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VII

An Attempt to discriminate and describe the Animals that made the Fossil Footmarks of the United States, and especially of New England.

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It is now about thirteen years since my attention was called to the fossil footmarks of New England; and every successive year has brought out some new developments of this curious subject. At first, even by most scientific men, it was regarded with extreme skepticism, and by others with ridicule. But facts, registered imperishably on tables of stone, have now, for the most part, given conviction to men of real science, and turned into admiration the scoffs of the superficial. It is now generally admitted, that the opening of these stony leaves of the earth's volume, with their deeply impressed hieroglyphics, has revealed a new chapter of preadamic history, which all are anxious to peruse. Fully to decipher it is no easy, although a fascinating, task. Thirteen years, however, have witnessed some progress in the work; and my object at this time is to present the most mature results that have been reached.

I have already, in other places, given such details respecting

the earliest discovery of fossil footmarks, that I shall omit them here; especially as my object is to give my latest, rather than my early, views of the subject. I shall, therefore, only mention the successive developments which my views have undergone.

The footmarks hitherto discovered in the United States out of New England amount to two or three species only; and although I shall describe these in the present paper, yet all the important characters on which I found my results are derived from those of the valley of Connecticut River.

The first account ever published of these footmarks was given in the *American Journal of Science* for 1836, where I figured and described seven species; that is, I supposed that these tracks were made by seven different species of animals. And since I had no evidence that all of them were not bipeds, and positive evidence that most of them were, I named the tracks *Ornithichnites*; but left the animals themselves unnamed. Five years of further examination enabled me to swell this list to twenty-seven species; of which I gave a description, with drawings of the natural size, in 1841, in my *Final Report on the Geology of Massachusetts*. Up to that time, however, I had no sure evidence that any of them were made by quadrupeds. Yet a large proportion of them bore such a strong resemblance to the tracks of saurian reptiles, that I denominated them *Sauroidichnites*; intending, however, by the term, merely to convey an intimation that they might prove to be reptilian. To the other tracks I applied the name of *Ornithoidichnites.* In 1841, when, in the Transactions of the Association of American Geologists, I gave an account of five more species of tracks, I first ventured to describe one species as of decidedly quadrupedal origin, namely, the *Sauroidichnites Deweyi.* In my Report on Ichnolithology, made to the Association of American

Geologists and Naturalists at Washington, in 1844, and published in the forty-seventh volume of the *American Journal of Science*, I described four other species of tracks; and in the same work for July, 1847, Vol. IV., New Series, I added two additional species. Several other new species have remained in my possession undescribed, from the pressure of more important duties. My present memoir will embrace *forty-nine species*, not simply of footmarks, but of the animals that made them, so far as their characters can be ascertained. Of these, twelve were certainly quadrupeds, four of them probably lizards, two chelonians, and six batrachians; two were annelids, or molluscs; three are of doubtful character; and the remaining thirty-two species were bipeds, so far as our present information extends. Eight of them seem to have been thick-toed tridactylous birds; fourteen others were probably narrow-toed tridactylous or tetradactylous birds; two were perhaps bipedal batrachians; and the remaining eight may have been birds, but will more probably turn out to have been either lizards or batrachians. Of these forty-nine species, forty-seven occur in the valley of Connecticut River, in Massachusetts and Connecticut.

I have little doubt that many will at once pronounce it impossible that the tracks of so large a number of animals should be distinguished in a few quarries in that valley. I shall shortly present the characteristics of each particular track, from which the comparative anatomist and zoologist can judge whether I have multiplied the species too much. But there are a few general considerations, which may take away all antecedent improbability as to the existence and discovery of so large a number.

And, first, we have now found these tracks in at least twenty-one places, scattered through an extent of nearly eighty miles; that is, from the Horse Race, three miles above Turner's Falls in Gill,

to Middletown in Connecticut. These localities occur at the Horse Race in Gill; near the ferry at Turner's Falls, on the Gill shore; below the falls, on the same shore; at the dam on the Montague shore, at the same falls; a mile and a half south of this spot, in Montague, on the road from Greenfield to Athol, on the east side of the canal; between the bridges over Connecticut and Deerfield rivers; at a quarry in the southeast part of Montague; near Pliny Moody's house in the north part of South Hadley; a mile west from this spot; on the west face of Mount Holyoke, beneath the trap, at Titan's Piazza; on the west bank of Connecticut river, at the east foot of Mount Tom, in Northampton; at South Hadley canal; at Cabotville; one mile south of Cabotville, on the road to Springfield; at Chicopee Falls; at a quarry on the west bank of Connecticut river, in Suffield, near the Enfield bridge; at Rocky Hill in Hartford; at the cove in Wethersfield; and at a spot one or two miles further south; at the Chatham quarries; and two or three miles west of Middletown. At so many localities, so widely scattered through the valley, we might expect to find the tracks of all the important species of animals that frequent the shores of an estuary.

This will be still more obvious, secondly, when we consider the position of the rocks at many of these localities. Ridges of trap-rock run nearly north and south through the whole extent of the sandstone, and by their protrusion they have lifted up the strata on the east side, while they overlie the sandstone on the west side. Now, in every instance but one, it is on the east or upper side of the trap that the tracks occur; and since the sandstone strata there are often tilted up from 20° to 50°, we have an opportunity of examining the edges of successive deposits made during a great length of time. Often the successive layers lie

open several rods in thickness, and sometimes, as at Turner's Falls, more than a quarter of a mile; and thus we can easily learn what animals trod upon the deposits through a series of thousands of years: for we can hardly suppose, that, in such fine sediment as that which composes these rocks, the accumulations could have been more than an inch or two each year.

Consider, thirdly, that we usually find the tracks limited to a belt of rock only a few feet wide, which formed the shore of the ancient estuary. Along this pathway, we should naturally expect to find the tracks of all the animals that trod those ancient shores.

Suppose, now, that only as many animals of this kind formerly lived in this valley as now do,—and since the climate was then tropical, and that was the period when the batrachian, lacertilian, and chelonian races were greatly developed (to say nothing of Struthionidæ), this cannot be regarded as an extravagant supposition,—might we not expect to find, at so many localities, and on so many hundred successive layers of rock, as many as forty-seven species of animals capable of being distinguished by their tracks? for we do not suppose that all species can be thus distinguished. However, it would be strange if I should not have sometimes been mistaken as to species, where they must be described only from their tracks, and, in consequence of imperfect specimens, have made two species out of one. After I have described the whole, naturalists can better judge on this point, and my only wish is to have all species dropped that have not good distinctive characters. The species which I regard as the most uncertain are the Brontozoum expansum, Steropezoum elegantius, Argozoum Redfieldianum and minimum, Platypterna Deaniana, Ornithopus Adamsonus, Plectropus minitans, Triænopus Emmonsianus, Anisopus gracilis, and the three species of Harpagopus. If all these should turn

out to be varieties of other species, it would reduce the number to thirty-eight species; thirty-six of which are found in New England.

