T. M. Stone Esqr.
with the Author's kind regards
22

ON THE

INTIMATE STRUCTURE OF BONE,

AS COMPOSING

THE SKELETON IN THE FOUR GREAT CLASSES OF ANIMALS,

MAMMALS, BIRDS, REPTILES, AND FISHES.

BY JOHN QUEKETT,

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[From the *Transactions of the Microscopical Society of London*, p. 46, part 2, vol. ii.]

On the Intimate Structure of Bone, as composing the Skeleton [illegible] the four great Classes of Animals, viz., Mammals, Birds, Re[illegible] tiles, and Fishes, with some Remarks on the great Value of t[illegible] Knowledge of such Structure in determining the Affinities [illegible] Minute Fragments of Organic Remains. By JOHN QUEKET[illegible] Assistant Conservator of the Museum of the Royal College [illegible] Surgeons of England.

(Read March 18, 1846).

PROFESSOR Owen, when President of this Society, in his first annu[illegible] address, delivered on the 15th of February, 1841, after alluding to t[illegible] great importance derived from the use of the microscope, in dete[illegible] mining the structure and affinities of minute fragments of fossil woo[illegible] goes on to say, "And if the microscope be thus essential to the fi[illegible] and true interpretation of the vegetable remains of a former world, [illegible] is not less indispensable to the investigator of the fossilized parts [illegible] animals. It has sometimes happened that a few scattered teeth ha[illegible] been the only indications of animal life throughout an extensi[illegible] stratum; and when these teeth happened not to be characterized b[illegible] any well-marked peculiarity of external form, there remained no oth[illegible] test by which their nature could be ascertained, than that of the mi[illegible] croscopic examination of their intimate tissue. By the microsco[illegible] alone could the existence of keuper-reptiles in the lower sandston[illegible] of the new red system, in Warwickshire, have been placed beyond[illegible] doubt.

"By the microscope, the supposed monarch of the Saurian tribes[illegible] the so-called *Basilosaurus*—has been deposed, and removed from t[illegible] head of the reptilian to the bottom of the mammiferous class. T[illegible] microscope has degraded the *Saurocephalus* from the class of reptil[illegible] to that of fishes; it has settled the doubts entertained by some of t[illegible] highest authorities in palæontology as to the true affinities of the g[illegible] gantic Megatherium, and by demonstrating the identity of its dent[illegible] structure with that of the Sloth, has yielded us an unerring indicati[illegible] of the true nature of its food."

Now if this be true of the structure of the teeth, which the brillia[illegible] results that Mr. Owen has obtained, by carrying out this mode of i[illegible] vestigation, have abundantly proved, why—I may ask—should not minute fragments of the other parts of the skeletons of extinct animals afford us, by the same method of manipulation, some indication of the particular class to which such fragments belong?

Having paid considerable attention to the minute structure of bones for several years past, and finding that there were certain characters peculiar to each great class which could be easily recognised, I have allowed no opportunity to pass without trying to determine, by microscopic examination, how far I could proceed with my investigations with certainty; and, to show the value of such investigations, I may mention the first result.

It happens, by a singular coincidence, that two years ago, this very day, my friend Dr. Falconer, the distinguished palæontologist of the Himalaya Mountains, having in his possession certain small bones of unusual form, from which circumstance he was at a loss to determine to what animal they belonged, I, at his request, made a microscopic examination of some sections of them, and comparing their intimate structure with that of other bones in my possession, was enabled to pronounce them reptilian, and to belong probably to an animal of the turtle order; and they subsequently proved to be the toe-bones of his *Colossochelys Atlas*, or gigantic Tortoise, nearly 20 feet in length. Encouraged by this success, I have, since then, extended my researches, and have found that, in each of the four great classes of animals, the bone-cells present certain peculiarities in their form, which, when once an observer is conversant with, he would be enabled to satisfy himself as to the true affinities of doubtful specimens of organic remains.

The microscope has, in skilful hands, already achieved wonders, but much remains still to be done, in this, as yet, uncultivated field; I have, therefore, ventured to bring the subject before the notice of the Society this evening, deeming it worthy of the attention of every individual who may be engaged in the pursuit of palæontology, geology, anatomy, or any of the collateral sciences: for when satisfactory evidence of the affinities of fossil bones cannot be obtained from external features alone, there are yet present in the minute structure certain characters which may materially assist the observer in the determination, if not at once fix their true position in the scale of animated beings. I need not dwell, at this time, on the conflicting statements which have so frequently been published, concerning the true nature of certain fossil bones, most, if not all, of which statements would probably never have appeared, had the intimate structure of the bones in dispute been well understood, and a minute fragment would have sufficed for this purpose. Before coming, however, to the immediate object of this paper, it will be necessary that I point out to you briefly the different parts of which a bone may be said to consist; and, as there are many members of our small community who do not practise the healing art, and have not, therefore, made the intimate structure of the animal body their particular study, I trust that, by a slight description, I shall be enabled to render the subject of which I am about to treat perfectly intelligible to all.

Every bone may be said to consist of two parts, a hard and a soft part: the hard is composed of carbonate and phosphate of lime, and of carbonate and phosphate of magnesia, deposited in a cartilaginous or other matrix; whilst the soft consists of that matrix, and of the periosteum which invests the outer surface of the bone, and of the medullary membrane which lines its interior or medullary cavity, and is continued into the minutest pores. If we take for examination a long bone of one of the extremities, say a femur, of a human subject, or of any mammalian animal, we shall find that it consists of a body or shaft and two extremities: if a vertical section of such a bone be made, we shall also find that the middle of the shaft contains a central cavity, termed the medullary cavity, which extends as a canal throughout the whole of it, or else is entirely or partially filled up with a cellular bony structure, which cells are termed cancelli, and the structure a cancellated structure. On a more careful examination of the bony substance or shaft, we shall find it to be slightly porous, or rather occupied, both on its external and internal surfaces, by a series of very minute canals, which, from their having been first described by our countryman Clopton Havers, are termed to this day the Haversian canals, and serve for the transmission of blood-vessels into the interior of the bone. Further than this we cannot proceed in our investigation without optical assistance; but if now a thin transverse section of the same bone be made, and be examined by the microscope with a power of 200 linear, we shall see the Haversian canals very plainly, and around them a series of concentric bony laminæ, from three to ten or twelve in number. If the section should consist of the entire circle of the shaft, we shall notice, besides the concentric laminæ around the Haversian canals, two other series of laminæ, the one around the outer margin of the section, the other around the inner or medullary cavity. Between the laminæ is situated a concentric arrangement of spider-like looking bodies, which have, by different authors, received the names of osseous corpuscles, calcigerous cells, lacunæ or bone-cells, according as to whether they were ascertained to be solid or hollow: these bone-cells, for this is the term which I shall apply to them, have little tubes or canals radiating from them, which are termed canaliculi by some authors, and tubes and pores by others: those bone-cells which are nearest the Haversian canals have the canaliculi of that side radiating towards and opening into the Haversian canals, whilst the canaliculi of the opposite side communicate or anastomose with those of the layer of canaliculi more external to them, and those in the outer row have most of their canaliculi given off from that side of the bone-cell which is nearest its own Haversian canal; hence arises the transparent white line which often may be noticed as surrounding each concentric system of laminæ and bone-cells: in some cases, however, part of the bone-cells of the external row anastomose with another series of bone-cells, which are situated between the concentric laminæ. The average length of the lacunæ or bone-cells in the human subject is the $\frac{1}{2000}$th of an inch: they are of an oval figure, and somewhat flattened on their opposite surfaces, and are usually about one-third greater in thickness than they are in breadth; hence, as will be presently shown, it will become necessary to know in what direction a specimen is cut, in order to judge of their comparative size. The older anatomists supposed them, from their opacity, to be little solid masses of bone; but if the section be treated with spirits of turpentine, coloured with alkanet root, or if it have been soaked in very liquid Canada balsam for any great length of time, it can then be unequivocally demonstrated that both these substances will gain entrance into the bone-cells through the canaliculi. The bone-cells, when viewed by transmitted light, for the most part appear perfectly opaque, and they will appear the more opaque the nearer the section of them approaches to a transverse one; for when the cells are cut through their short diameter, they are often of such a depth that the rays of light interfere with each other in their passage through them, and darkness results, whereas if the section be made in the long diameter of the cells, they will appear transparent. When viewed as an opaque object, with a dark ground at the back and condensed light, the bone-cells and canaliculi will appear quite white, and the intercellular substance, which was transparent when viewed by transmitted light, is now perfectly dark. It happens in most, if not all, fossil bones, that the bone-cells, however much they may have been soaked in turpentine, or even boiled in Canada balsam, are nevertheless still opaque: this arises from the earthy matter, in which they have been so long imbedded, having gained entrance into the bone-cells through the canaliculi: this even happens in the bones of mummies, where, as Mr. Smee has shown, the bone-cells are frequently full of the bituminous and other matters with which the bodies were prepared. The structure between the bone-cells, which, with perfect consistency, may be called the intercellular substance, by an ordinary magnifying power, appears to be homogeneous; but under higher powers, as Mr. Tomes has described, it will be found to be minutely granular, the granules varying in size from $\frac{1}{6000}$ to $\frac{1}{14000}$ of an inch: they can be readily seen in a bone which has long been subjected to the action of boiling water or steam, the granules being, in fact, the true ossific matter of the bone. If a vertical section be prepared, in a similar manner to the horizontal one just described, and be examined with the same power, we shall find that the Haversian canals, for the most part, take a longitudinal direction, and that the bone-cells also assume a linear arrangement. Some few of the Haversian canals run at right angles to the section, and these communicate with the openings previously noticed, both on the exterior and interior of the shaft. Thus much may be said to compose the hard part of bone; we must now turn our attention to the soft part. This, as has been before stated, consists of the periosteum, which invests the outer, and of the medullary membrane, which invests the inner surface, lines the Haversian canals, and is continued from them, through the canaliculi, into the interior of the bone-cells, and of the cartilaginous or other matrix which forms the investment of the minute ossific granules. The earthy matter of the bone may be readily shown by macerating the section for a short time in a dilute solution of caustic potash; but the granules, according to Mr. Tomes, may be best obtained by subjecting bone to high-pressure steam, or to a red heat, till the animal matter is removed, the mass may then be reduced to powder, and a little dilute acid added, which will destroy all the broken granules before the entire ones are at all affected.

