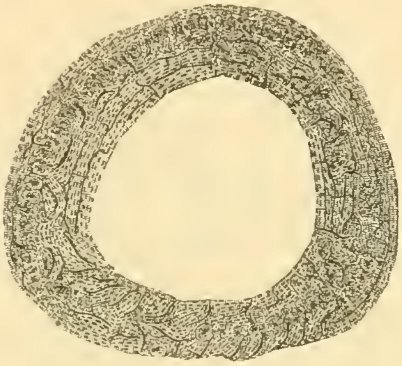

Fig. 292
Left femur of Taxidea americana (American badger)

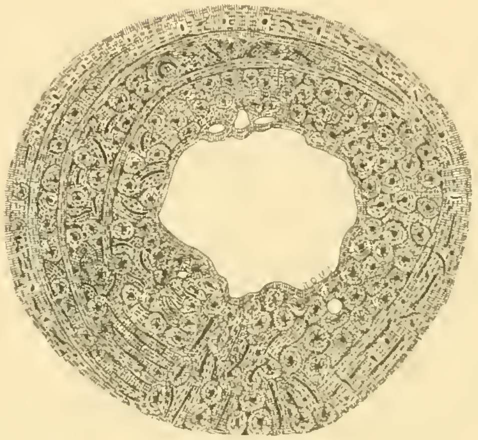

Fig. 293
Right femur of Melursus labiatus (sloth bear)

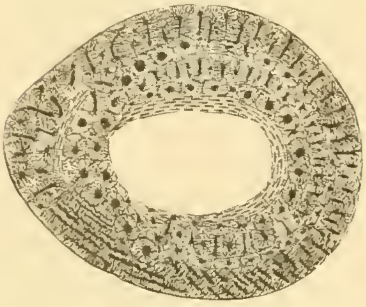

Fig. 295
Right femur of Didelphis virginiana (opossum)

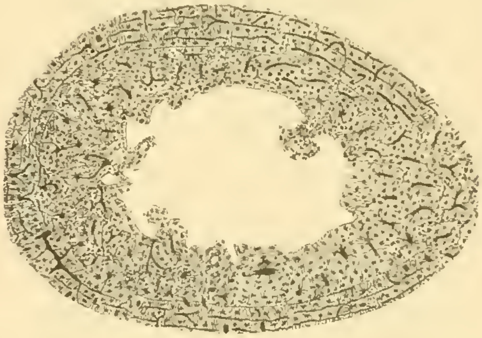

Fig. 296
Left femur of Manis (scaly ant-eater)

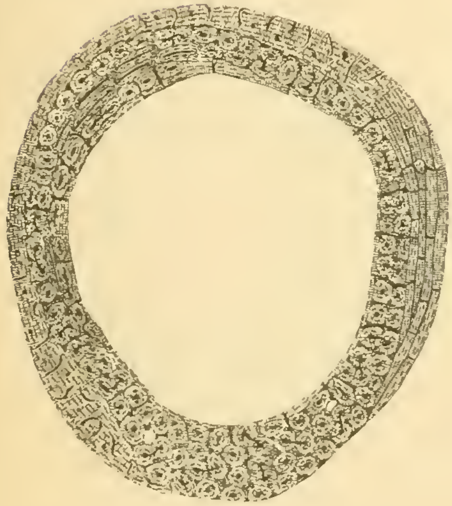

Fig. 294
Left femur of Canis aureus (jackal)

Fig. 297
Right femur of Haplondontia olympica,
sewellel (mountain beaver)

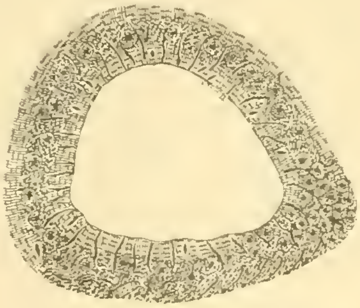

Fig. 298
Left femur of a Erethizon (porcupine)

MAMMALS

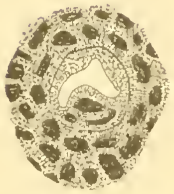

FIG. 299
Right femur of a white fetus of 2-2½ months

FIG. 300
Right femur of a white fetus of 3-3½ months

FIG. 301
Right femur of a white fetus of 4 months

FIG. 302
Right femur of a white fetus of 5-7 months

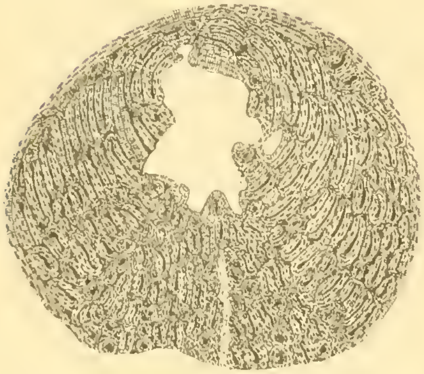

FIG. 303
Right femur of a white fetus of 8-9 months

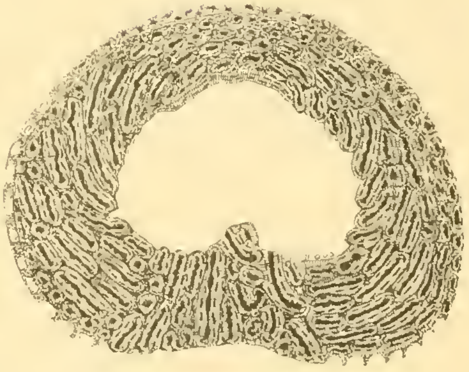

FIG. 304
Right femur of negro fetus of 9 months

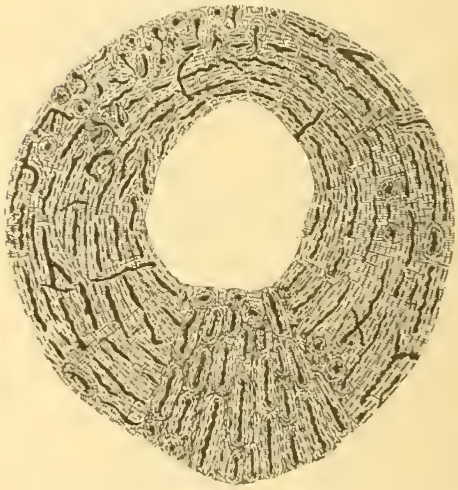

FIG. 305
Right femur of white fetus of 8½ months
(Craniorrhachischisis)

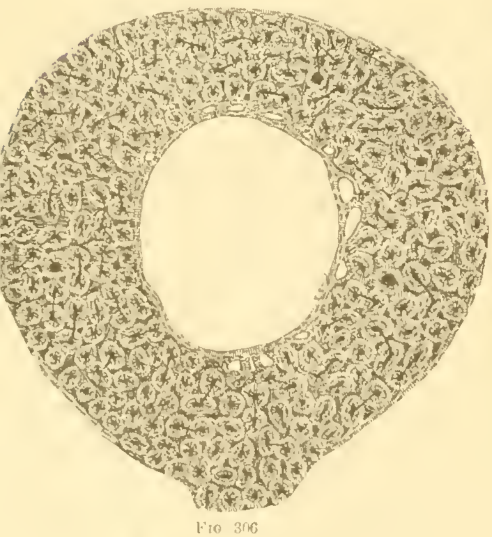

FIG. 306
Left femur of a negro. No. 228481, U. S. N. M.

FIG. 307
Femur of mixed negro and white (half white).
No. 247368, U. S. N. M.

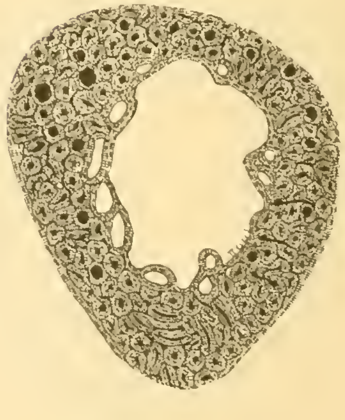

FIG. 308
Left femur of a negro. No. 3, Med. Dept.,
Tulane Univ.

MAN (WHITE, BLACK)

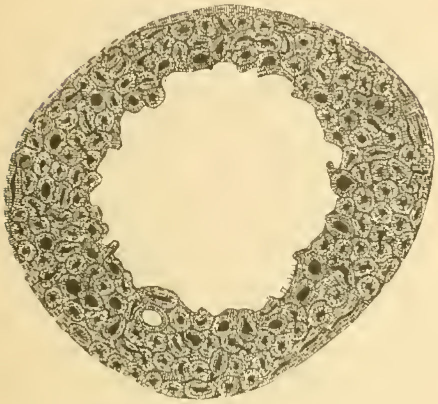

FIG. 309
Left femur of a negro. No. 87, M. D. T. U.

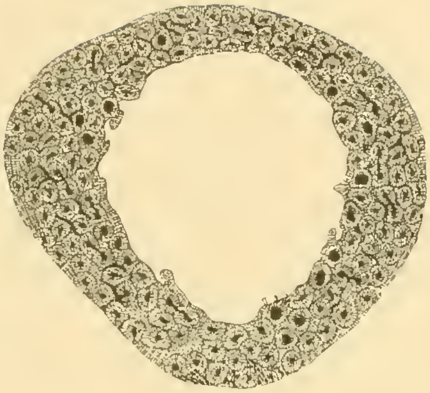

FIG. 310
Right femur of a negro. No. 7, M. D. T. U.

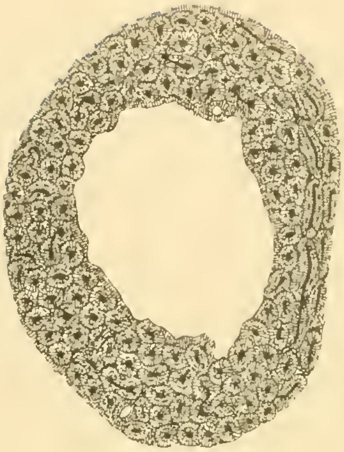

FIG. 311
Left femur of a negro. No. 4, M. D. T. U.