Hitherto I have spoken of names given to the tracks. But two or three years ago, my friend, James D. Dana, Esq., suggested the desirableness of applying names to the animals that made the tracks. Accordingly, at the meeting of the Association of American Geologists and Naturalists in New Haven, in 1845, I presented a catalogue of all the animals then known through their tracks, which was printed in the abstract of the proceedings of that meeting. But as the names were not accompanied by drawings or descriptions, they would not be allowed as authoritative by the rules adopted among naturalists; and therefore, in this paper, I have made several alterations, as well as additions, and have given full descriptions, as well as outline sketches. And in regard to the latter I would add, that, for the discrimination of species, they are better than full-shaded drawings of individual specimens, because they present more distinctly the essential characters. My outline drawings, moreover, it should be remarked, are not always derived from a single specimen. For when a particular part on one specimen was defective, I have copied that part from other specimens which exhibited it more fully. So that, in fact, the outline tracks which accompany this paper are, in most cases, *restored tracks*; and yet, in general, they are copied from single, very perfect specimens. In no case is any part supplied by imagination; and hence, in a few instances, I have been obliged to omit some parts of the track.

My mode of obtaining these outlines, almost without exception, has been, first to trace them exactly upon plates of mica, laid over the tracks, several pieces when necessary being fastened togeth-

er, and afterwards to copy them on thin paper placed over the mica. When reduced subsequently, the proportions were accurately preserved.

I ought here, however, to consider an opinion, which I have met occasionally, and which goes against the whole system of giving scientific names to fossil tracks, or to the animals that made them. It is considered a useless show of learning, because it is supposed that the data afforded by tracks alone are not definite and full enough to discriminate species, which can be done only by the discovery of their skeletons.

I take a different view of this subject, and maintain, that, by the principles of fossil zoölogy, we are fully justified in classifying and naming animals from the evidence of their tracks alone; and in support of this opinion, I offer the following reasons.

In the first place, no naturalist who has seen a good suite of these fossil footmarks will doubt that they prove the existence of certain animals during the deposition of the new red sandstone of the Connecticut Valley. Many are skeptical on the subject till they have actually seen good specimens; but a glance of the eye usually carries the conviction to the mind, that the tracks were made by animals, almost as certainly as if their skeletons were standing before the observer.

In the second place, these extinct animals have never been described. Very few vertebral animals have been found in the new red sandstone of any country, and none in that rock in our country, save fishes. Those which have left only their tracks, therefore, deserve names as much as any other animals, living or fossil, if we can find out what are their characters.

In the third place, every one who examines these tracks admits at once that they were made by several distinct species of animals.

He sees that some of them were impressed by bipeds, others by quadrupeds; some by thick-toed animals, and others by narrow-toed; some by three-toed, others by four-toed, and others by five-toed animals, some by long and narrow heeled, others by short and broad heeled, and others by *heelless* animals. Nor can he, by any effort of the imagination, conceive how they all were made by a single animal. I never knew a man who attempted to do this. Let any one examine the outline drawings accompanying this paper, and he will be satisfied on this point. Now there must be some very decided characters in these tracks, that produce this conviction of differences in the animals that made them. And why may not these peculiarities be expressed on paper, and thus in fact become the basis of generic and specific characters? True, they are imperfect; but so are the characters of a large part of the genera and species of fossil animals and plants.

In the fourth place, the feet of animals furnish excellent characters for distinguishing classes, orders, genera, and species. To be satisfied of this point, let any one compare the feet of mammiferous animals with those of reptiles; or the latter with those of birds; or among the Mammalia, the feet of the Ruminantia with those of the Carnivora, or Marsupialia; or, among birds, the feet of the Grallae with those of the Passeres, or Palmipedes; or the feet of the kangaroo, or Platypus, with those of the tiger or hog; or those of the Struthio Rhea with those of the eagle, or albatross, or jacana. Indeed, the characters of several of the orders of birds are drawn from their feet. Many other animals could, to a considerable extent, be classified on the same basis. When we attempt in the same way to distinguish genera and species, we are met by too many exceptions to make such characters an easy and safe guide. But in the absence of better distinctions, they might be used with

tolerable success; so true is the correlation between different parts of animals. Hitherto, as I shall endeavour to show in this paper, only a small part of the characters that have a permanent value in distinguishing the feet have been pointed out, merely because they are not needed for living animals. Nevertheless, where only a mould or cast of the foot remains, they may be of great service.

I might add, in this connection, that the classes of animals which seem to have made the fossil footmarks are of all others most easily distinguished by their feet; I mean reptiles and birds. The chief difficulty in the case lies in the fact, that, in the red-sandstone period, some of these animals seem to have differed not a little in their structure from the tribes now living. The sure laws of comparative anatomy, however, are not violated.

In the fifth place, many fossil animals have been described from characters no more numerous, or definite, than those derived from their feet alone. A single bone or the fragment of a bone is, indeed, sometimes alone sufficient to enable the comparative anatomist to construct the whole animal. But it is not every bone that will do this; and as to plants, it is still more difficult to make out their true place in the botanical scale from single parts. And we know that, in many instances, animals have been named and described which were subsequently found to have been referred even to the wrong class; as, for example, the Pterodactyle and Zeuglodon. Indeed, the possession of an entire skeleton is not always sufficient to distinguish the species, nor even the genus (*Ossemens Fossiles*, Tom. III. p. 524, 3d ed.). Fossilization usually obscures the characters of organic beings; and every possible degree of uncertainty may be found in the catalogues of fossil animals. Yet in all cases, except the one under consideration, the principle seems to have been acted on, to give a name to an unknown animal, exhum-

ed from the rocks, according to all the light that can be obtained. If the zoologist can only be satisfied that the animal once existed, and has not already been described, he feels justified in fixing upon it a name, which shall serve, at least, till a better one can be obtained. Why, then, should not the same principles guide us in respect to the beings that produced the fossil footmarks? Even if we admit that there is more uncertainty in our conclusions than in any case where a portion of the animal is preserved, (which, I fancy, no one who studies ichnolithology will maintain,) I do not see that the principle by which names are given is different.

Baron Cuvier has finely described the definiteness and certainty with which we can infer the character of an animal from its track, although when he wrote fossil footmarks were unknown. "Any one," says he, "who observes merely the print of a cloven hoof, may conclude that it has been left by a ruminant animal, and regard the conclusion as equally certain with any other in physics or morals. Consequently, this single footmark clearly indicates to the observer the forms of the teeth, of all the leg-bones, thighs, shoulders, and of the trunk of the body of the animal which left the mark. It is much surer than all the marks of Zadig."