The animal matter may be procured by using dilute muriatic acid instead of caustic potash, when the earthy matter will be removed, and the section will exhibit nearly the same form as when the earthy constituent was present; and when viewed microscopically, it will be noticed that all the parts characterizing the section, previous to its maceration in the acid, will be still visible, but not so distinct as when both constituents were in combination. When, however, the animal matter is removed, the bone will not exhibit the cells and the canaliculi, but will be opaque and very brittle, and exhibit nothing but the Haversian canals and a granular structure.

If we consider what has been already mentioned as entering into the composition of a bone, viz., the medullary cavity, the Haversian canals, the canaliculi, and the bone-cells, we shall find that every part thus described has been more or less hollow; where, then, is the true bony substance? This is no other than the small granules of ossific matter which are situated between the canaliculi of the bone-cells, each granule having an investment of soft animal matter, by which the whole mass of granules is kept in firm apposition.

The parts, then, which a transverse or a longitudinal section of a long bone of a mammalian animal will exhibit, will be the Haversian canals, the concentric bony laminæ, the bone-cells and their canaliculi, although all these parts, except the bony laminæ, may be seen in all mammalian bones, whether long or otherwise; they are, nevertheless, so differently arranged in the flat bones, such as those of the skull, and in the irregular bones, such as the vertebræ, as to require a short description at this stage of our enquiry.

The bones of the cranium are, in all cases, composed of two thin layers, of compact texture, which enclose another layer of variable thickness, which is cellular or cancellated. The two outer layers are called tables, the one being the outer, the other the inner table, and the middle or cancellated layer is termed the diploë: in this last the principal blood-vessels ramify. The outer table of the skull is less dense than the inner; the latter, from its brittleness, is termed by anatomists the vitreous table. When a vertical section of a bone of the skull is made, so as to include the three layers above mentioned, bone-cells may be seen in all, but each of the three layers will differ in structure: the middle or cancellated structure will be found to resemble the cancellated structure in the long bones, viz., thin plates of bone, with one layer of bone-cells without Haversian canals; the outer layer will exhibit Haversian canals of large size, with bone-cells of large size and a slightly laminated arrangement; but the inner or vitreous layer will be found to resemble the densest bone, as the outer part of the shaft of a long bone for instance, and will exhibit both smaller Haversian canals and more numerous bone-cells of ordinary shape around them. The same thing will hold good of the ribs, scapula, and os innominatum, and of the irregular bones, such as the vertebræ, the small bones of the wrist, and ankle-joints, they being, in fact, nothing more than a cancellated or spongy tissue, enclosed by a compact layer of denser bone. It will be noticed that the bone-cells in all these bones are less regular in their size than in the long bones, and hence there will be required more caution before pronouncing an opinion upon them ; but luckily for the microscopist, the denser parts of fossil bones are the last to be destroyed, and every fragment he is likely to meet with will almost be certain to contain a spot where the cells present their normal characters.

In birds the majority of the bones are hollow, and the solid walls thin, but very compact in structure: the medullary cavity of the shaft of the long bones, which in Mammalia is either filled with marrow or with a cancellated tissue, is, in birds, often smooth, and is lined by a membrane, which is a continuation of that membrane which forms the air-cells of the lungs, and which gains admittance into the interior of the bones by a large opening, termed the pneumatic foramen, which is situated in the proximal extremity of each long bone: the extremities of the bones are not so thickly cancellated as those of the Mammalia, but the cancelli are supplied by small tubes of bone, which shoot across from one side of the wall to that of the other, like so many little pillars; everything being wisely arranged with an evident view to as much lightness as is compatible with strength. In those birds whose wings are not destined for flight, the pneumatic foramen still exists in some of the long bones, but is absent in others. In all these birds the solid walls of the bones are much thicker, and the medullary cavity is more cancellated : to such an extent does this thickening of the walls take place, that in the Penguin nearly every bone in the body is solid, and in the Apteryx not a bone is permeated by air. The bony matter, although sparingly used, is of greater specific gravity in birds than in any of the other classes of animals, in consequence of there being a larger amount of earthy matter in it; and in some bones, where the foramen exists, it almost rivals, in density and in whiteness, the purest ivory; whilst in others, where the foramen is absent, the bony matter is of a yellow colour, from the oily matter contained in the medullary cavity.

A transverse section of the long bone of a bird, when contrasted with that of a mammal, will exhibit the following peculiarities. The Haversian canals are much more abundant and much smaller, and they often run in a direction at right angles to that of the shaft, by which means the concentric laminated arrangement is in some cases lost; the direction of the canals often follows the curve of the bone; the bone-cells also are much smaller and much more numerous, but the number of canaliculi given off from each of the cells is much less than from those of mammals: the average length of a bone-cell of the Ostrich is $\frac{1}{2000}$th of an inch, the breadth $\frac{1}{6000}$th.

In the thin crania of the small birds the Haversian canals are absent, and the bone-cells are very numerous, but the canaliculi proceeding from them are very few in number, and the granular matter is very well seen; but when the crania are thicker, there are two plates of bone, each containing bone-cells, with a system of Haversian canals between, forming a diploë or cancellated structure. In some of the small birds, I have noticed that small tubes of bone, each provided with the characteristic bone-cells, extend inwards towards the dura mater, but the precise office which these tubes perform I cannot at present determine. A striking contrast between the transverse section of the long bone of a bird and that of a mammal will be exhibited when they are viewed with a power of about 50 linear; that of the mammal will show the Haversian canals with the concentric laminæ around them, whilst that of the bird will appear to be composed of large curved laminæ, which follow the direction of the outer margin of the bone which is due to the Haversian canals, running for the most part transversely: the concentric arrangement around the Haversian canals, like that of the Mammalia, is only to be seen when the canals run at right angles to the section.