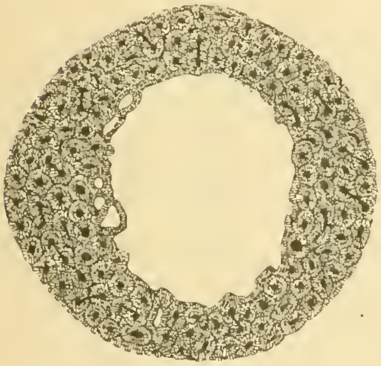

FIG. 312
Right femur of a negro. No. 84, M. D. T. U.

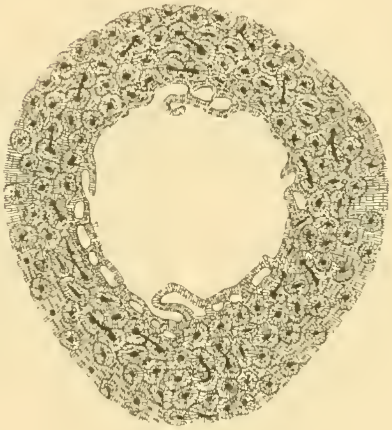

FIG. 313
Left femur of a negro. No. 10, M. D. T. U.

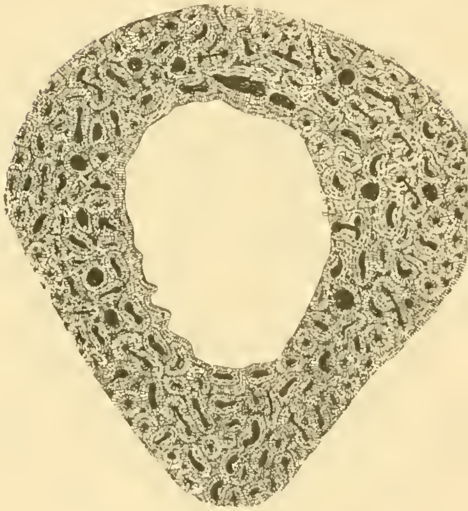

FIG. 314
Right femur of a negress, age 40. No. 123, M. D. T. U.

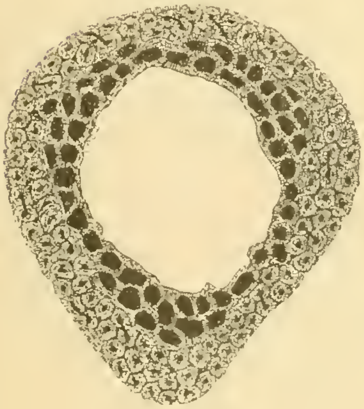

FIG. 315
Left femur of a negro. No. 79, M. D. T. U.

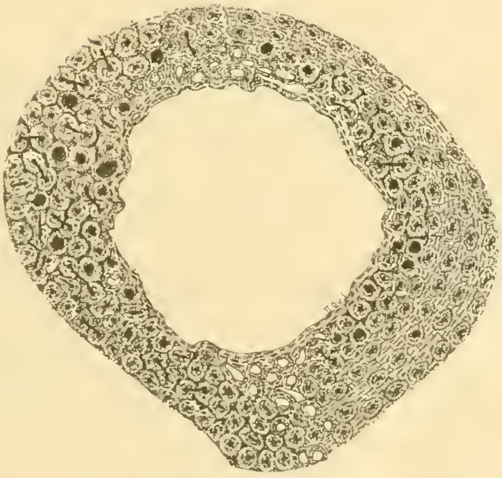

FIG. 316
Left femur of a negro. No. 224714, U. S. N. M.

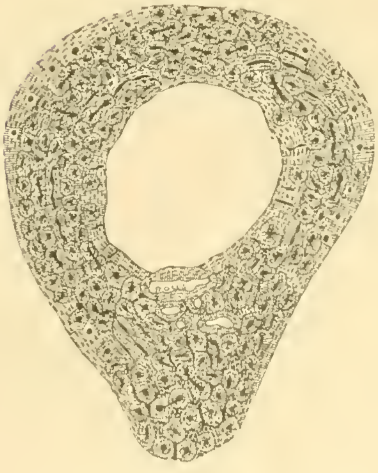

FIG. 317
Left femur of a negro. No. 11, M. D. T. U.

MAN (BLACK)

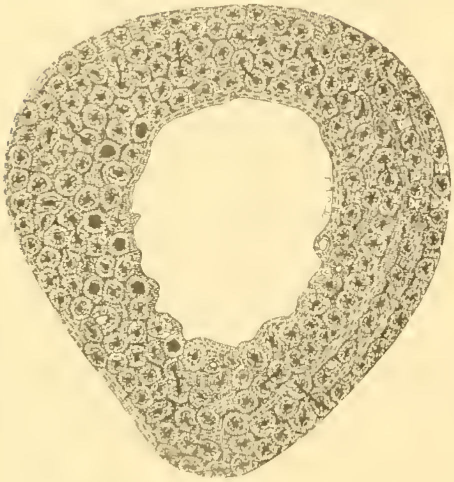
Fig. 318
Right femur of a negro. No. 2, M. D. T. U.

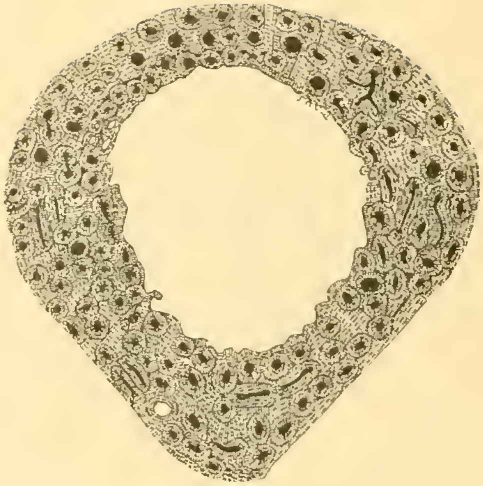
Fig. 319
Left femur of a negro. No. 56, M. D. T. U.


Fig. 320
Left femur of a negress. No. 220, C. M. C.

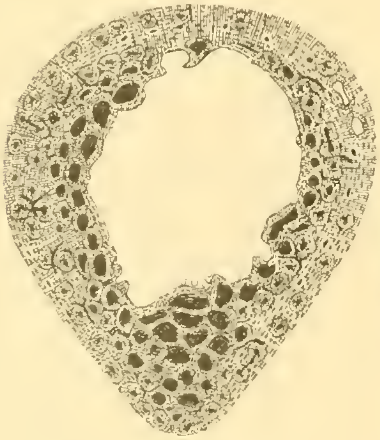
Fig. 321
Right femur of a negress. No. 220, C. M. C.
Amputated at lower third

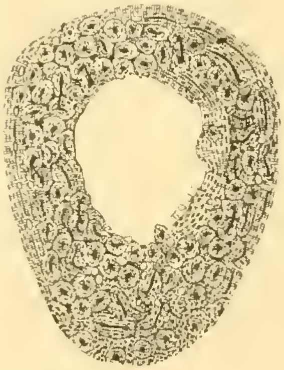
Fig. 322
Left femur of a negress age 14.
mixed black and white.
No. 226, C. M. C.

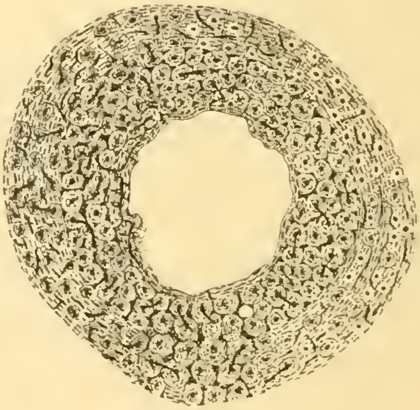
Fig. 323
Femur of a negro. No. 1, M. D. T. U.

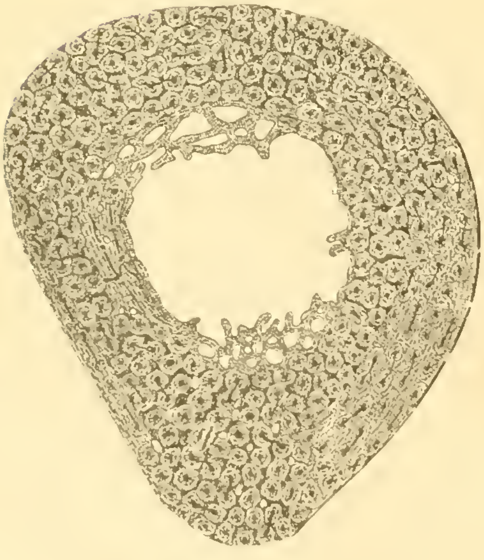
Fig. 324
Right femur of a Kaffir negro. No. 263196, U. S. N. M.

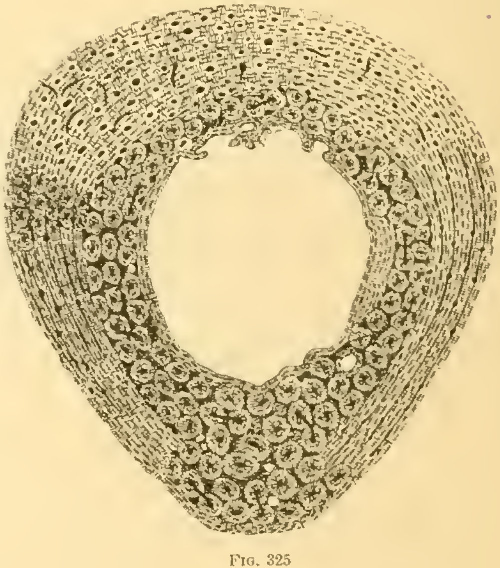
Fig. 325
Right femur of a negro. No. 248674, U. S. N. M.

MAN (BLACK)

FIG. 326
Left femur of a negro. No. 248674, U. S. N. M.