In the sixth place, we have the highest authority for applying names to animals whose tracks are the only evidence of their existence.

This was done by Professor Kaup in the case of the Chirotherium. True, Professor Owen has subsequently given the name of Labyrinthidon to a batrachian whose bones he has examined, and which he conjectures to have been identical with the Chirotherium. But if I understand the rules of priority in regard to names adopted by naturalists, if no doubt exists as to the identity of the

Chirotherium and Labyrinthidon, the former name must be retained, and the latter dropped, and Professor Owen's right to apply another name depends solely on the doubt of their identity. And should that identity be hereafter made out, I do not see why his name ought not to be superseded by that of Professor Kaup. At any rate, I have never seen any intimation from the naturalists of Europe, that the latter had not good grounds for giving a name to a track-discovered animal.

A second example may be derived from Professor Owen. In his Report on British Reptiles, he gives the name *Testudo Duncani* to the animal that made the tracks on the new red sandstone of Scotland, which were described by Dr. Duncan in 1828. And in doing this, who can show,—who in Europe has attempted to show,—that Mr. Owen has not strictly conformed to the rules of zoölogical nomenclature ?

Finally, convenience in description imperiously demands the application of names to these vanished animals of a former world, who have left only their footmarks behind. The naturalist cannot intelligibly describe the different sorts of these tracks, without giving to them distinctive characters; and unless he regards them all as varieties of one species,—which no scientific man will do,—how can he speak of them without the most inconvenient circumlocution, if he affixes no names either to the tracks or to the animals? Until he do this, he will find himself in inextricable embarrassment.

Upon the whole, I am led to the conclusion, that, in attempting to devise and affix names to the animals that made our fossil footmarks, if not to the tracks themselves, I am conforming to the strictest scientific principles. I may fail in drawing out their distinctive characters correctly; I may mistake varieties for species,

or confound different species together. But to such mistakes he who describes living, or other fossil animals, is always liable; and it cannot be an unpardonable offence, where the difficulty of correct discrimination is so much greater. I desire to have my names and distinctive characters judged of by the strictest rules of zoology and comparative anatomy; and if I am not right, let others make me so.

I beg leave to state here, however, that I do not base the names which I propose upon a supposed knowledge of the true place of the animals in the zoölogical scale; but rather upon some peculiarity of the feet, or supposed resemblance to known objects. So that should the animals be shown by subsequent discoveries to be very different from what I suppose them, still their generic and specific names will be equally unobjectionable.

The way is now prepared for enumerating and describing those characters, derived almost wholly from their footmarks, by which I propose to discriminate the lost animals that once trod the shores of this country, and particularly of that ancient estuary which extended from Long Island Sound across Connecticut and Massachusetts.

1. *Distinction between the thick-toed, or pachydactylous, and the narrow-toed, or leptodactylous, tracks*.—This distinction is very striking. The former show moulds or casts of toes, of great width, with distinct claws and protuberances, corresponding, probably, to the phalanges. The latter class, with a few exceptions belonging to intermediate species, probably, show very narrow toes, in which neither claws nor phalangeal protuberances can be distinguished. Sometimes the toes are very narrow, appearing almost as if the mud had been impressed by the blade of a knife, certainly by a toe not thicker than those of some delicate species of lizards.

It has been thought by some, that the difference between these two sorts of tracks was the result, not of a difference in the feet of the animals, but of the state of the mud impressed by them; that is, in the case of the narrow-toed tracks, the mud is supposed to have slid back so as to narrow the impression. That the mud did thus more or less collapse, in some cases, is evident. But it will not, in my opinion, explain the broad difference between these two sorts of tracks; and for the following reasons.

This supposition regards all the tracks as made by thick-toed animals. If so, only the mud near the surface would slide back and bring the margins of the impressions near together; and where that impression extends some inches in depth, as it does sometimes, the inferior layers of the narrow-toed tracks ought to be broader; but this is never the case to any great extent. As the track is at the surface (in respect to the width of the toes), so it is on all the layers. Secondly, no sliding back of the mud, after a thick-toed animal trod upon it, would obliterate the distinct phalangeal protuberances, without distorting the track in other respects. Thirdly, both sorts of tracks are not unfrequently found upon the same layer of rock, as at Wethersfield, Northampton, and Gill; and each exhibits its peculiar characteristics. Fourthly, the feet of living animals exhibit similar differences. Compare, for instance, the feet of the Struthionidæ with those of the Ardea, or Charadrius; or those of the thick-toed frogs with those of the Iguana, &c. Why, then, should we not look for diversities equally great among the fossil animals?

This character is a very important one in the classification of these animals. The group which I have denominated Struthionidæ is beautifully distinguished from all others in this way; they being all pachydactylous. For a long time I had supposed

that no others were so; but some of the quadrupeds, it appears, are almost equally entitled to this name, and the recently discovered Otozoum is eminently pachydactylous, although probably a batrachian.

2. *Winged feet*.—Two species of the pachydactylous animals appear to me to have been wing-footed, like the American coot and the grebe; for the membrane seems to have extended to the tip of the claw, as in the grebe. Their tracks are quite shallow, and the toes of great width, as distinctly lobate as those of the coot. The margin of the track appears as if a membrane had made a slight impression; but the whole depression has not that rounded form which is exhibited in the other pachydactylous tracks. Hence I have separated two species into a distinct genus on this ground. And yet it is possible to conceive such to have been the semifluid state of the mud when the track was made that the bottom of the depression beneath the animal's foot filled up in part, and the margin also partially slid inwards. Yet in such case the claw, it seems to me, would be scarcely affected at all; whereas, in fact, the peculiarity above described is most striking in that part of the track, and at present I incline to the opinion, that this character is to be relied upon for a generic distinction.

3. *Number of toes*.—This would seem at first view to be one of the best of characters; since in living animals the number of toes is rather constant in different classes of animals. But it requires a good deal of care not to be deceived in respect to the actual number of toes in the fossil footmarks. In living animals, especially birds, the hind toe is usually articulated to the tarso-metatarsus above its extremity, so that it often does not reach the ground, or only its extremity does so. And in the fossil footmarks we sometimes find that only the extreme point made an impression; and

that, too, only upon the uppermost layer. While the other toes seem to have depressed the layers of mud an inch or two, or more, in depth, this one reaches only a slight distance downward. Hence we often obtain specimens, apparently very perfect, in which the hind toe is wanting, when in fact it was present on a higher layer. The same liability to deception occurs in some cases when a short toe was attached to some part of a long heel, as it is in some reptiles. It might be only very rarely that it made an impression, save perhaps upon the highest layer.