In the Reptilia, the bones may be either hollow, cancellated, or solid, and, generally speaking, whichever form prevails, the bone may be said to be very compact and heavy, but the specific gravity not so great as that of birds or mammals. The short bones of most of the Chelonian reptiles are solid, but the long bones of the extremities are either hollow or cancellated: the ribs of the serpent tribe are hollow, the medullary cavity performing the office of an Haversian canal; the bone-cells are accordingly arranged in concentric circles around the canal. The vertebræ of these animals are solid, and the bone, like that of some of the birds, is remarkable for its density and its whiteness. When a transverse section is taken from one of the long bones, and contrasted with that of a mammal or bird, we shall notice at once the differences which the reptile presents; there are very few, if any, Haversian canals, and these of large size; and at one view, in the same section, we shall find the canals and the bone-cells arranged both vertically and longitudinally: the bone-cells are most remarkable for the great size to which they attain; in the turtle they are $\frac{1}{375}$th of an inch in length: the canaliculi, too, are extremely numerous, and are of a size proportionate to that of the bone-cell. In most bones, especially the flat bones, or thin plates taken from any of the flat bones, the cells are arranged most frequently in parallel rows, without any Haversian canals: the canaliculi are of very large size, and are remarkable for their numerous bifurcations;

their ramifications are so thickly grouped together, that in very thin and uncut fragments of bone, they form so close a net-work over the bone-cells as almost to obscure them by their opacity. The surface of such bones will present a minutely-dotted appearance, which is caused by the numerous canaliculi which open upon it. If the section be very thin, it may be seen that the dots are really perforations of the bone. The cells attain their greatest length in the compact bones, such as those of the extremities, but in the flat bones they are, generally speaking, much shorter and broader; and if the bone be a recent one the contents of the cells may be distinctly seen. It will often happen that in a transverse section there may be noticed cells which appear at first sight like those of the Mammalia, they being of a rounded figure, and having their canaliculi arranged like those of the latter class. When they are more carefully examined, it will be found that they are nothing more than long cells cut across their short diameters.

In fishes we have a greater variation in the minute structure of the skeleton than in either of the three classes already noticed; and there are certain remarkable peculiarities in the bones of fishes, which are so characteristic, that a bone of one of these creatures can never be confounded with that of any animal of a higher class, when once the true structure has been satisfactorily understood. We lose now those characters which were evident in mammals and birds, and often, to a certain degree, in reptiles, viz., the concentric laminated arrangement of the bony matter, with a corresponding concentric arrangement of bone-cells around the Haversian canals; and we shall find that the true Haversian canals may be even absent in some fishes, their place being supplied by numerous layers of bone-cells. All the varieties of structure in the bones of fishes which I have yet made out may be referred to one of the following heads: by far the greater number of bones exhibit nothing more than a series of ramifying tubes, like those of teeth; others exhibit Haversian canals, with numerous fine tubes or canaliculi, like ivory tubes, connected with them; others consist of Haversian canals with fine tubes and bone-cells; whilst a rare form, found only as yet in the sword of the Sword-fish (*Istiophorus*), exhibits Haversian canals and a concentric laminated arrangement of the bone, but no bone-cells. The Haversian canals, when they are present, are of large size and very numerous, and then the bone-cells are, generally speaking, either absent or but few in number, their place being occupied by tubes or canaliculi, which are often of large size. The bone-cells are remarkable for their quadrate figure, and for the canaliculi which are derived from them being few in number: they are readily seen to anastomose freely with the canaliculi given off from neighbouring cells; and if the specimen under examination be a thin layer of bone, such as the scale of an osseous fish, from the cells lying nearly all in one plane, the anastomosis of the canaliculi will be rendered beautifully distinct. In the majority of the bones of fishes the cells are not present, their place being occupied (as has been before stated) by enlarged canaliculi or tubes; but in all the hard bones, the enlarged tubes and the cells together, or else the cells alone, will be found. In the hard scales of many of the osseous fishes, such as the *Lepidosteus* and *Callicthys*, and in the spines of the *Siluridæ*, the bone-cells are very beautifully seen: in the true bony scales composing the exo-skeleton of the cartilaginous fishes the bone-cells are to be seen in great numbers. In the spines of some of the Ray family I have noticed a peculiar structure; the Haversian canals are large and very numerous, and communicating with each canal are an infinite number of wavy tubes, which are connected with the canals in the same manner as the dentinal tubes of the teeth are connected with the pulp cavity; and if such a specimen were placed by the side of a section of the tooth of some of the Shark tribe, the discrimination of one from the other would be no easy matter. In the spine of a Ray the analogy between bone and the ivory of the teeth is made more evident, for in this fish we have tubes, like those of ivory, anastomosing with the canaliculi of bone-cells. In the scales, too, of the Dog-fish, and in a species of Shark, termed the *Squalus galeus* or tope, I have noticed a similar analogy to the dental structure; in the same animals the bone-cells are absent, but, as in the dental structure, their place is supplied by ramifying canaliculi or tubes. As a general rule, I may notice that in scales and other thin plates of fishes' bone the cells are of a quadrate figure, but in the bones composing the internal skeleton they are much more elongated, like those of the Reptilia, but the cell is never so broad or so long, neither are the canaliculi so numerous as those of the latter class. In Plate vii. fig. 4, may be seen some of the cells which approach nearest those of reptiles, but still the eye will detect many differences between them and those in fig. 3.

Having said thus much on the minute structure of the bone composing the skeleton in the four vertebrated classes, let us proceed at once to the application of the facts which have been laid down; and let us, for example, suppose that a fragment of bone of an extinct animal be the subject of investigation. It has been stated, that the bone-cells in Mammalia are tolerably uniform in size, and if we take $\frac{1}{2000}$th of an inch as a standard, the bone-cells of birds will fall below that standard, but the bone-cells of reptiles are very much larger than either of the two preceding, and those of fishes are so entirely different from all three, both in size and shape, that they are not for a moment to be mistaken for one or the other, so that the determination of a minute yet characteristic fragment of fishes' bone is a task easily performed. If the portion of bone should not exhibit bone-cells, but present either one or other of the characters mentioned in a preceding paragraph, the task of discrimimation will be as easy as when the bone-cells exist. We have now the mammal, the bird, and the reptile, to deal with: in consequence of the very great size of the cells and their canaliculi, in the reptile, a portion of bone of one of these animals can readily be distinguished from that of a bird or a mammal: the only difficulty lies between these two last; but notwithstanding that on a cursory glance the bone of a bird appears very like that of a mammal, there are certain points in their minute structure in which they differ, and one of these points is in the difference in size in their bone-cells. I have stated that the average size of the cells in Mammalia is $\frac{1}{2000}$th of an inch, whilst in birds they are much smaller: to determine accurately, therefore, between the two, we must, if the section be a transverse one, also note the comparative sizes of the Haversian canals, and the tortuosity of their course, for the diameter of the canal bears a certain proportion to the size of the bone-cells, and after some little practice the eye will readily detect the difference. The fragments necessary for the purpose of examination are to be selected with some little care, and on the whole a small chip (or two) from the exterior of the shaft of a long bone is sufficient; but as many fossil bones are coated with a layer of earthy deposit on their external surface, it will be requisite to get beneath this deposit, as it very seldom happens that the bone-cells are visible in it, but by a fragment from about the middle of the laminæ of the shaft the characteristic bone-cells can at once be recognised. But in the comparison of the bone of a mammal with that of a bird, I prefer transverse sections, as from the peculiarity in the arrangement of the Haversian canals in the latter class, it is highly important always to bear in mind that the specimens used for comparison should be cut in one and the same direction, for as it has been stated that the bone-cells, on which we are to rely for our determination, are always longest in the direction of the shaft of the bone, it would follow, that if one section were transverse, and the other longitudinal, there might be a vast difference in the measurement of the bone-cells, in consequence of their long diameter being seen in the one case, and their short diameter in the other; and hence the caution of having all the sections made in one direction. In all doubtful cases the better plan is to examine a number of fragments, both transverse and longitudinal, taken from the same bone, and to form an opinion from the shape of bone-cell which most commonly prevails.