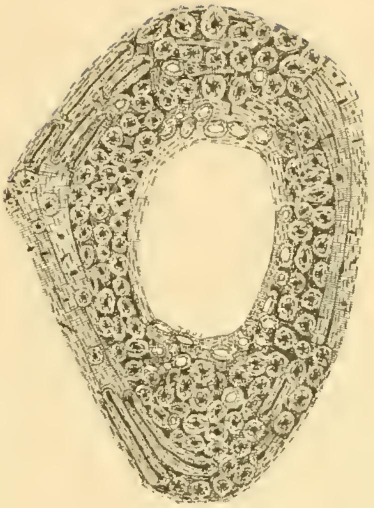

FIG. 327
Tibia of a negro. No. 248674, U. S. N. M.

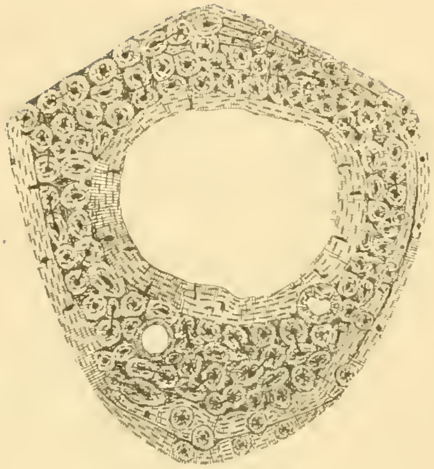

FIG. 328
Fibula of a negro. No. 248674, U. S. N. M.

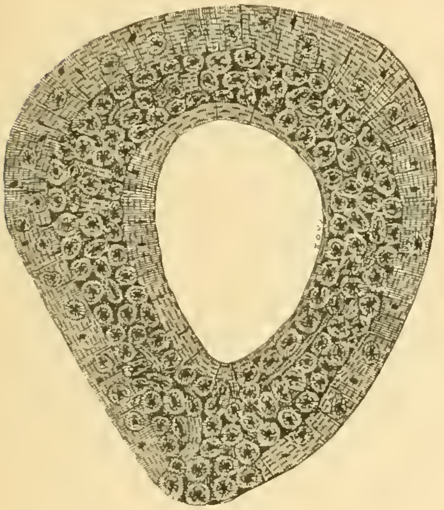

FIG. 329
Ulna of a negro. No. 248674, U. S. N. M.

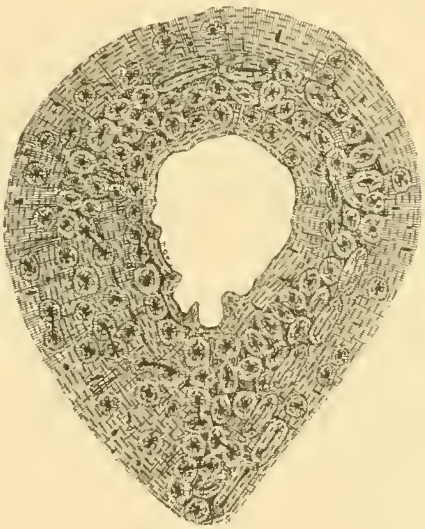

FIG. 330
Radius of a negro. No. 248674, U. S. N. M.

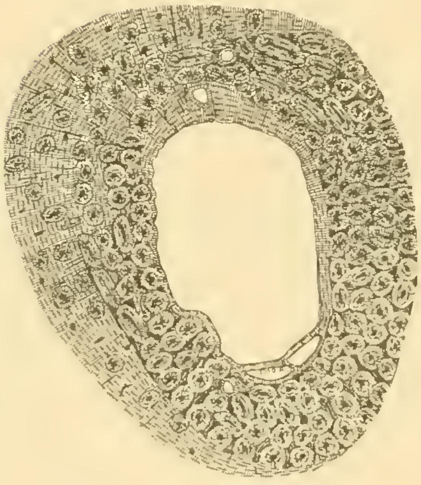

FIG. 331
Humerus of a negro. No. 248674, U. S. N. M.

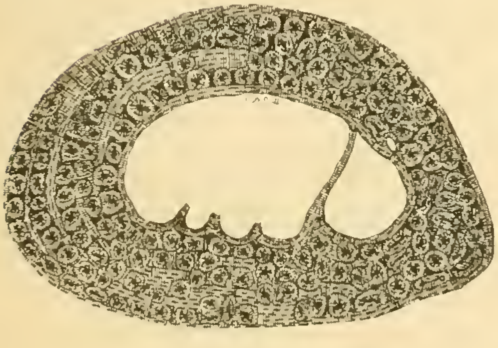

FIG. 332
Clavicle of a negro. No. 248674, U. S. N. M.

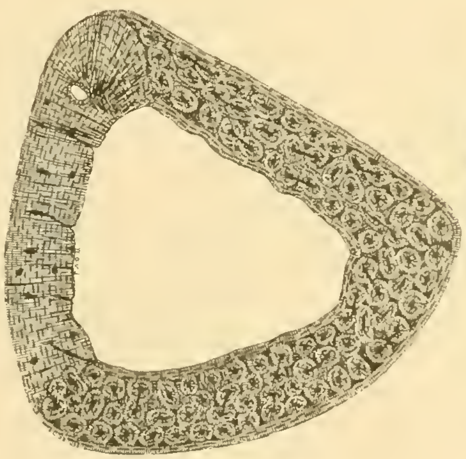

FIG. 333
Metatarsal bone of great toe of negro.
No. 248674, U. S. N. M.

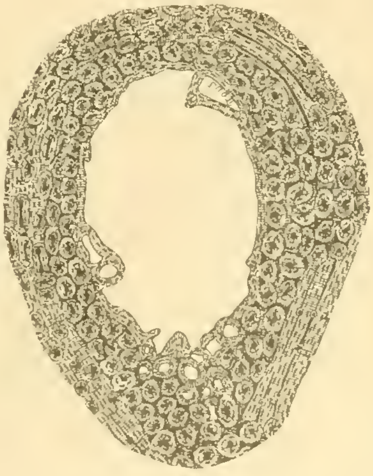

FIG. 334
Left femur of negro. No. 224713, U. S. N. M.

MAN (BLACK)

FIG. 335
Right femur of a negro. No. 83, M. D. T. U.

FIG. 336
Right femur of a negro. No. 6, M. D. T. U.

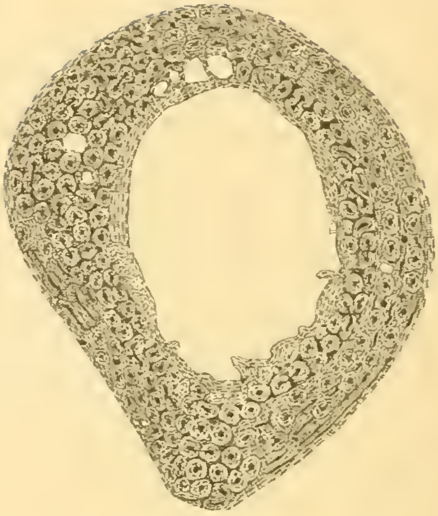

FIG. 337
Right femur of a negro. No. 63, M. D. T. U.

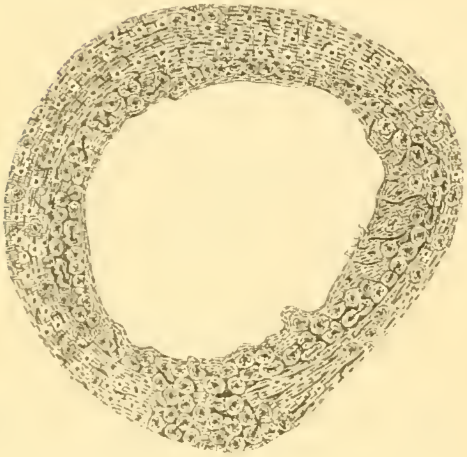

FIG. 338
Left femur of a negro. No. 5, M. D. T. U.

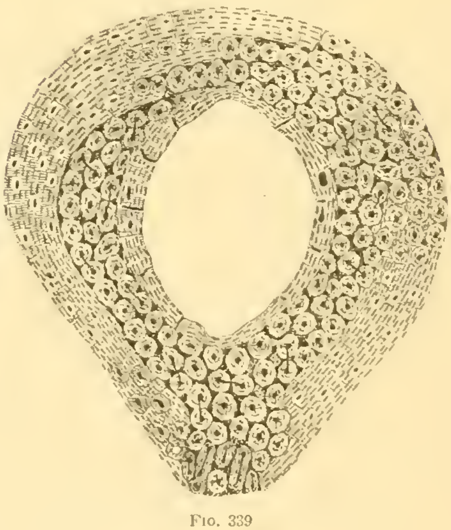

FIG. 339
Right femur of a negro. No. 8, M. D. T. U.

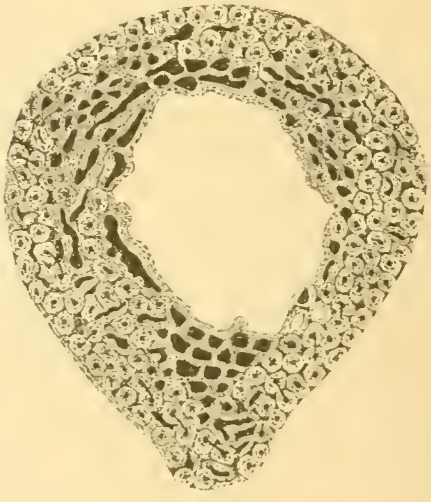

FIG. 340
Left femur of a negro. No. 7, M. D. T. U.

FIG. 341
Right femur of Pueblo Indian child one year old. No. 258675(z) U. S. N. M.

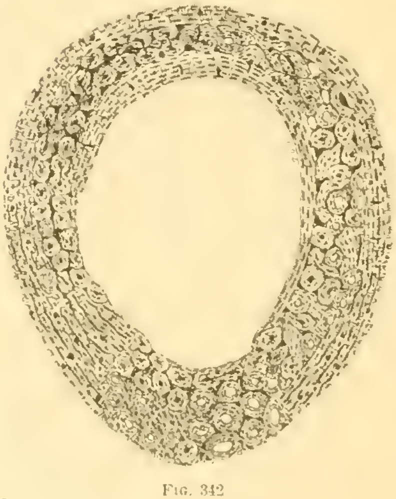

FIG. 342
Left femur of Pueblo Indian child six years old No. 258675(L), U. S. N. M.