The changes that take place in tracks in a vertical direction, that is, on successive layers of rock, is one of the most fruitful sources of error as to their true character and the number of toes. I have specimens which show the same track, or parts of it, to the depth of four or five inches; and if such a rock be split in different places, it will often show considerable diversity of forms, and yet it may be that all of them shall be quite distinct; so that, if we have only one layer, it is very difficult often to determine whether it was the identical layer on which the animal trod, or one above or below it. In following a track downward, the hind toe, if it had one, usually first disappears; next the heel, then the lateral toes, while the central one sinks the deepest.

In the plates annexed, I have given several examples of the changes that occur in tracks in a vertical direction, as they are shown upon successive layers of the rock. These, however, I ought to remark, are rather extreme cases. Plate 15, figs. 10-13, exhibits a track of *Triœnopus Baileyanus* on four successive layers, the whole about two inches in thickness, fig. 10 being the uppermost layer. The dotted lines around the heel will be described in a subsequent part of this paper. Figs. 14-16 of the same plate show the *Triœnopus Emmonsianus* on successive layers, but little more than

an inch in thickness. In this case, the three toes, near their roots, produce the appearance of a heel on the inferior layers; probably because, being so near together, all the mud between them was depressed together. Figs. 17-19 of the same plate exhibit a track of the hind and fore foot of *Plectropus longipes*, so united as to seem to be only one track. Nor is there any evidence, from this specimen, of two tracks having been made almost in the same spot. But the specimen of the same species, very analogous to this, shown on Plate 10, figs. 1-3, as seen on different layers, makes it almost certain that they are tracks of the hind and fore foot in both instances. The more detailed account of these specimens will be reserved until I come to describe the Plectropus longipes.

The above statements show us the great difficulty, in some cases, of ascertaining the precise layer of rock on which the animal walked. Where the surface was considerably firm, and quite different materials were drifted in afterwards, this question is not difficult to decide; for then the impression extends very little distance up or down, and is quite imperfect, save on one layer, which of course will be regarded as the one originally trodden upon. And fortunately such is the case with the larger proportion of tracks. But where the materials were very soft, it would seem as if the toes sank considerably into the mud, and were withdrawn without much disturbance; though afterwards the edges of the impression thus made approached each other. In no other way can we explain the extreme narrowness of some of the tracks found on the fine red shale, of Wethersfield especially. There, as already remarked, the impressions sometimes extend through from one to four inches, and the layers are bent down so as to be almost perpendicular to the surface. Some have thought that in this case we could determine how far the animal sank, by finding where the depressed laminæ of rock

cease to be fractured, and come out in regular curves, when they are split asunder. As far, indeed, as the foot did sink, we should not expect the rock would cleave in curved layers. But may not the narrow toes have bent down the layers so much, beneath where they reached, that they (i.e. the layers) would meet in an angle at the bottom so acute, that, when the rock was split open, they would break across rather than cleave asunder? In such a case, we should infer by this rule that the animal sank deeper than was the fact. And, indeed, I have sometimes found the print of a lateral toe, for instance, showing a perfectly continuous lamination across its depression, while that of the middle toe, nearly an inch deeper, was fractured. Although, therefore, this principle does help us somewhat in determining the layer on which the animal trod, it cannot be implicitly followed. If possible, we should obtain dissections of the track from top to bottom; and by combining the impressions on the successive layers, we shall probably get an accurate view of the entire foot. On one layer we may find a mere digitigrade, and on another or higher layer a plantigrade impression; on one a heel, or a fourth toe, and on another neither. I think it true in general, however, that the layer on which the animal trod was usually nearer the bottom of the impressions than the top.

Those who have seen the manner in which successive layers of copper, deposited in the process of electro-metallurgy, retain the slightest markings upon the surface, will readily conceive that fine mud would do the same; less perfectly, indeed, but still so as to preserve the form of a track through many successive layers. On this ground, they will not be surprised that several layers often present the track with so nearly equal distinctness, that the one originally impressed can no more be distinguished, than the film

of copper that was first deposited can be from those superimposed afterwards.

The oblique direction in which the impressions often pass through successive layers, while their distinctness is not impaired, is a matter of surprise, and not so easily explained. Sometimes the track seems to advance, and sometimes to recede, and sometimes to move laterally on the successive layers, taking the lowest one as the fixed basis. This might proceed in part from the oblique direction in which the foot of the animal was exerted; as when running, for instance, the impression would be made so as to reach the successive layers farther and farther backward, because the legs incline forward; or suppose the surface to be inclined, and the animal going directly or obliquely up or down upon it. It is clear that the impression, in such case, would be communicated to the successive layers obliquely to the surface, so as to produce the phenomena which we actually observe. Again, if the tracks be made beneath the water, on light, loamy mud, it is easy to see that waves or currents might produce slight movements in the successive deposits, without destroying the impressions. Or if the surface were slightly inclined, gravity would produce the same effect on such mobile materials.

In general, we find but little difference in the size of the tracks on successive layers; yet, upon the whole, the tendency is rather to enlarge downwards. Decidedly the most striking example of this which I have noticed is represented in Plate 17, figs. 3 and 4, which are one half the natural size. Fig. 3 shows a track of *Ornithopus gallinaceus*, or of *Triænopus Emmonsianus*, I am not certain which, on an upper surface; fig. 4 shows the same, as it appears in relief, only one inch lower. The latter is the most dis-

tinct; and hence I doubt not that the upper track is smaller chiefly from the filling in of materials upon the original impression.

These examples, to which I might add more, show how careful we ought to be not to confound the impressions of the same track on different layers with different species. Nothing but long experience in ichnolithological researches will prevent such mistakes.

The number of toes (to return to the character which we were considering) varies from three to five; though, if the sketches on Plate 18 are the tracks of animals, we might call them didactylous. But they are so anomalous that I leave them out of the account, especially as they may belong to invertebrate tribes, if they are indeed real tracks.

From the details that have been given, we see that this character (the number of toes), although important, is in some cases of difficult determination.

4. *Absolute and relative length of the toes.*—In these characters there is a good deal of constancy; and hence they afford good grounds for specific and even generic distinctions. There are, however, some difficulties in the determination of these points. One is, the uncertainty that often exists, whether the track before us exhibits the very surface on which the animal trod. If it be above or below that plane, the toes will always be too short, although their relative length (the most important character) may not be essentially altered. But the greatest difficulty lies in determining how far backward the toes extend; that is, where the toes end and the heel begins. In the thick-toed tracks, this point can generally be decided with accuracy; though it hardly can be in the case of the anomalous *Otozoum.* But in the narrow-toed tracks, especially if they are digitigrade, and if their divarication is small, we can get only an approximate measurement of the length of the toes. The

rule which I have usually followed, where it could be adopted, has been, to measure the lengths of the toes of the leptodactylous tracks, from the point where the lateral front toes prolonged backward cross each other. This at least does well for the relative, if not for the absolute, length of the toes.