If we examine minutely the excellent table of the comparative sizes of the blood-particles in the four great classes of animals, drawn up with much care and attention by Mr. Gulliver, we shall find that, with very few exceptions, the blood-particles of the human subject are much larger than those of birds measured in the short diameter, and that those of reptiles are much larger than either of the two preceding; and I have already mentioned that the bone-cells are the largest in the reptiles, the next largest in the mammal, and the smallest in the bird: now it would indeed be a curious result, if it should ultimately turn out that the bone-cells of an animal are always in proportion to the size of the blood-discs: my investigations at present are not yet in a sufficiently forward state to warrant my coming to such a conclusion, but still there are many cases in which it holds good. It is well known to anatomists, that in proportion to the size of the blood-discs so is the size of the capillaries, and as the capillaries may vary so will the size of the muscular fibres, the nervous fibres, and in fact every tissue and organ of the body, so that when the size of the blood-discs is known, some general idea may be formed of the sizes of the different component parts of the other tissues; and should this mode of generalizing ultimately prove to be applicable to the bone-cells as well, we shall be able not only to determine the class of a fossil fragment, but to predict the size of the blood-particles, and when they are once known the size and proportions of the other soft tissues may at once be inferred.

The laws of Nature are undeviating in the construction of the skeleton of vertebrate animals: the same regularity in structure, the same method of arrangement of the bone-cells, has existed from the time when the surface of our planet was first inhabited by a vertebrate animal up to the present period. The largest bones of the mighty Iguanodon (say of 100 feet in length), of the Ichthyosaurus—the tyrant of the water in former ages, of the gigantic Tortoise of the Himalaya range (some 20 feet in length), present no appreciable difference, in their minute structure, from the pigmy race of lizards that we now tread under our feet. The bones of the gigantic *Dinornis* exhibit no difference in structure from those of its now only existing representative, the *Apteryx*. The bones of the Mastodon and the huge Megatherium, the giants of the land, are no more remarkable for the coarseness of their structure than are those of the smallest of the mammiferous quadrupeds, the mouse, and such has been the prevailing law from the commencement of the earth's existence, and such, no doubt, will continue to the end of time.

MEASUREMENT OF BONE-CELLS IN PARTS OF AN ENGLISH INCH.

TRANSVERSE SECTIONS.

HUMAN . . .	Long diameter,	one of the largest,	$\frac{1}{1440}$.
		one of the smallest,	$\frac{1}{2400}$.
	Short diameter,	one of the largest,	$\frac{1}{4000}$.
		one of the smallest,	$\frac{1}{8000}$.
OSTRICH . .	Long diameter,	one of the largest,	$\frac{1}{1333}$.
		one of the smallest,	$\frac{1}{2250}$.
	Short diameter,	one of the largest,	$\frac{1}{3425}$.
		one of the smallest,	$\frac{1}{9650}$.
TURTLE . . .	Long diameter,	one of the largest,	$\frac{1}{375}$.
		one of the smallest,	$\frac{1}{1150}$.
	Short diameter,	one of the largest,	$\frac{1}{4500}$.
		one of the smallest,	$\frac{1}{3840}$.
CONGER EEL .	Long diameter,	one of the largest,	$\frac{1}{330}$.
		one of the smallest,	$\frac{1}{1133}$.
	Short diameter,	one of the largest,	$\frac{1}{4500}$.
		one of the smallest,	$\frac{1}{8000}$.

Additional Observations on the Intimate Structure of Bone. By JOHN QUEKETT, Assistant Conservator of the Museum of the Royal College of Surgeons of England.

(Read November 11, 1846).

IN a paper which I laid before this Society at the meeting held March 18th, 1846, entitled, "On the Intimate Structure of Bone, as composing the Skeleton in the four great Classes of Animals, viz., Mammals, Birds, Reptiles, and Fishes, with some Remarks on the great Value of the Knowledge of such Structure in determining the Affinities of Minute Fragments of Organic Remains," after describing briefly the various parts of which the shaft of a long bone of the Mammalia is composed, viz., 1st, a central or medullary cavity,—2ndly, a series of small canals (Haversian), around which are arranged concentric laminæ of bony matter,—3rdly, of a concentric arrangement of spider-like looking bodies, which have been variously termed osseous corpuscles, calcigerous cells, lacunæ or bone-cells, each cell having little tubes or canals, termed canaliculi, proceeding from them,—I went on to show that the average length of the bone-cells in the human subject was about $\frac{1}{2000}$th of an inch, that they were of an oval form, somewhat flattened on their opposite surfaces, and usually one-third greater in thickness than in breadth; that the bones of birds were all more or less hollow, and the Haversian canals much smaller and more numerous than in Mammalia, that the bone-cells also were of much smaller size, and their long diameters often placed at right angles with the shaft of the bone; that in the Reptilia the Haversian canals are large and not numerous, but the bone-cells and their canaliculi are remarkable for their very large size, whilst in fishes the Haversian canals were entirely absent in some bones, and abundant in others: when entirely absent, their place appeared to be supplied by bone-cells which presented several peculiarities, serving to distinguish them from those of the mammal, the bird, or the reptile, they being, for the most part, of a quadrate figure, and the canaliculi given off from them but few in number, and readily seen to anastomose freely with the canaliculi from other cells. I then proposed to apply the characters derived from the bone-cells to the determination of the class of animals to which any minute fragment of fossil or other bone may have belonged. I also stated that anatomists had long been familiar with the fact, that in proportion to the size of the blood-corpuscles so is that of the capillaries, and of the muscular and nervous fibres; and it would appear that the same thing held good with respect to the bone-cells. From the highly valuable table of the comparative sizes of the blood-discs, published by Mr. Gulliver, we learn, that the blood-particles are largest in reptiles, smallest in Mammalia and birds, and in fishes of an intermediate size; and it has been already stated, that the bone-cells are largest in reptiles, and are much smaller in Mammalia and birds; hence it would appear, that the bone-cells are subject to the same law as the capillary, muscular, and other systems; and in the advanced stages of the inquiry, it may possibly turn out, that if one or other of these systems be known the size of the others may be readily inferred.

Since my last communication, of which the preceding is a brief abstract, I have extended my researches to the investigation of the minute structure of the bone of those Reptilia in which the blood-particles are the largest, and have taken as examples some of the perennibranchiate Reptilia, viz., the Siren, the Proteus, the Menopome, the Menobranchus, and the Axolotl, and the result of the examination has been highly satisfactory, for I find, as I had predicted, that the bone-cells would be the largest in those animals which had the largest blood-discs. In the Siren they appear to have attained their greatest size; and this reptile, as far as I can learn, has larger blood-discs than any other existing animal: the portions of bone examined were taken from the skull, and from a vertebra, and these fragments exhibit cells of enormous size; some of them are oval, others of a quadrilateral figure, with very large but not very numerous canaliculi, whilst others are not so broad, but much more elongated, and the canaliculi so numerous as to form a dense net-work around the cells, which nearly obscures them. The latter or elongated cells are chiefly found in the thick or dense portions of bone, where they are arranged in parallel rows, like those of the Turtle and Python before alluded to, whilst the former or broad cells occurs in the thinner plates of bone, and never are arranged in rows, but are scattered irregularly about; and if the bone be recent, the granular contents of the cells will be readily made out: if the specimen be a thin one, and mounted in Canada balsam, it will sometimes happen that the cells contain air, and in the process of mounting the balsam will enter the canaliculi and obscure them, and the cell will then appear like a large bubble of air, for which it has been more than once mistaken. The bones of all the perennibranchiate Reptilia before enumerated present the same form of cells, but in none do they equal in size those of the Siren.