FIG. 342½
Left femur of Pueblo Indian youth. No. 258675(82), U. S. N. M.

NEGRO. PUEBLO INDIAN.

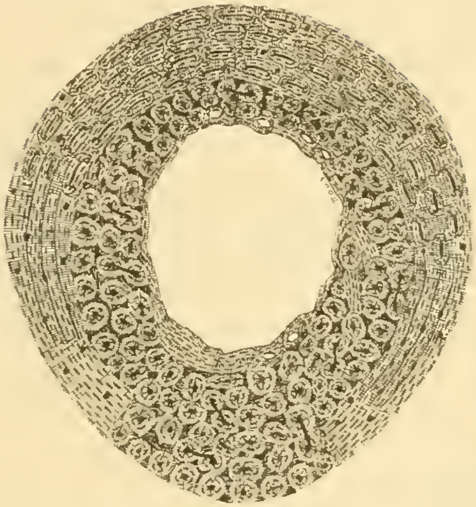

Fig. 343
Femur of Pueblo Indian adult. No. 258675(x) U. S. N. M.

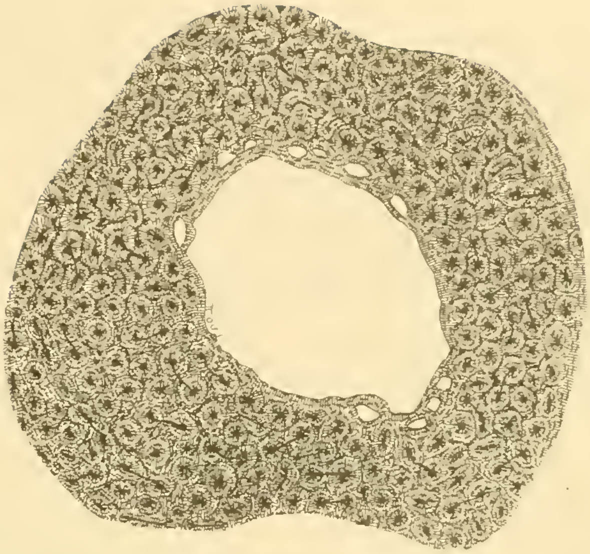

Fig. 344
Right femur of Pueblo Indian adult. No. 227339, U. S. N. M.

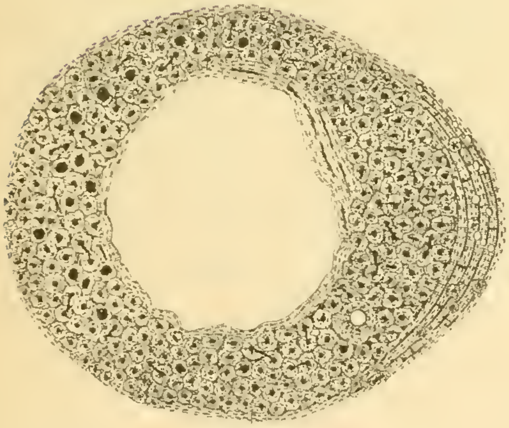

Fig. 345
Left femur of Peruvian Indian. No. 266469(b), U. S. N. M.

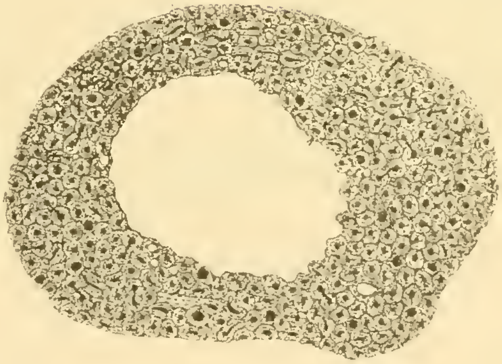

Fig. 346
Left femur of Peruvian Indian. No. 266469(a), U. S. N. M.

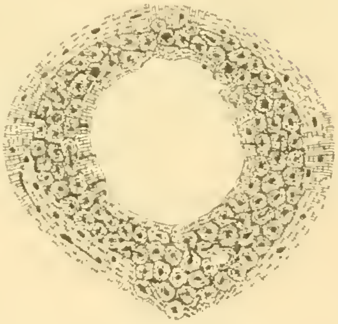

Fig. 347
Left femur of Chicama Indian of Peru. No. 2, U. S. N. M.

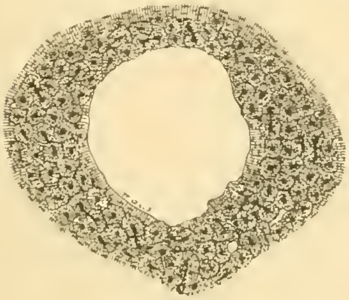

Fig. 348
Right femur of Chicama Indian of Peru. No. 3, U. S. N. M.

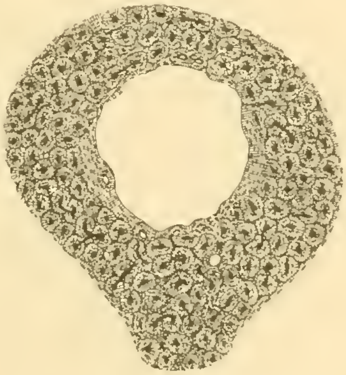

Fig. 349
Right femur of Chicama Indian of Peru. No. 1, U. S. N. M.

Fig. 350
Left femur of Chicama Indian of Peru. No. 4, U. S. N. M.

MAN (YELLOW-BROWN)

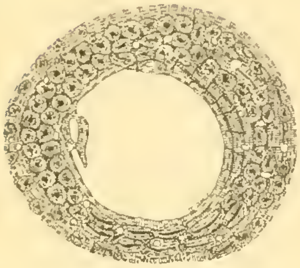

FIG. 351
Left femur of Chicama Indian of Peru. No. 7, U. S. N. M.

FIG. 357
Left femur of Pachacamac Indian of Peru (child). No. 12, U. S. N. M.

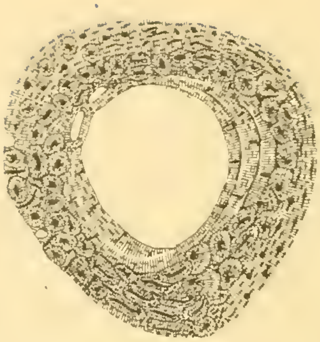

FIG. 360
Right femur of Pachacamac Indian of Peru (adult). No. 15, U. S. N. M.

FIG. 361
Left femur of Pachacamac Indian of Peru. No. 7, U. S. N. M.

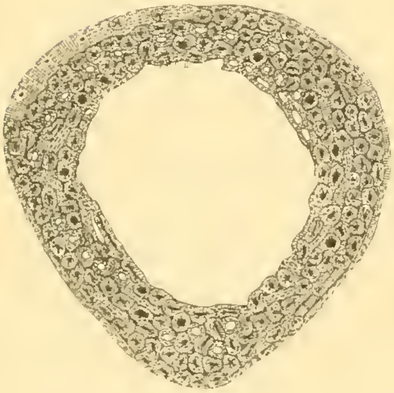

FIG. 362
Right femur of a Japanese male. No. 245, C. M. C.

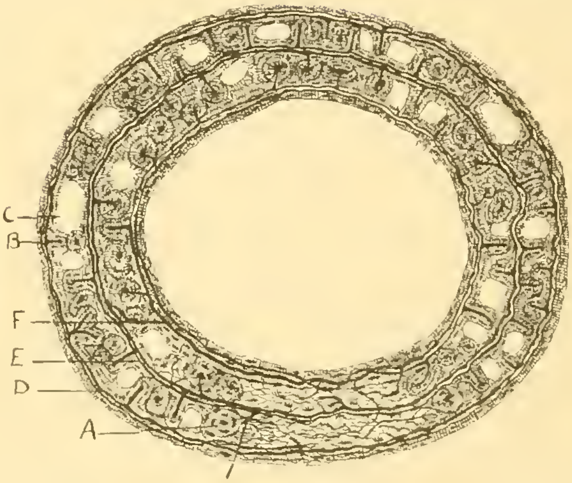

FIG. 363
Femur of Egyptian child of XII Dynasty. No. 256479(de) U. S. N. M.

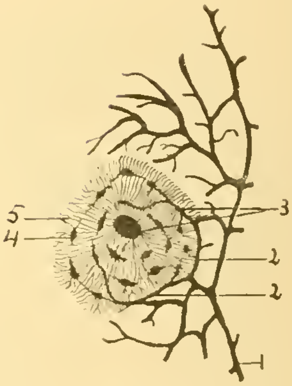

FIG. 363a
Vascular origin of an Haversian system as seen in Fig. 363 at A

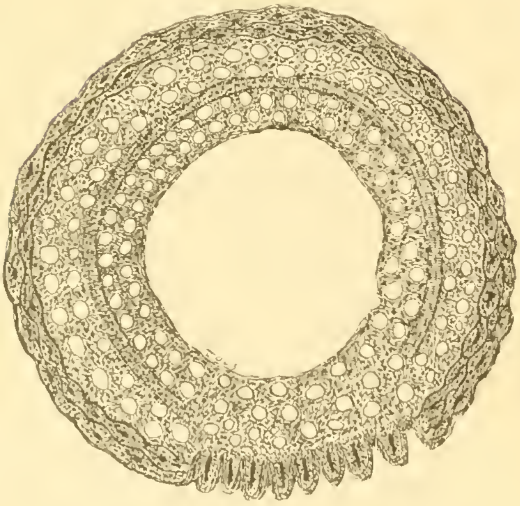

FIG. 364
Femur of Egyptian child of XII Dynasty. No. 256479 (d) U. S. N. M.

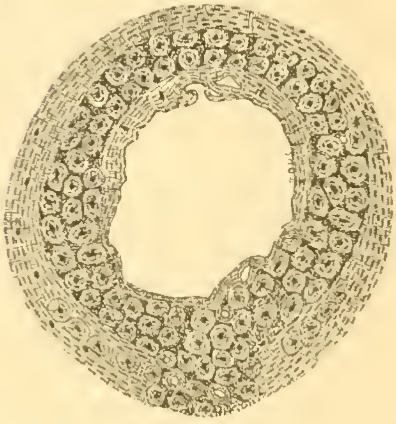

FIG. 365
Right femur of Egyptian child of XII Dynasty. No. 256479(a3), U. S. N. M.