These characters are more important and more easily ascertained in those tracks which have only three toes directed forwards, and these nearly straight, than in those with a greater number directed forward, or which are much curved. In the first-named tracks, I find the fourth or hind toe always the shortest; the inner toe, of the three directed forward, the next longest; the outer one, still longer; and the middle one, the longest of all. This, I believe, agrees with the relative length of the toes of birds. Where four toes are directed forward, as Plate 15, figs. 6-9, Plate 16, figs. 4-6, and also Plate 11, figs. 1 and 2, the same order is observed. It is generally the same in the five-toed species, as Plate 13, fig. 2, and Plate 14, fig. 1. But sometimes, as in Plate 16, fig. 2, the outer toe but one is longest, and the outer one much the shortest, as in many of the living Ranidæ.

5. *Divarication of the lateral toes*.—In many living species, as, for example, the Palmipedes among birds, this is a very constant and reliable characteristic. Nor is this constancy confined to the web-footed animals. Where the toes are free, they diverge at a pretty constant angle; and so it seems to be with the fossil footmarks. I speak now of those where three toes are directed forward; for the chief application and use of this character are confined to these. They do, indeed, diverge a few degrees more or less in different specimens; but the variation is so limited, that a practised eye often recognizes a species by this mark. The angle is measured by lines drawn from the tips of the lateral toes to the middle of their posterior extremity.

6. *Angle made by the inner and middle toe, and the outer and middle toe*.—These angles are perhaps not quite as constant as that between the lateral toes; for in treading upon the mud, the strain upon the foot seems sometimes to have varied a little the position of the middle toe, Still, this character ought not to be neglected. In some instances, the curvature of the toes is so great, that it is difficult to measure the angles described under this and the preceding heads. But I have made it a rule to draw the lines forming the angles, from the middle of the toes, at their origin, to their tips.

7. *Projection of the middle toe beyond the lateral ones*.—This is not exactly equivalent to the difference in length between the middle and lateral toes, because the middle toe generally does not reach backward so far as the others. It is an important and constant character, and serves to distinguish several species; as the *Argozoum dispari-digitatum* from the *A. pari-digitatum*.

8. *Distance between the tips of the lateral toes*.—This is determined by the angle of divarication and the length of the lateral toes; but as it would need the solution of a case in trigonometry, it is easier to measure the distance; for it is useful in comparing one track with another.

9. *Distance between the tips of the middle and the inner and outer toes.*—These elements are also determined by the previous ones; but it is more convenient to measure than to calculate them. It is obvious that they are among the permanent characters, and therefore useful for settling the genus and species.

10. *Position and direction of the hind toe*.—This character applies only to those tracks that have three toes directed forward, and a single one behind. And it is obvious that the latter may have a great variety of positions and directions, and furnish, therefore, (since these characters are constant in the same species,) good

indices of different species. In many species of birds, the hind toe is simply the outer toe prolonged backwards, bringing the fourth toe (*pouce* of the French) always on the inside of the foot. And this is its situation in the fossil tracks; as in the *Ornithopus Adamsonus*, *gallinaceus*, *gracilior*, and *loripes*, Plate 8, figs. 1-4. In the *Plectropus minitans* and *longipes* it is short, and proceeds from a long heel, a little behind the origin of the toes, at right angles nearly to the heel, like the spur of the domestic cock. Plate 8, fig. 4, and Plate 9, fig. 3. In the *Triænopus Baileyanus* (Plate 10, fig. 4), it is very slender, proceeding from about the same place on a long heel, but directed forwards, so as to make quite an acute angle with the heel. In the *Triænopus Emmonsianus*, (Plate 10, fig. 5), it proceeds from the end of the heel, and is directed somewhat backwards, so as to form with the heel on the anterior side an obtuse angle. In the *Polemarchus gigas* (Plate 9, fig. 1), this toe, which is quite stout, proceeds laterally from a very thick, rounded heel, at right angles to the axis of the foot. When this toe runs directly backward, it is difficult to distinguish it from a narrow heel, as in the *Macropterna rhynchosauroidea*, Plate 15, fig. 9. In this case I have indeed considered this projection as a heel, as the generic name implies. But the track of the snow-bird (*Fringilla Hudsonia*) is almost exactly like fig. 9, except the short outer toe; and it is a hind toe that makes the posterior impression. (See Transactions of the Association of American Geologists and Naturalists, Plate 11, fig. 8.)

In dissecting some specimens of *Plectropus*, I have been struck with another fact. On the highest layer the fourth toe appears to project at right angles with the heel, and some distance back from the roots of the other toes. But a little farther down we find its extremity turned backward, and its other end forward, until at

length it lies nearly on a line of the outer toe backward, which is a characteristic of another genus, the *Ornithopus*; and as the heel frequently disappears, the track is likely to be confounded with the *Ornithopus gallinaceus* (Plate 8, fig. 1), although generally they appear very much unlike. This singular change of position in the hind toe I find it very difficult to explain by any of the hypotheses which I have suggested above, in describing the fourth character.

11. *Character of the claw.* — This embraces its length and width; yet, with one exception, the length only is noticed. In the genus *Æthyopus*, the width of the claw indicates, if I mistake not, that it was winged. It is only in the pachydactylous tracks that the length of the claw, if it existed, can be ascertained, except in the *Argozoum Redfieldianum*, where a single specimen reveals it; and I doubt not it exists in all the leptodactylous feet, whose extremities are always acuminated.

The ratio between the length of the claw and that of the foot, in all the species where claws have been measured, is as follows:-

Brontozoum giganteum	9.9
" Sillimanium	6.75
" expansum	5.9
" gracillimum	6.2
" parallelum	8.1
Æthyopus Lyellianus	6.2
" minor	5.7
Argozoum Redfieldianum	6.2

These numbers do not differ from one another more, perhaps, than can be explained by uncertainties of measurement, which in the case of the claw must be considerable. Hence we may conclude that the length of the claw varies in the same proportion as that of the foot; at least, as nearly so as in living animals.

12. *Width of the toes*. — I have attempted to apply this character only to the pachydactylous tracks, as the others are so nearly alike, and so narrow, that no importance would attach to the measurements. The numbers given in the description of the several species of thick-toed animals are obtained from the same specimen, and merely indicate the greatest and least breadth of the phalangeal protuberances. Usually these measurements can be made with a good degree of accuracy, and therefore this character is one of considerable importance.