The structure, then, of the bone of the perennibranchiate Reptilia may be characterized by the almost entire absence of the Haversian canals, except in the large bones, and by having their place supplied by enormously long and broad, and sometimes quadrilateral, bone-cells, with large canaliculi, anastomosing freely with those of neighbouring cells: the canaliculi are large, like those of fish, but not so numerous as those of the ordinary reptiles, as may be seen by comparing figs. 4, 5, and 6, with fig. 3, in Plate vii. In fact, everything agrees with the characters presented to us by the blood of these animals. I have never yet seen the blood of the Menopome, Proteus, or Axolotl, but should infer, from the structure of their bone, that their discs or corpuscles, as they are termed, are not so large as those of the Siren. As some of the highest authorities in comparative anatomy are still at issue respecting the true class to which the Lepidosiren belongs, some regarding it as a reptile, others as a fish, I was anxious to ascertain what evidence of its true nature might be obtained from the structure of its bone; and I may here state, that a thin fragment from the base of the cranium exhibits two forms of very large cells, the one of a quadrilateral figure, like those of the Siren, the other of an elongated form, similar to those of the Turtle, but much greater in breadth: the first kind were distributed irregularly, and at wide intervals apart from each other, whilst those of the second or elongated kind were arranged in parallel rows, with a dense net-work of canaliculi around them, so dense in some parts as almost to obscure the cell: in all these characters the structure agrees with that of the bone of the perennibranchiate Reptilia just described, no cells at all resembling them having as yet been found in any of the orders of fishes. The cells of the latter animals which come nearest to those of Reptilia are depicted in Plate vii. fig. 4; they are from the Conger Eel, and are elongated like those of the Turtle, but have not the breadth, nor so great a number of canaliculi as those of the latter animal, and they are so entirely different to the cells of any of the perennibranchiate Reptilia, that not a moment's hesitation need be required to satisfy an inexperienced observer of their want of identity. The elongated cells are rarely to be found, except in the bones composing the endo-skeleton of fishes: in the scales, and other thin plates of osseous matter, the cells are of a small quadrilateral figure, and have but few canaliculi, as may be seen in Plate viii. fig. 1, which represents a portion of the scale of the *Lepidosteus* magnified 440 diameters. The other peculiarities in the bone of fish having been mentioned in the preceding paper, and being so entirely different in structure from any other bones of the higher animals, from the fact of their having no bone-cells at all, I need not again allude to them here. The Lepidosiren, then, however much its other true ichthyic characters may prevail, may be said to be, as to the structure of its bones, more like a reptile than a fish; and thence it may be inferred, that the blood-corpuscles are nearly equal in size to those of the perennibranchiate Reptilia, to which the bone-cells are most nearly allied.

MEASUREMENT OF BONE-CELLS IN PARTS OF AN ENGLISH INCH.

MENOPOME . . .	Long diameter,	one of the largest,	$\frac{1}{450}$.
		one of the smallest,	$\frac{1}{700}$.
	Short diameter,	one of the largest,	$\frac{1}{1300}$.
		one of the smallest,	$\frac{1}{2100}$.
PROTEUS	Long diameter,	one of the largest,	$\frac{1}{570}$.
		one of the smallest,	$\frac{1}{980}$.
	Short diameter,	one of the largest,	$\frac{1}{883}$.
		one of the smallest,	$\frac{1}{1200}$.
SIREN	Long diameter,	one of the largest,	$\frac{1}{290}$.
		one of the smallest,	$\frac{1}{480}$.
	Short diameter,	one of the largest,	$\frac{1}{540}$.
		one of the smallest,	$\frac{1}{975}$.
LEPIDOSIREN . . .	Long diameter,	one of the largest,	$\frac{1}{375}$.
		one of the smallest,	$\frac{1}{494}$.
	Short diameter,	one of the largest,	$\frac{1}{980}$.
		one of the smallest,	$\frac{1}{2200}$.
PTERODACTYLE . .	Long diameter,	one of the largest,	$\frac{1}{445}$.
		one of the smallest,	$\frac{1}{1183}$.
	Short diameter,	one of the largest,	$\frac{1}{4000}$.
		one of the smallest,	$\frac{1}{5225}$.

EXPLANATION OF THE PLATES.

Plate V.

Fig. 1. A transverse section of the human clavicle, magnified 95 diameters, which exhibits the Haversian canals, the concentric laminæ, and the concentric arrangement of bone-cells around them. Some of the Haversian canals are white, others black; the latter are filled with a deposit of opaque matter, used in the grinding and polishing the section: the outer margin of each of the series of concentric laminæ is white and transparent, which is caused by the canaliculi of the outer row of bone-cells being given off only from one side of the cell, and that side being the one nearest its own Haversian canal.

Fig. 2. A transverse section of the femur of an Ostrich, magnified 95 diameters. When contrasted with the preceding figure, it will be noticed that the Haversian canals are much smaller and much more numerous, and many of them run in a transverse direction. The bone-cells are very much smaller, and the concentric laminated arrangement only visible where the canals run at right angles to the section. When the concentric laminæ do exist they are not so numerous as in Mammalia; rarely more than from three to five are found around any one Haversian canal.

Plate VI.

Fig. 3. A transverse section of the humerus of a Turtle (*Chelonia Mydas*). It exhibits traces of three Haversian canals, with a slight tendency to a concentric arrangement of bone-cells around them: the bone-cells are large and very numerous, but occur for the most part in parallel rows: in these rows the cells are seen in their longest diameters, whilst in the immediate neighbourhood of the Haversian canals they present their short diameters.

Fig. 4. A horizontal section of the lower jaw of a Conger Eel, which exhibits a single plane of bone-cells arranged in parallel lines: there are no Haversian canals present; and when this specimen is contrasted with that of fig. 3, it will be noticed that the canaliculi given off from each of the bone-cells of this fish are very few in number in comparison with that of the reptile.

Fig. 5. A portion of the cranium of the Menopome, which exhibits numerous bone-cells of a large size: they are arranged in parallel lines, and are much farther apart than those of the Eel or Turtle. No Haversian canal is present, but there is a disposition to a concentric arrangement, as seen on the left-hand side of the figure: at this part the bone-cells are the largest.

Fig. 6. A portion of the cranium of a Siren (*Siren lacertina*), which is remarkable for the large size of the bone-cells and of the canaliculi, they being larger in this animal than in any other yet examined; as in the preceding specimens no Haversian canals are present.

The above four specimens are magnified 95 diameters.

Plate VII.

Fig. 1. A portion of human clavicle, magnified 440 diameters, to show the bone-cells and their canaliculi: the largest of the bone-cells are about $\frac{1}{800}$th, the shortest about $\frac{1}{1000}$th of an inch in length.

Fig. 2. A portion of the transverse section of the femur of an Ostrich, magnified 440 diameters. An Haversian canal is seen longitudinally divided, with the small bone-cells arranged in parallel lines on either side of it. The length of the bone-cells are on an average about $\frac{1}{1800}$th of an inch.

Fig. 3. A portion of the humerus of a Turtle (*Chelonia Mydas*), magnified 440 diameters, in which the elongated bone-cells with numerous canaliculi are well exhibited: the length of these bone-cells varies from $\frac{1}{400}$th to the $\frac{1}{875}$th of an inch.

Fig. 4. A portion of the lower jaw of a Conger Eel, magnified 440 diameters: the bone-cells are neither so long or so broad as those of the Turtle, but the canaliculi are larger and less numerous. The longest bone-cell in this specimen is $\frac{1}{340}$th, the shortest $\frac{1}{1200}$th of an inch.

Fig. 5. A portion of the cranium of a Menopome, magnified 440 diameters, showing the large size of the bone-cells and the canaliculi: although many of the cells are not so long as those of the Turtle, they are nevertheless nearly twice as broad. The length of the cells varies from the $\frac{1}{350}$th to the $\frac{1}{700}$th of an inch.

Fig. 6. A portion of the cranium of the Siren (*Siren lacertina*), magnified 440 diameters. The bone-cells in this animal are the largest known; they are quite as long as those of the Menopome, and are much broader. Some of them are as much as the $\frac{1}{300}$th of an inch in length by the $\frac{1}{500}$th in breadth.

Plate VIII.

Fig. 1. A portion of the scale of the *Lepidosteus osseus*, which exhibits the quadrate form of bone-cell, with few canaliculi, which is generally found in thin plates of bone of fishes.