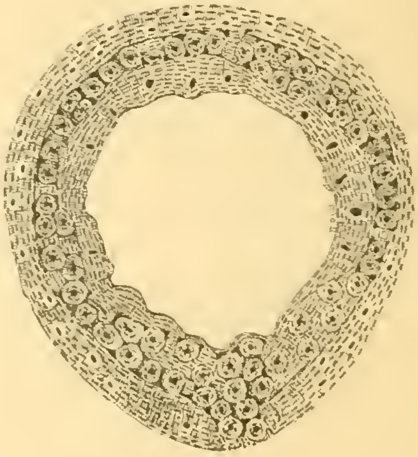

FIG. 366
Femur of Egyptian youth of XII Dynasty. No. 258675(a) U. S. N. M.

MAN (PERUVIAN INDIAN AND EGYPTIAN)

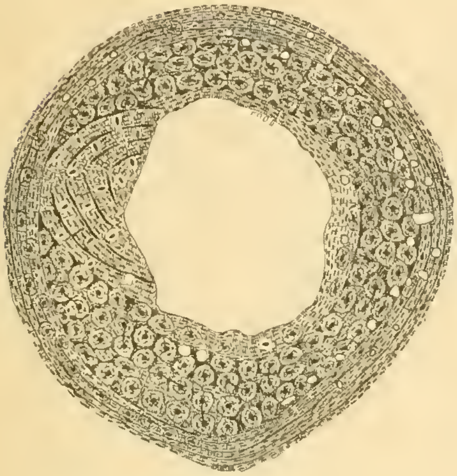

FIG. 367
Right femur of Egyptian adult of XII Dynasty.
No. 256481(d), U. S. N. M.

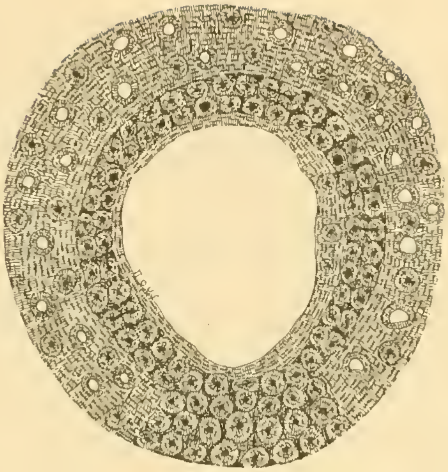

FIG. 368
Left femur of Egyptian adult of XII Dynasty.
No. 256481(a), U. S. N. M.

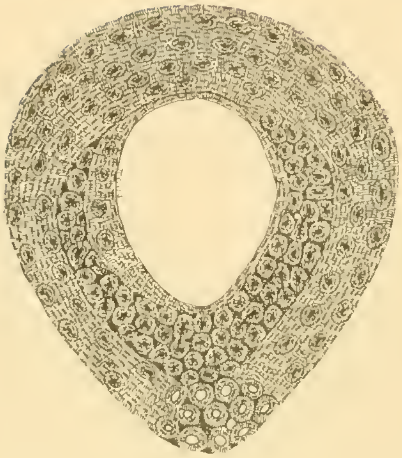

FIG. 369
Right femur of Egyptian adult, XII Dynasty.
No. 258675(e), U. S. N. M.

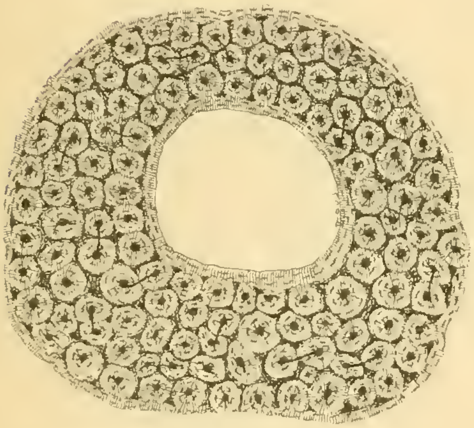

FIG. 370
Femur of Egyptian adult of XII Dynasty.
No. 256478(23), U. S. N. M.

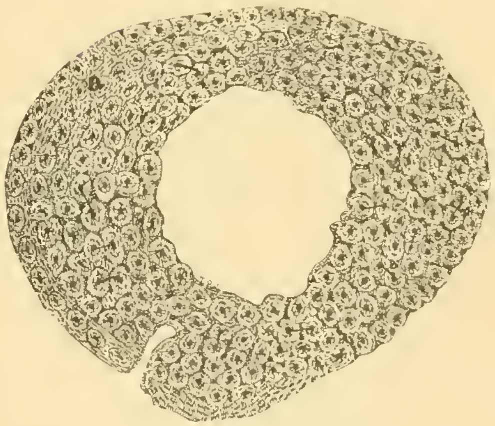

FIG. 371
Right femur of Egyptian adult of XII Dynasty.
No. 256478(x) U. S. N. M.

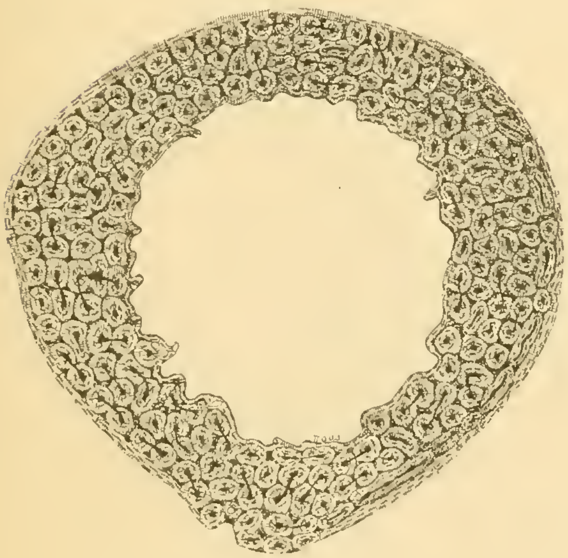

FIG. 372
Femur of a male white. No. 1629, U. S. N. M.

FIG. 373
Right femur of a female white. No. 147, M. D. N. U.

MAN (EGYPTIAN AND WHITE)

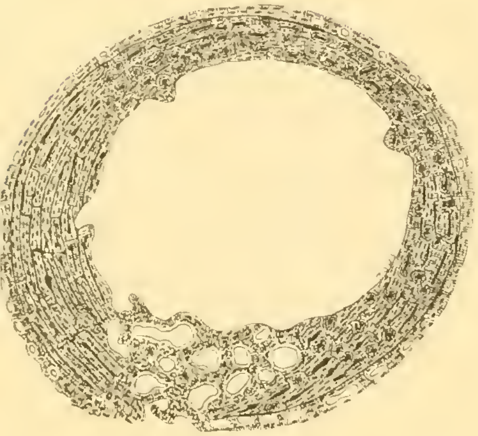

FIG. 374
Right femur of a white child less than one year old.
No. 249588, U. S. N. M.

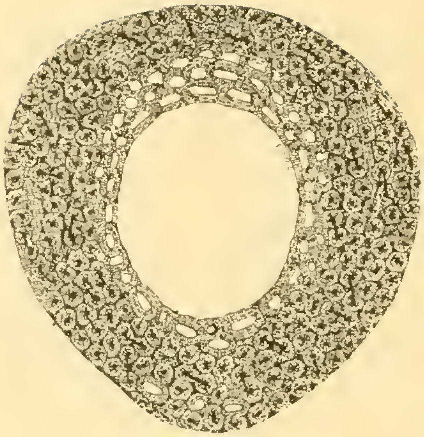

FIG. 375
Femur of a male white. No. 53, C. M. C.

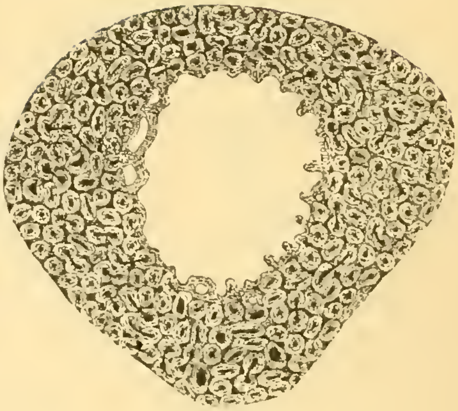

FIG. 376
Right femur of a male white. No. 171, M. D. N. U.

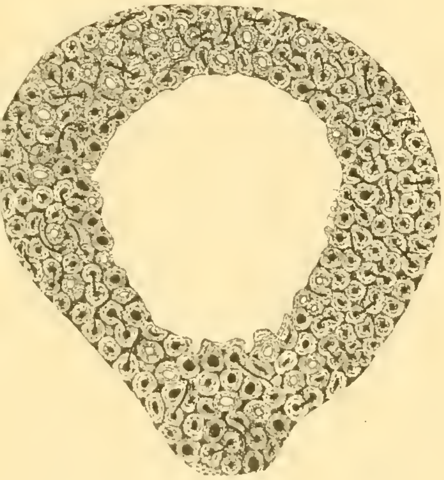

FIG. 377
Left femur of a male white. No. 95, C. M. C.

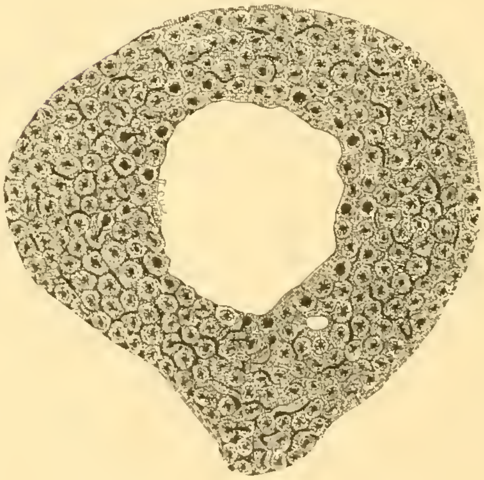

FIG. 378
Left femur of a male white. No. 96, C. M. C.