The following numbers express the ratio between the average width of the toes in these several tracks, and the length of the foot:-

Brontozoum giganteum	8.2
" Sillimanium	10.0
" expansum	5.8
" gracillimum	6.2
" parallelum	7.5
Æthyopus Lyellianus	5.8
" minor	5.3

It is clear that the great differences in these ratios cannot be explained by inaccuracies of measurement; and hence the thickness or breadth of the toes is a good character by which to distinguish species; as, indeed, an inspection of the outlines of the pachydactylous tracks on Plates 1, 2, and 3, will evince.

13. *Number and length of the phalangeal expansions*. — These points can of course be determ ined only in the thick- toed species; but then they are of great importance, especially the number of expansions on different toes; for in living animals it is well known that this character determines sometimes the class to which an individual belongs, and in the fossil footmarks this is the main

argument that leads to the conclusion that some of them were made by birds.

In estimating the number of phalanges from the tubercular expansions in the footmarks, I have supposed that the ungual and penultimate phalanges would make but one impression; and in general this conclusion is borne out by an examination of the feet of living animals.

It is also sometimes difficult to distinguish between impressions made by the phalanges, and those of the metacarpal or metatarsal bones. The tracks of the anomalous *Otozoum Moodii* exhibit this difficulty more distinctly than any other, as the detailed description of that species will show. Plate 12.

The number of phalangeal impressions on the tracks is greatest in the outer toe in all cases yet met with; and hence they are usually less distinct there, - so indistinct often that their measurement is difficult; and, indeed, the mere length of these impressions has not as yet been applied as a generic or specific distinction.

14. *Character of the heel.* — The fossil footmarks show much variety in this part, and being a constant part, it is of much value in determining the nature of the animal. In very many cases, the metacarpal or metatarsal bones seem to have been placed in so oblique a position, that neither they, nor the integuments beneath them, reached the ground; and we have accordingly only the imprint of the toes, as in *Platypterna tenuis* (Plate 7, fig. 2) and *Argozoum minimum* (Plate 6, fig. 5); that is, the feet were digitigrade. Indeed, in some cases the middle toe seems to have been articulated so high to the metatarsus or metacarpus, that it reached the ground only a good deal in advance, a striking example of which is shown in the *Typopus abnormis* (Plate 10, fig. 6).

A more common case is where the cushion beneath the metacarpal or metatarsal bones made an impression, but the bones themselves left no distinct imprint. This was usually the case with the pachydactylous tracks. But in two species at least, viz. the *Brontozoum Sillimanium* and *B. parallelum*, a distinct impression remains of the double-headed extremity of what was probably a tarso-metatarsal bone (Plate 3, figs. 2 and 4); for, besides these two rounded impressions, we have the four others in the outer toe which all the other tracks exhibit. Many of the leptodactylous tracks exhibit an impression of the cushion beneath the bones that lie behind the toes, forming a heel which slopes upward and backward so gradually, that it is impossible to say exactly where it terminates. For the mud yielded a little beyond the margin of the track, and this fact, in many instances, is a great hindrance to finding out the exact size and shape of the foot, and moreover is the grand difficulty of giving a satisfactory representation of these tracks. For this reason, I have in many instances, in the accompanying sketches, left the posterior part of the heel without an outline; as in *Platypterna tenuis*, *Ornithopus Adamsanus*, and some others.

In other cases, the posterior margin of a rounded heel is strongly marked, not, as we might at first suppose, because the animal sunk deeper on account of the peculiar state of the mud, but because it was a heavier animal, and one that trod more upon his heel; for we find the same deep impression wherever it trod. Examples of this sort are *Polemarchus gigas*, *Palamopus Dananus*, and sometimes *Triæno pus Emmonsianus*, Plates 9, 10, and 11.

A few species present us with a heel of a very peculiar character, of whose exact nature I am yet in doubt. Just behind the point where the toes originate, the surface in the track rises above the

general level of the stone, while behind this ridge is a depression, in the bottom of which are minute ridges, radiating backward a considerable distance, which I have represented on Plate 5 by lines, the whole heel having the appearance of a brush. I formerly suggested, that this might have been produced by coarse hairs upon the animal's heel; but I now give up that idea, and imagine it to have been produced by radiating rugosities on the heel, or by the partial adhesion of the mud to the heel, as the animal raised its foot, conjoined with the subsequent action of the water; and I have sometimes thought it possible that the whole might be merely slight ripple-marks. But whatever may have been the origin of these marks, we may be sure that a large and rather remarkable heel belonged to the animal.

The long and narrow heel is a common one in these footmarks. In many instances, it seems to have been made by a long metatarsal or metacarpal bone, which did not lie horizontally upon the ground, but was inclined at various angles, according to the manner in which the animal pressed upon it, and moved forward. Hence the imprint would vary in different specimens, and its posterior termination be difficult to fix exactly. This character is shown on figs. 2 and 3, Plate 9, of *Plectropus minitans*, where it is obvious that the heel lay in a sloping position. In the *Anomœpus scambus* the whole of the tarsal or carpal joint is sometimes exhibited, and a part of the fore leg, as in Plate 13, fig. 4. At other times we see a graceful swelling out of the heel a little in advance of the tarsal or carpal joint, as in figs. 3 and 1 of *Anomœpus scambus*. The same is sometimes seen on *Plectropus minitans*, Plate 10, fig. 1.

The long heel of the hind foot of *Macropterna*, as already observed, may have been a toe; indeed, it bears a strong resemblance to the posterior toe on the hind foot of the *Phyllurus Milii*

and *Cuvieri* (*Dictionnaire Classique d'Histoire Naturelle*, Plate 120), which are lizards.

In some of the quadrupeds, the heel differs in the hind and fore feet; as, for example, the *Macropterna recta* and *divaricans* (Plate 15, figs. 6 and 7); the one being long, and the other rounded. The heel of the *Typopus abnormis* appears to come under the long variety; but it is very anomalous (Plate 10, fig. 6); as also is that of the unnamed track on Plate 15, fig. 2.

The difference between the heel of the fore and hind foot is likewise well exhibited in the *Anomœpus scambus*, and *Ancyropus heteroclitus*, Plate 13, figs. 1-6, and Plate 15, figs. 3 and 4. This character alone would form a good one for generic, as well as specific distinctions.

15. *Irregularities of the under side of the foot*. — The depth of the impression in the rock, made by the different parts of the foot, show which of them projected farthest downward. In this way we ascertain that usually the middle toe was rather the most prominent on the bottom of the foot; at least, most of the weight of the animal pressed upon it; for we find, as already stated, that as we cleave off successive layers of the rock, the middle toe remains longer than the others. And of the middle toe, its central parts make the deepest impression; showing that that part bent downwards most. Of the toes, the fourth, or hind one (where three are directed forward), disappears first; showing that its articulation was higher up than the others. The heel vanishes next; proving that it was placed on a higher level than the body of the foot. |

One cannot inspect a series of specimens of footmarks without seeing at once that a part of the animals that impressed them were plantigrade and a part digitigrade. Of the former, all the pachydactylous tracks (*Brontozoum* and *Otozoum*) are examples;

of the latter, the genera *Argozoum* and *Platypterna*, on Plates 6 and 7, furnish examples.