Fig. 2. A small portion of bone, taken from the exterior of the shaft of the humerus of a Pterodactyle, which exhibits the elongated bone-cells characteristic of the higher orders of Reptilia.

Fig. 3. A transverse section of the spine of a Silurus, which exhibits numerous branching tubes or canals, like those of teeth, but no bone-cells.

Fig. 4. A horizontal section of a scale or flattened spine from the skin of a Trygon or Sting Ray, which exhibits large Haversian canals, with numerous wavy parallel tubes, like those of *dentine*, communicating with them. It will be noticed that this specimen shows, besides these wavy tubes, numerous bone-cells whose canaliculi communicate with the tubes, as in many specimens of *dentine*.

Fig. 5. A portion of the base of the cranium of a Lepidosiren (*Lepidosiren annectens*, Owen), which shows two forms of very large bone-cells, similar to those in the Menopome and Siren and other perennibranchiate Reptilia.

Fig. 6. A portion of the base of the cranium of a Lepidosiren, magnified 95 diameters, which exhibits both the elongated and the quadrate form of bone-cells, for the purpose of comparison with those of the Menopome and Siren, in Plate vii. figs. 5 and 6, which are similarly magnified.

Pl. V.

Fig. 1. Human. Magd. 95 dias.

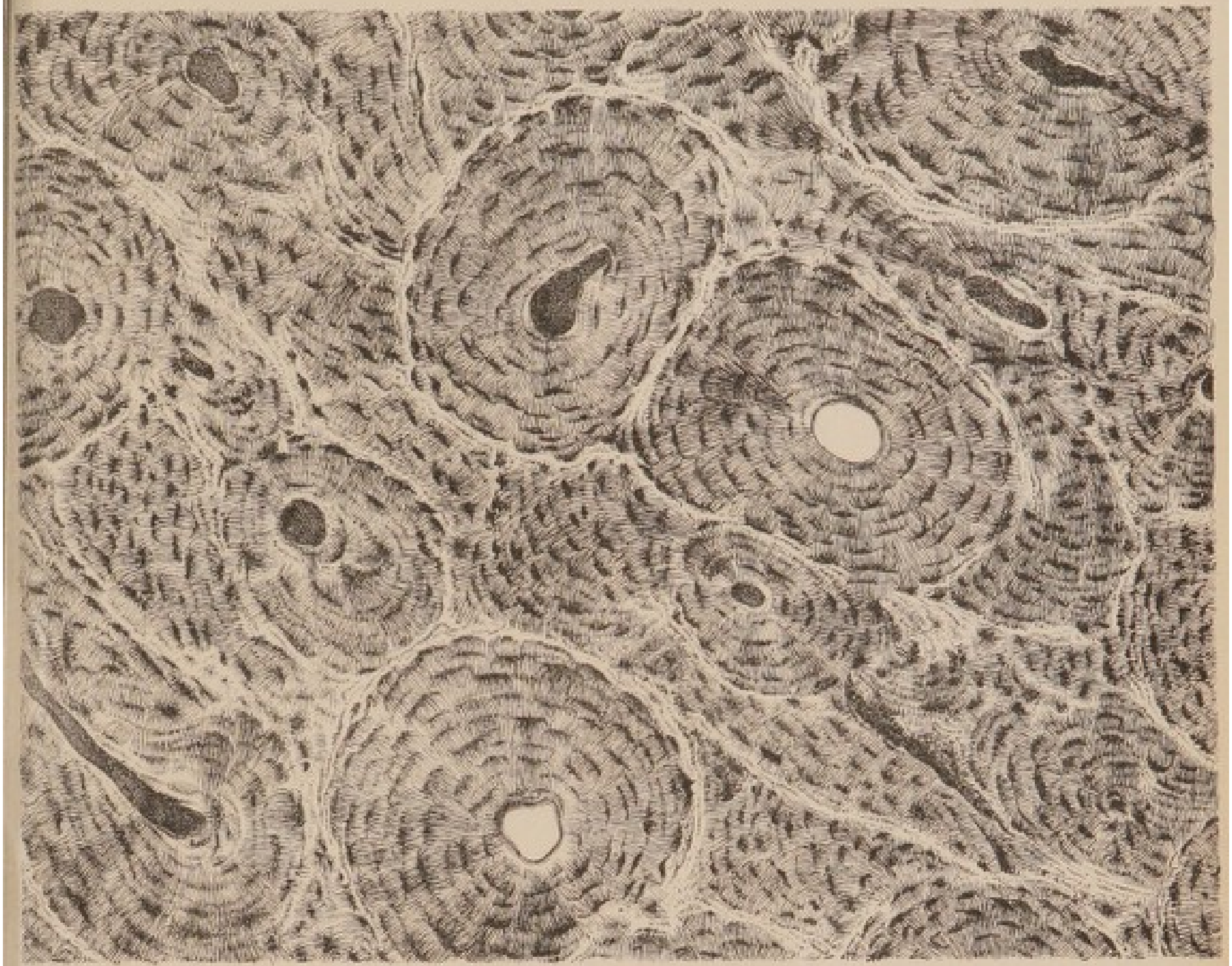
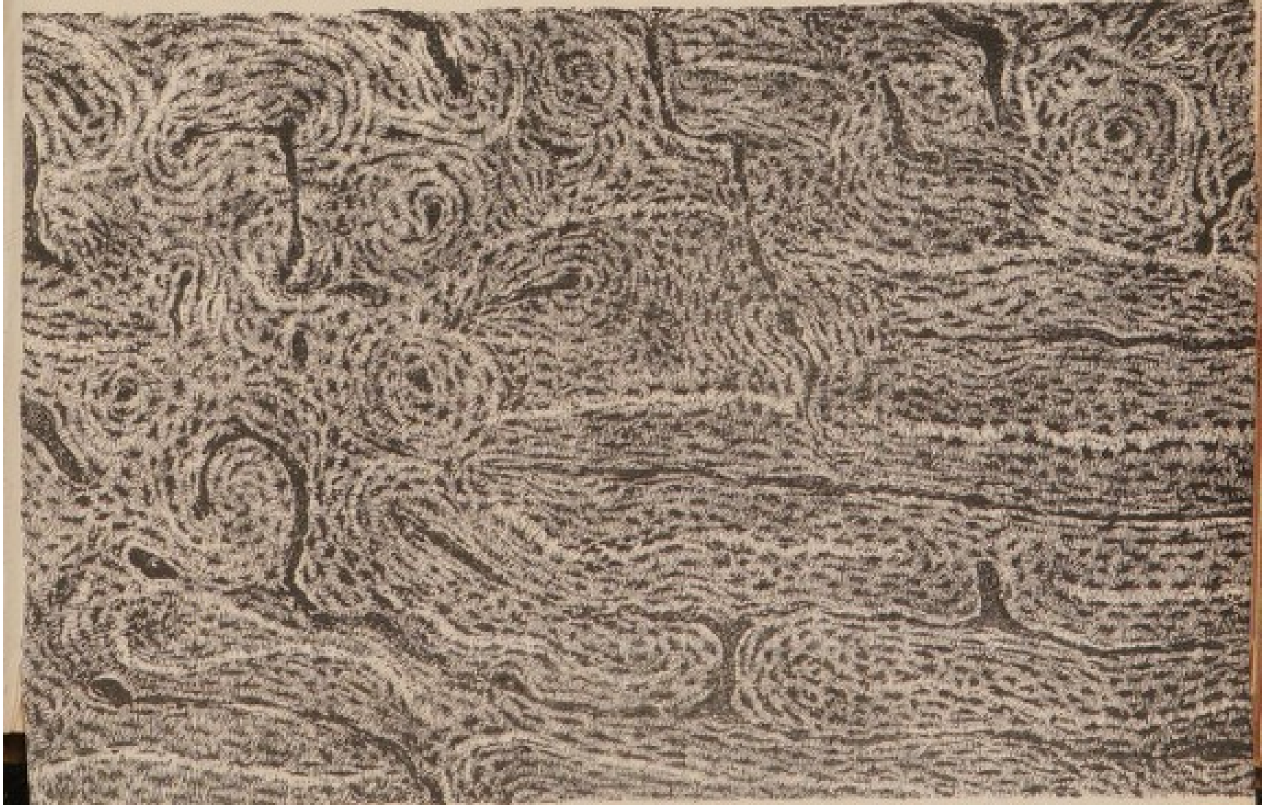


Fig. 2. Ostrich. 95 dias.