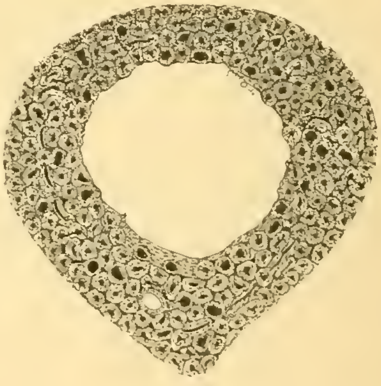

FIG. 379
Left femur of a male white, age 45. No. 168,
M. D. N. U.

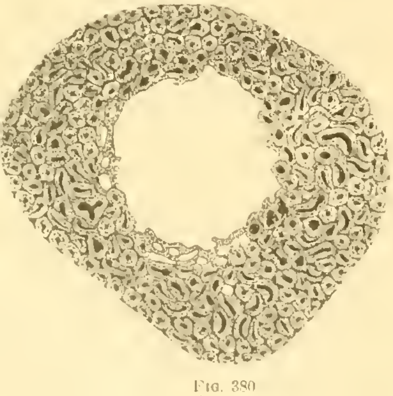

FIG. 380
Left femur of a male white, age 50. No. 10,
M. D. N. U.

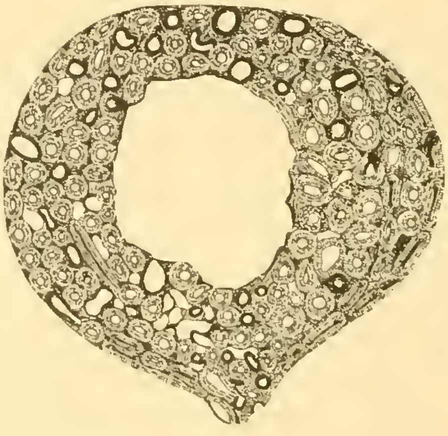

FIG. 381
Femur of a female white, age 52. No. 227876,
U. S. N. M.

FIG. 382
Femur of a female white, age 60, No. 227880,
U. S. N. M.

MAN (WHITE RACE)

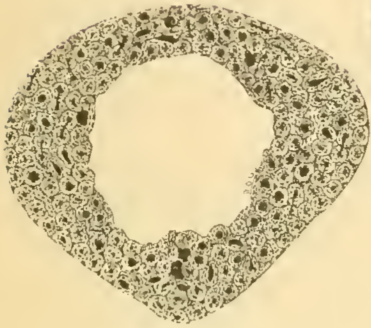

FIG. 384
Left femur of a male white.
No. 162, M. D. N. U.

FIG. 385
Right femur of a male white.
No. 244, C. M. C.

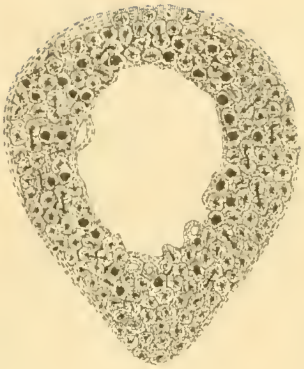

FIG. 386
Right femur of East Indian male.
No. 223, C. M. C.

FIG. 387
Left femur of No. 223 C. M. C.
amputated

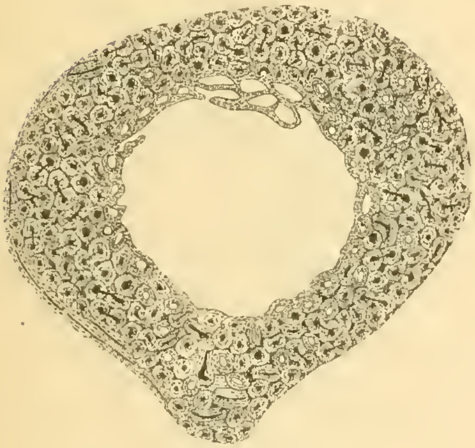

FIG. 388
Right femur of a male white. No. 228479,
U. S. N. M.

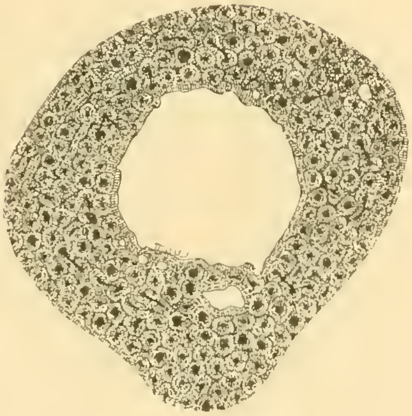

FIG. 389
Right femur of a male white, age 45. No. 154,
M. D. N. U.

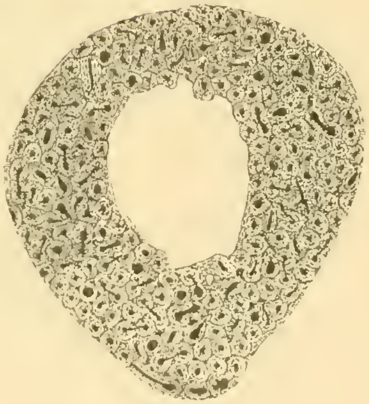

FIG. 390
Left femur of a male white. No. 146,
M. D. N. U.

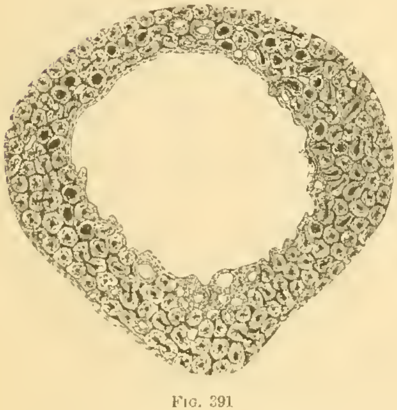

FIG. 391
Left femur of a male white. No. 159,
M. D. N. U.

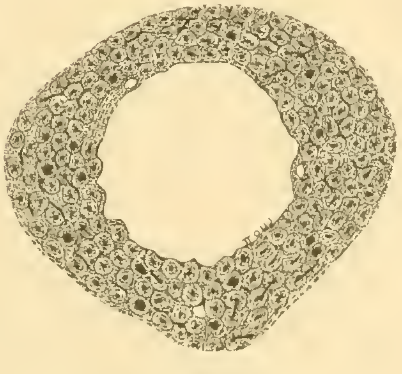

FIG. 392
Right femur of a male white. No. 167,
M. D. N. U.

FIG. 393
Right femur of a male white. No. 172,
M. D. N. U.

MAN (WHITE RACE)

FIG. 394
Right femur of a male white. No. 242,
C. M. C.

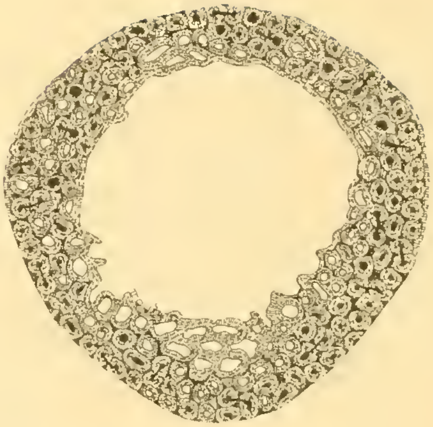

FIG. 395
Right femur of a male white, age 60. No. 145
M. D. N. U.

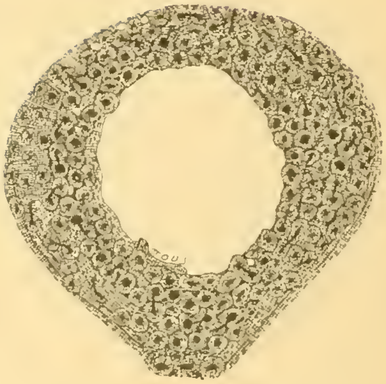

FIG. 396
Left femur of a female white. No. 174,
M. D. N. U.

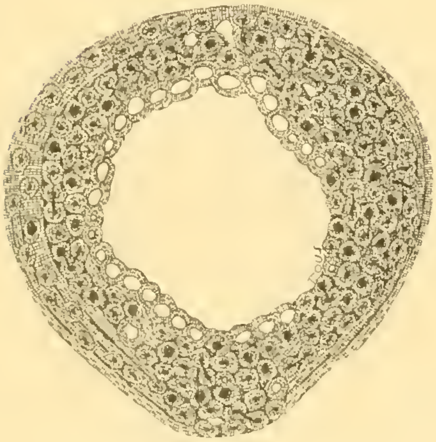

FIG. 397
Right femur of a male white. No. 157,
M. D. N. U.

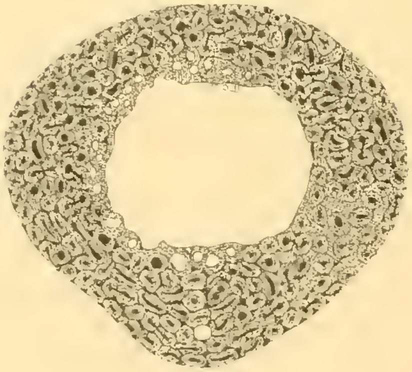

FIG. 398
Left femur of a male white. No. 161,
M. D. N. U.

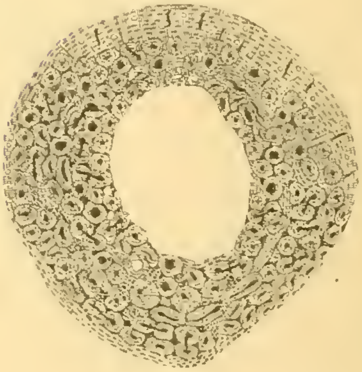

FIG. 399
Right femur of a male white. No. 153,
M. D. N. U.

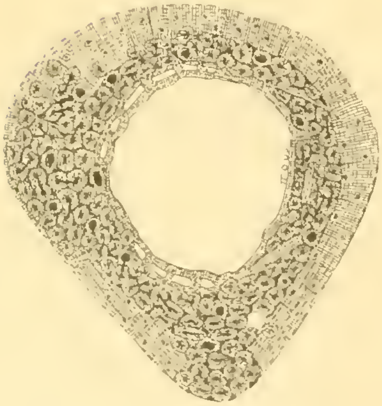

FIG. 400
Right femur of a male white. No. 243,
C. M. C.