But there is an intermediate and remarkable variety, in which the heel and toes made a deep impression, but a space between them is left unimpressed, and not unfrequently rising above the original surface, either in a curve or a ridge. We have examples of this in *Steropezoum ingens* and *elegans* (Plate 5), in *Harpedactylus concameratus* (Plate 14, fig. 3), and in *Triænopus Baileyanus* and *Emmonsianus* (Plate 10, figs. 4 and 5). In such cases it cannot be doubted that the long os calcis, or sometimes perhaps the carpal or tarsal bone, which formed the heel, was so articulated to the other bones of the foot as to constitute an arch, or even to form an angle, considerably acute, as in some quadrupeds; so that when the mud was impressed by the heel and the toes, it would be crowded upwards between them. This would exactly explain the appearance of some of the tracks above referred to; and it gives us an accurate view of the character of the bottom of the foot, and to some extent of its osseous structure. Sometimes the elevation of the rock, behind the toes, is irregular; indicating a corresponding irregularity on the bottom of the foot, as in *Steropezoum elegans*, Plate 5, fig. 2.

16. *Versed sine of the curvature of the toes*. — Some species of the footmarks are remarkable for the curvature of the toes. In the tracks with three toes directed forward, the middle toe always curves towards the line of direction on which the animal was advancing, and the lateral toes usually curve outwards near their tips. (See the figures of *Steropezoum ingens* and *elegans*, *Argozoum Redfieldianum*, the species of *Platypterna*, and especially of *Ornithopus loripes*, Plate 5, figs. 1 and 2, Plate 6, fig. 1, Plate 7, figs l - 4, and Plate 8, fig 3.)

In *Polemarchus gigas*, the outer toe curves slightly inwards like the others (Plate 9, fig. 1). In most of the four and five-toed tracks, the curvature is all one way, so as to make the curves of the several toes somewhat concentric; sometimes towards the line of direction, as in the species of *Harpedactylus* (Plate 14, figs. 2 and 3); at other times it is away from the line of direction, as in *Anomœpus Barrattii* (Plate 14, fig. 1) and *Ancyropus heteroclitus* (Plate 15, fig. 3). The curvature of the hind toe is usually so small, that I have not attempted to measure it.

If a straight line be drawn from the root to the tip of the toe, and another perpendicular to it where the curve is most distant, the length of this last line, measured from the centre of the toe, I call the *versed sine.*

I have sometimes suspected that this curvature resulted from the position of the animal's feet in relation to the line of direction; so that when it made a muscular effort to urge forwards the body, it would throw the toes into a curved position But upon reflection, such a movement, it seems to me, would cause the toes to slide so much, that some vestige of the movement would remain, which I have never seen. I rather incline to the opinion, therefore, that this curvature is the natural state of the foot, and such as we see in many reptiles.

17. *Angle made by the axis of the foot with the line of direction.* — By the line of direction, I mean the course taken by the animal as it walked along the surface. To determine this accurately, we must have at least three tracks, and if possible four. The axis of the foot is a line drawn from the middle of the heel to the tip of the longest toe. Now in some species of animals, as they walk, these two lines nearly or quite coincide; as in the Grallæ among birds. But in other animals, with short legs, or

those whose feet diverge from the axis of the body, the divarication between these lines may be quite large. Nay, in some reptiles (ex gr. *Algyra barbarica*, Griffith's Cuvier, Vol. IX., p. 212, represented on Plate 23, fig. 6, of this paper), the hind foot is so situated, that it makes a very obtuse angle with the line of direction; and, in fact, the hind and fore feet point in nearly opposite directions; so that from the tracks alone one cannot determine in which direction the animal moved. It is obvious, then, that this is an important character, sufficient to distinguish species, and even genera.

18. *Distance of the middle of the heel, or posterior part of the foot, from the line of direction*. — I might have selected the tip of the longest toe as the point from which to measure, instead of the middle of the heel. But whichever extremity of the foot is used, the position of the other end is fixed, if we know the divarication between the axis of the foot and line of direction. And it is obvious that the distance to the right and left of the line of direction, at which we find the tracks, will depend partly and mainly upon the distance between the points of insertion of the legs upon the animal's body, and partly upon their length. Hence it must be a constant character, and cannot vary much in the same animal, except, perhaps, in some of the sprawling quadrupeds. I have never depended upon it alone to distinguish species; but I think it might be safely done, when the character is well marked.

19. *Length of the step*. — By running the eye over the column which shows the ratio between the length of the foot and the step, in the table of the characters of species, annexed to this paper, it will be seen that there is a general correspondence between the length of the foot and of the step. Yet the differences in the ratios make it equally obvious, that some of the animals were short-

legged, and some long-legged. Some may suppose that these differences only show that the animals moved with different rapidity at different times. There is, indeed, a considerable diversity in the length of the step of the same species on different specimens; but such cases as the *Brontozoum parallelum*, *Typopus abnormis*, *Anisopus Deweyanus*, and *gracilis*, at one extreme, and *Otozoum Moodii* at the other, make it evident that each animal had its peculiar type of progress and of stride. Yet there is so much difference in that stride, at different times, that I have not depended on that character alone to establish a species.

In giving the length of the step in the quadrupedal tracks, I have measured from track to track of the same foot.

20. *Size of the foot*. In a few instances the species of footmarks scarcely differ except in size; the best example of which is in the genus *Steropezoum*, whose three species (Plate 5, figs. 1-3) resemble one another in form, although I have seldom seen the peculiar heel of the *ingens* and *elegans* upon the *elegantius*, and the first two differ considerably in the ratio between the length of the middle toe and its extension beyond the two others. The question arises, whether the smaller species should not be considered as the young of the other. This is possible. But then we ought to find specimens of every intermediate size, which has not yet been done. And besides, is it probable that very young animals would often frequent such thoroughfares as the localities of footmarks seem to have been, where so many sorts of animals resorted, and where, in the dearth of food that must sometimes have existed, the young ones must often have been devoured if present? Are living animals wont to bring their offspring into such places, till they have attained considerable size?

Considerations like these have led me to the conclusion, that

probably, when tracks of the same form differ a good deal in size, they are made by different species, perhaps of the same genus. Yet in view of the difficulty of proving this, I have avoided depending upon this character alone, except, perhaps, in the single case of the *Sterop ezoum elegan tius*; and as to this specie s I feel no great confidence. Nevertheless, the tracks of many species, and even genera, of living animals differ less than the *S. elegans* and *elegantius*.