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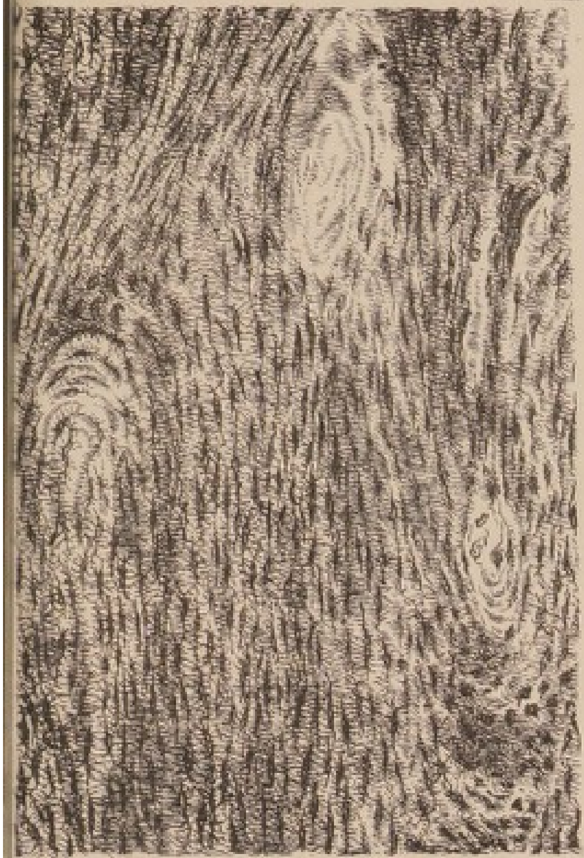
Pl. VI.

Fig. 3. Turtle

Mag.d 95 dia.s

Fig. 4. Conger Eel



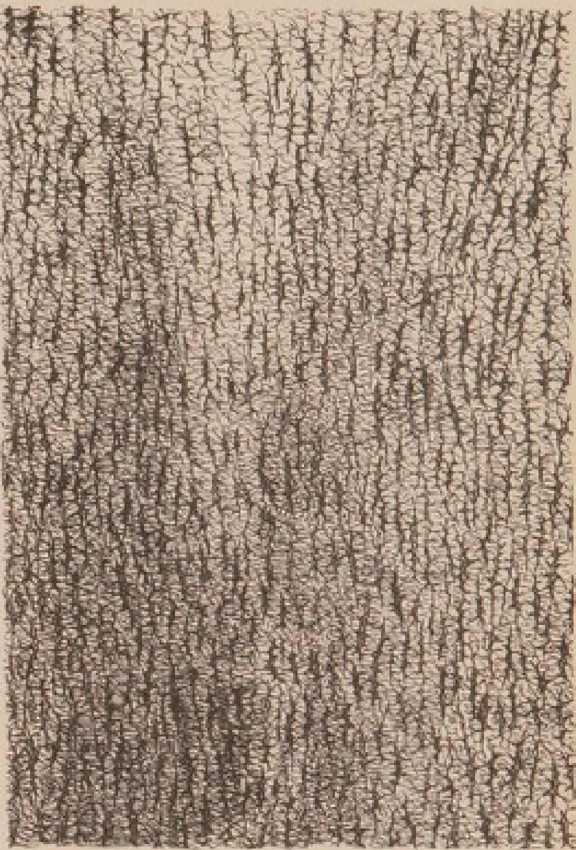
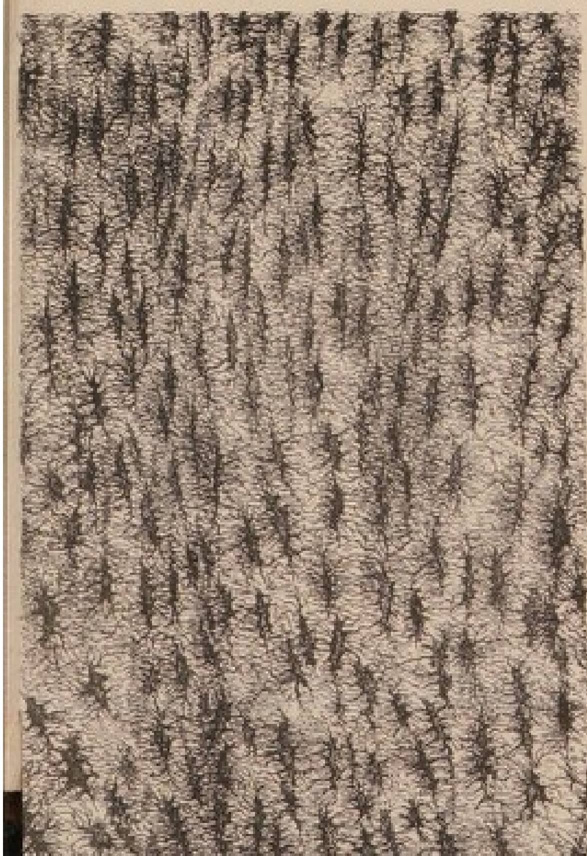


Fig. 5. Menopome.

95 dia.s

Fig. 6 Siren.



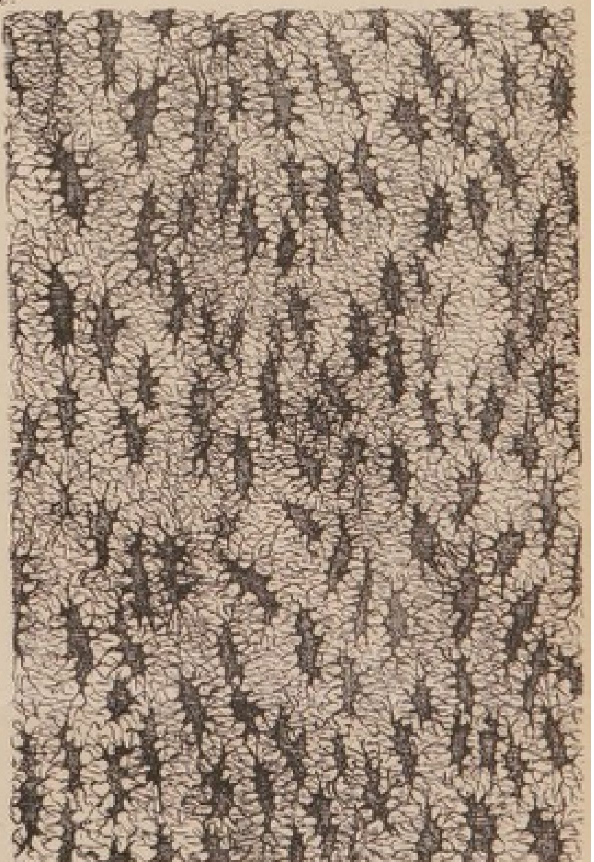


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Fig. 1. Human.

Magn 440 dia.

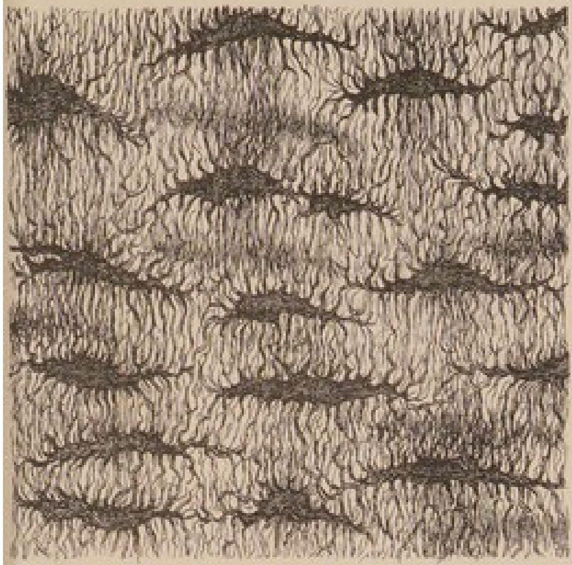

Fig. 2. Ostrich.