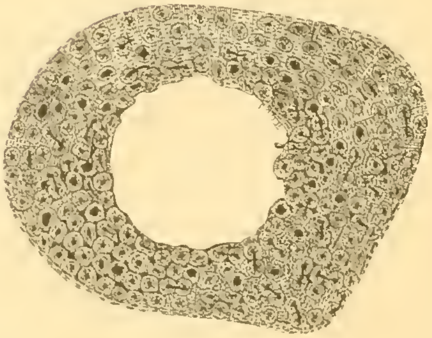

FIG. 401
Left femur of a male white. No. 148,
M. D. N. U.

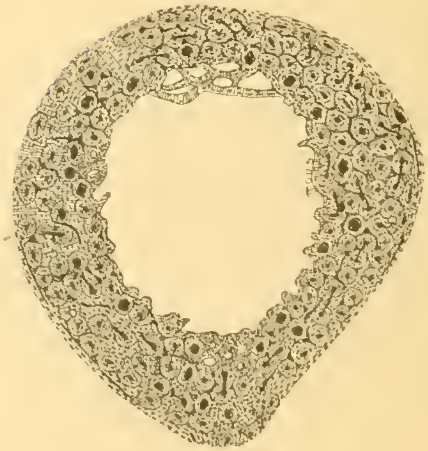

FIG. 402
Left femur of a male white. No. 230,
C. M. C.

MAN (WHITE RACE)

Fig. 403
Left femur of a male white. No. 97, C. M. C.

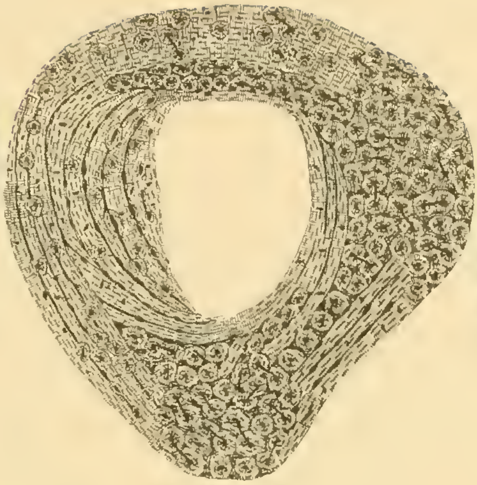

Fig. 404
Left femur of a male white. No. 99, C. M. C.

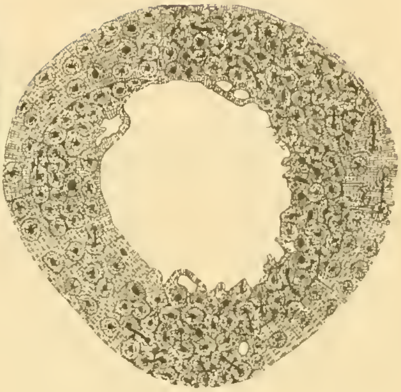

Fig. 405
Right femur of a male white. No. 160, M. D. N. U.

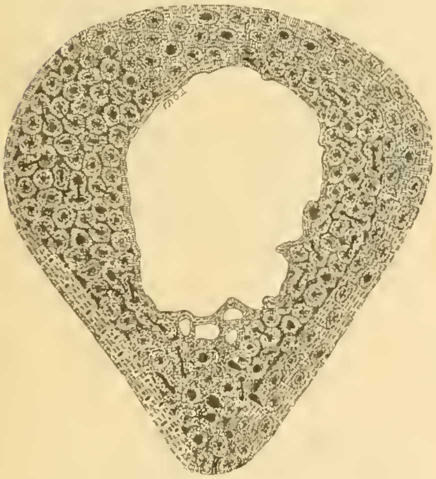

Fig. 406
Left femur of a male white. No. 163, M. D. N. U.

Fig. 407
Right femur of a male white. No. 156, M. D. N. U.

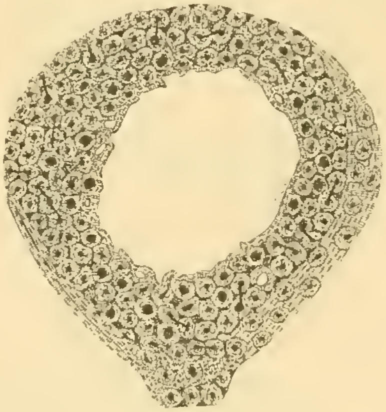

Fig. 408
Left femur of a male white. No. 169, M. D. N. U.

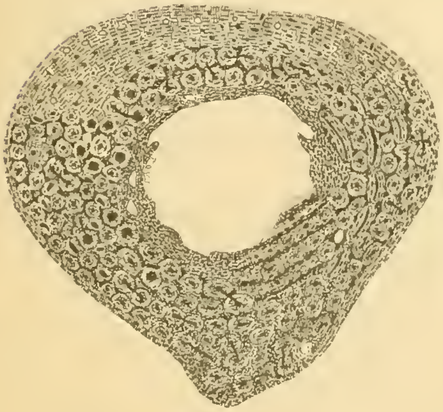

Fig. 409
Right femur of a male white, age 35. No. 151, M. D. N. U.

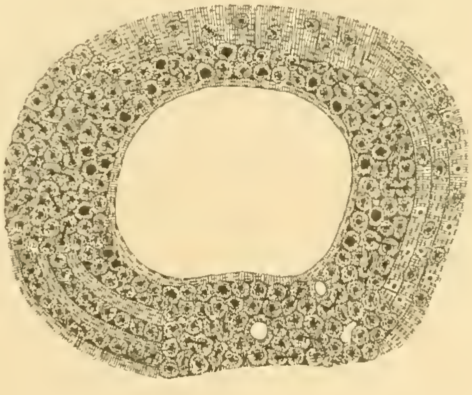

Fig. 410
Left femur of a male white. No. 100, C. M. C.

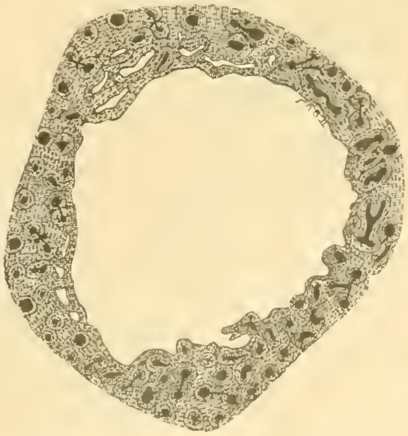

Fig. 411
Right femur of a female white. No. 150 M. D. N. U.

MAN (WHITE RACE)

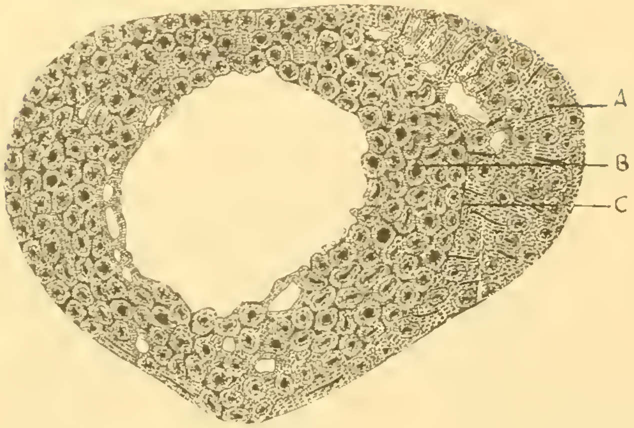

FIG. 412
Left femur of a male white. New bone development seen on the right.
No. 152, M. D. N. U.

FIG. 413
Left femur, 33 mm. below the section 412. The femur has become double. No. 152, M. D. N. U.

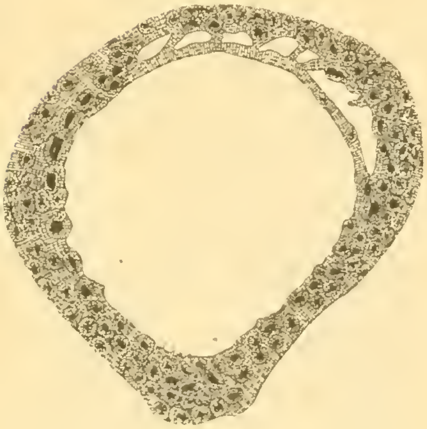

FIG. 414
eft femur of a female white. No. 164, M. D. N. U.

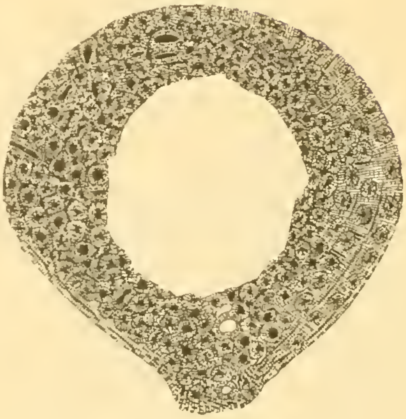

FIG. 415
Left femur of a female white. No. 166, M. D. N. U.

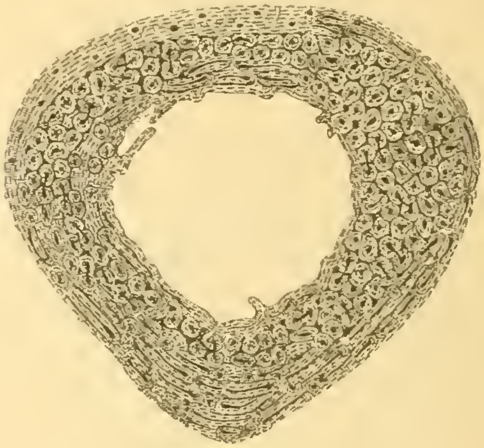

FIG. 416
Right femur of a male white, age 22 (suicide). No. 175 C. M. C.