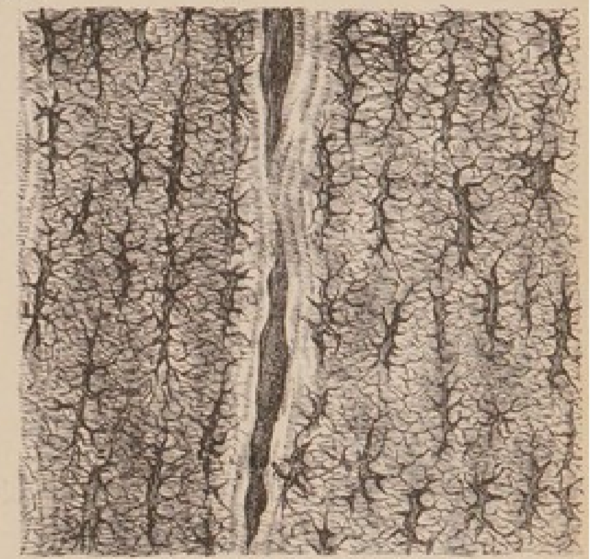

Fig. 3. Turtle.

440

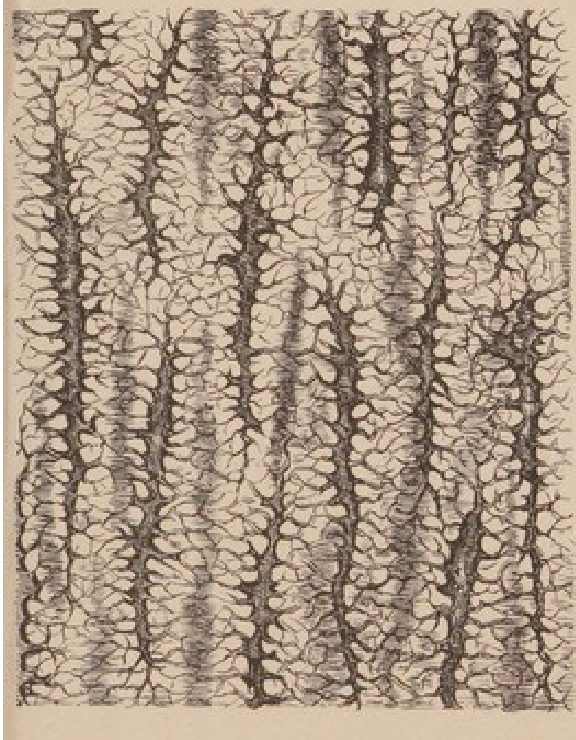

Fig. 4. Conger Eel.

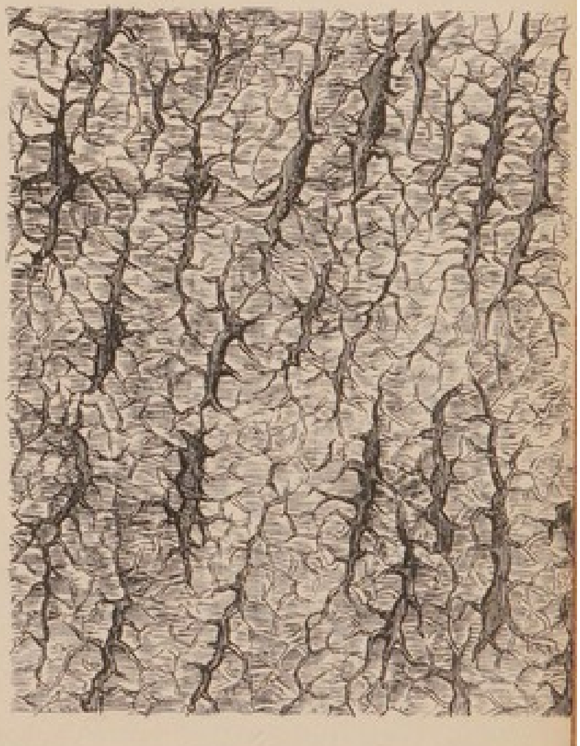

Fig. 5. Menopome.

440

Fig. 6. Siren.

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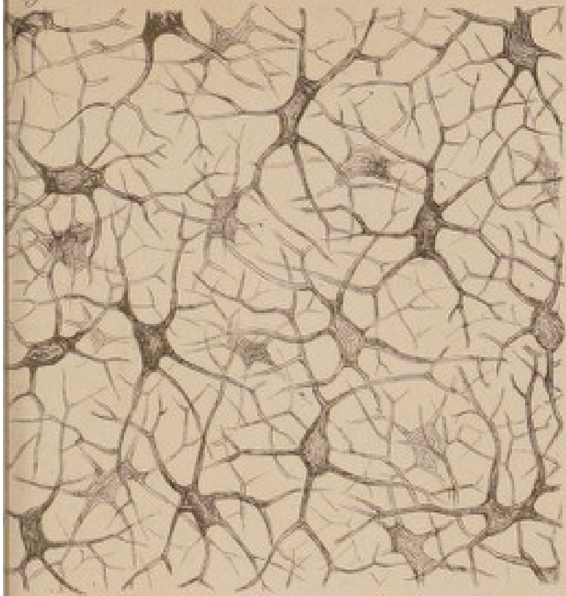
Lepidosteus.

Fig. 1. *440 dia.s*

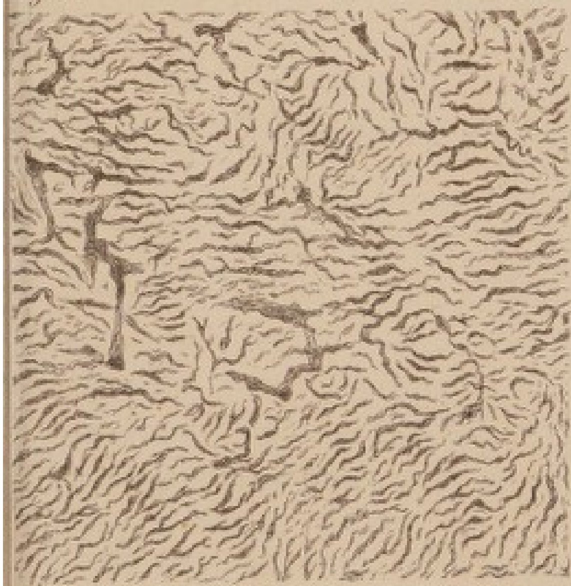


Pterodactyle.

Fig. 2. *440 dia.s*

Silurus.

Fig. 3. *95 dia.s*

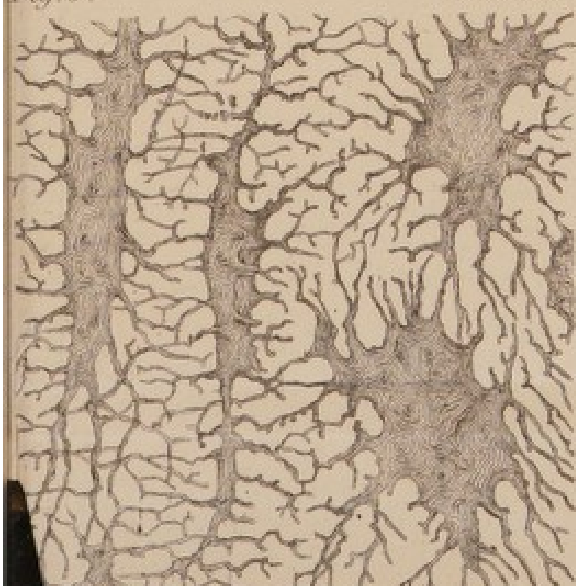


Ray.

Fig. 4. *95 dia.s*

Lepidosiren.

Fig. 5. *440 dia.s*



Lepidosiren.

Fig 6. *95 dia.s*

Leonard, del. et lith. *Printed by Reeve Brothers.*