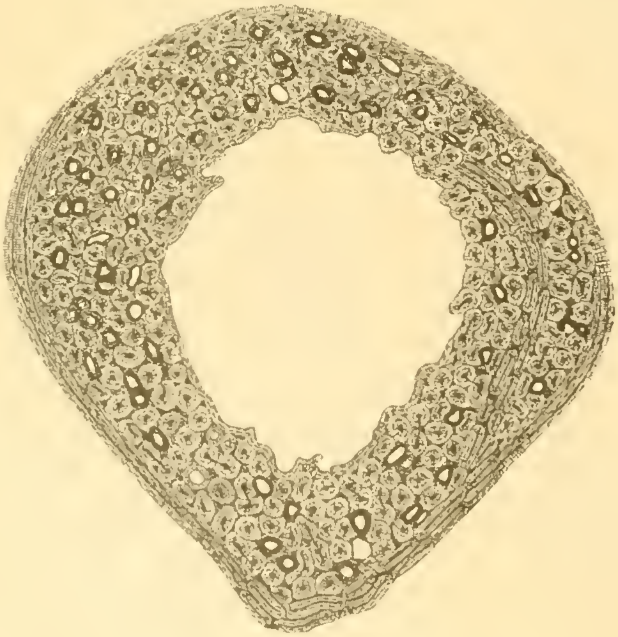

FIG. 417
Left femur of a male white. No. 98, C. M. C.

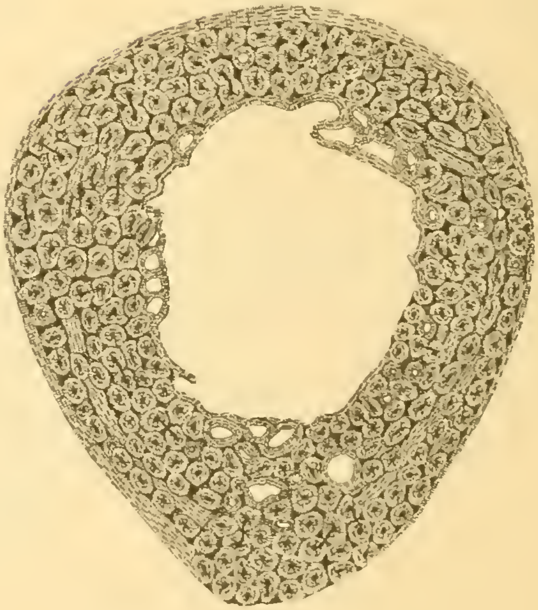

FIG. 418
Left femur of a male white. No. 91, C. M. C.

MAN (WHITE RACE)

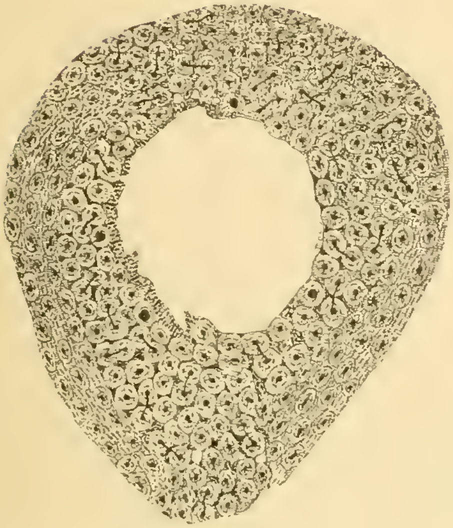

Fig. 419
Femur of an Australian. No. 227420, U. S. N. M.

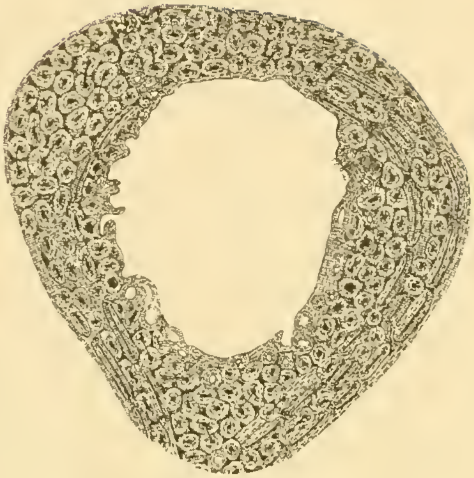

Fig. 420
Left femur of a male white. No. 94, C. M. C.

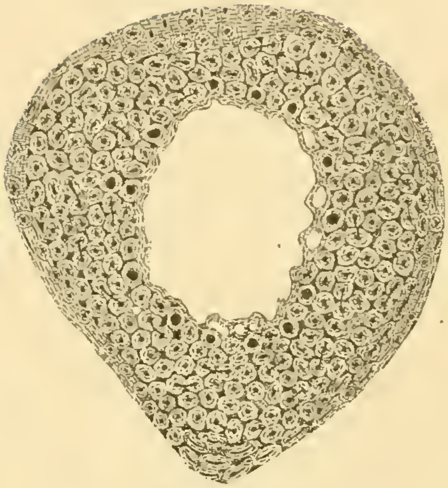

Fig. 421
Right femur of a male white. No. 142, M. D. N. U.

MAN (AUSTRALIAN; WHITE RACE)

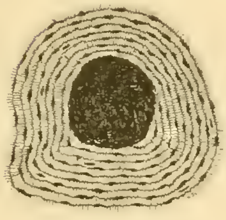

Fig. 423
A single Haversian system enlarged showing lamellæ

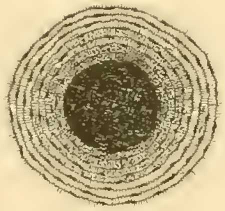

Fig. 424
Haversian system showing early stage of senility

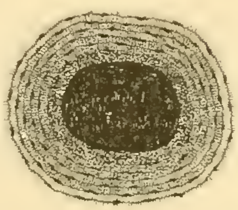

Fig. 425
Haversian system showing later stage of senility

Fig. 426
Haversian system showing latest stage of senility

DIAGRAMS SHOWING STAGES OF SENILITY

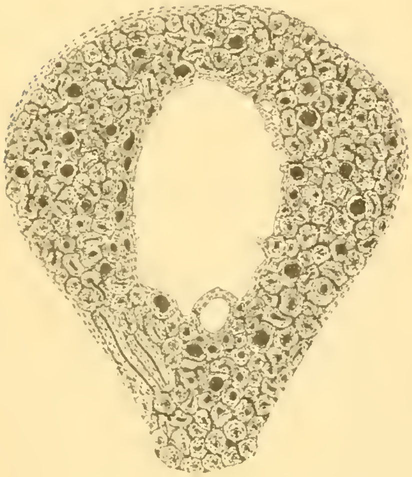

FIG. 428
Right femur of male white (convict). No. 2, M. D. Neb. U.

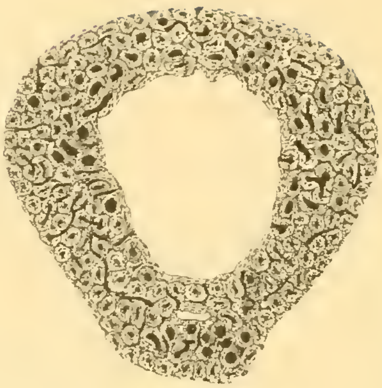

FIG. 429
Right femur of a male white (convict). No. 3, M. D. Neb. U.

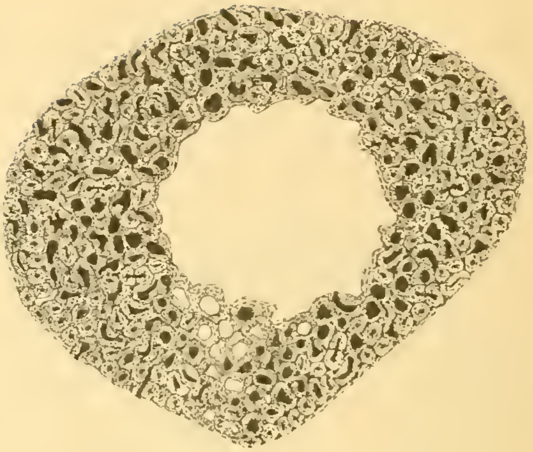

FIG. 436
Right femur of a male white. No. 274, C. M. C.

FIG. 437
Right femur of a male white. No. 275, C. M. C.

FIG. 439
Right femur of a male white. No. 277, C. M. C.

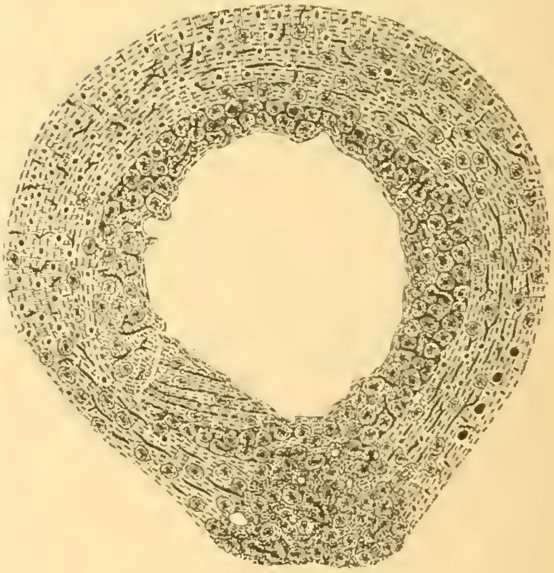

FIG. 445
Right femur of a white male. No. 284, C. M. C.

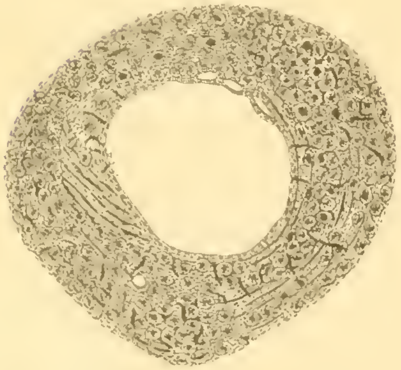

FIG. 451
Right femur of a male white. No. 289, C. M. C.

FIG. 452
Left femur of a male white. No. 296, C. M. C.

FIG. 453
Left femur of a male white, age 40 (case of idiopathic epilepsy).
No. 1, N. S. H.

MAN (WHITE RACE)