21. *Character of the integuments of the foot.* — In a few instances, the ridges, furrows, pits, and anfractuosities of the animal's feet are exhibited upon its tracks. As yet, however, I have not been able to employ this character as a distinctive mark of the na ture of the an imal , pa rtly , pe rhap s, be caus e I ha ve no t had opportunity to make extensive comparisons with the feet of living animals on this point.

22. *Coprolites.* — A few coprolites have been discovered of one species of these animals, the *Argozoum Redfieldianum*; and Dr. Dana has deduced from their analysis a beautiful argument to show the nature of the animal that produced them. But its elucidation has bee n pre sente d ful ly in the *Ame rican Jou rnal of Sci ence*, Vol. XLVIII. p. 46.

23. *Means of distinguishing between the tracks of bipeds and quadrupeds.* — Persons who have never turned their attention to this subject will probably suppose that this is a very easy matter. But they would think otherwise should they attempt to make the distinction; especially in many cases of fossil footmarks, where imp erfec t spe cimen s are oft en all tha t can be obt ained . And even in studying the tracks of living animals, we shall sometimes be liable to confound those of bipeds and quadrupeds. Thus the dog, for instance, sometimes moves along without bringing all his

feet to the ground, and by a sort of double hop, which produces a series of tracks of a very dubious character.

The regular alternation of the right and left foot, on each side of the line of direction, is a most decisive indication of the biped origin of a row of tracks. And usually the right and left foot can be readily distinguished. In the pachydactylous tracks, the two protuberances of the inner toe, while the outer one has four, settle this point. When a fourth toe points backward, we know which foot made the impression, because that toe is always on the inside. So it is where it proceeds from a long heel. If the toes are curved, the curvature of the middle toe is generally inward in bipeds; that is, when the toes curve to the left it is the right foot, and *vice versâ*; and, finally, a less certain mark to guide us is the relative length of the toes, since the inner toe is almost always shortest. This is less certain only because we cannot always determine which toe is the shortest.

The regular movement of a quadruped in walking or running, not leaping, produces two nearly parallel rows of tracks, of the character represented on Plate 19, fig. 1. Here, as the fore foot is lifted up to advance, the hind foot is brought up nearly to the same place; and hence it is, that we have put unequal intervals between the tracks. But some animals — the cat, for instance — are frequently in the habit of bringing the hind foot so exactly into the place just vacated by the fore one, that it is only by careful examination, upon a long row of tracks, that the double impression can be recognized; and moreover, some animals of this sort bring their tracks so nearly into a single line, that a biped origin is readily ascribed to them. The sketch on Plate 19, fig. 2, is not an exaggeration of some cases of this sort, which have fallen under my notice. Here it is only the fifth im-

pression that gives any evidence of quadrupedal origin, save in the number of the toes; which, indeed, in living animals, is a good criterion for the most part. But we shall see in the sequel that some quadrupeds have lived with only three toes (at least on the fore feet) directed forward, and some bipeds with at least four toes directed forward (e.g. the *Macropterna* and *Otozoum*); so that the number of toes is a somewhat equivocal character.

There are some quadrupedal animals, whose tracks would be arranged in two rows; not, as first described, with two approximate tracks succeeded by a wide interval, but probably, for the most part, equidistant. The extreme tracks on Plate 19, fig. 3 (that is, those at the ends of the rows), were copied from the feet of the banded Proteus (*Menobranchus lateralis*), sent to me alive, in April, 1848, by Rev. J. W. Ray, from Oswego, N.Y., where it was caught in the autumn of 1847. The sketches were obtained by placing the animal, soon after death, in a natural position, such as I had often seen it assume when alive. They are shown on the plate of the natural size. Now as this animal's legs are not more than an inch or two long, it is clear that in walking he could not bring up the hind foot half way to the fore one, but might be expected to leave its tracks somewhat as represented by the dotted impressions on the plate, though probably they would not be as nearly equidistant as the sketches are. It is plain, however, that such an animal would leave two rows of tracks, not alternating, nor arranged as in fig. 1 of the same plate. Among the fossil footmarks, we have an analogous case in the tracks of *Macropterna divaricans* (leaving out the fore feet), as is shown on Plate 19, fig 5; and also, more exactly, in *Ancyropus heteroclitus*, shown on Plate l9, fig. 4.

The angle made by the line of direction and the axis of the feet, as well as the distance of the feet laterally from that line, are

other means of distinguishing bipedal from quadrupedal tracks. For in the latter the axis of the feet usually lies more oblique to the line of direction, and they are more distant from it, than in the former. In some of the tortoise tribe, for instance, the feet point almost at right angles to the line of direction, and are very wide apart. In this case, however, we have double rows of tracks, which at once remove all doubt.

Conclusion. — Such are the characters on which I rely to discriminate and describe the animals that made the fossil footmarks. They depend for their value upon the principles of comparative anatomy and zoölogy. They assume that such relations exist between the feet and general structure of animals, that, knowing the one, we can usually determine the other. I acknowledge these relations to be sometimes too obscure to conduct us to an infallible result. But the same is true in respect to most of the parts of animals from which the comparative anatomist draws his conclusions. We cannot, indeed, depend upon any *one* of the characters derived from the feet to conduct us to certain results. But when several conspire to the same end, we feel stronger confidence in the conclusion. If applied to living animals, it seems to me they would enable us to decide with a good degree of confidence upon the following points:—

1. Whether the animal is a biped or a quadruped.
2. Whether vertebral or invertebral.
3. To what class it belongs.
4. To what order or family. Here, however, I think we should often fail.
5. To what genus. Here, also, I think we should not unfrequently confound different genera; for the feet of many genera are too nearly alike to be distinguished by their tracks. As ap-

plied to fossil footmarks, however, the only result of the mistake would be to lead us to describe too few genera; that is, to confound more than one genus under one name, - an error far more venial in natural history than its opposite.

6. To what species. And since a specific description embraces the whole animal, - or, in the present instance, its whole track, - I think we can be more sure of being led right by these characters as to species, than as to genera.

Adopting these principles as my guide, I have arranged the fossil footmarks of the United States, mainly of New England, according to the following synopsis. I have no great confidence in the arrangement into groups, except in a few instances; and only in a few cases have I ventured to attach names to the groups. In the genera and species I have more confidence.

GROUP I. (STRUTHIONIDÆ ?)

Genus 1. BRONTOZOUM (Βροντης and ζωον).

1. B. giganteum.
2. B. Sillimanium.
3. B. loxonyx (λοξος, *oblique*, and ονυξ, *a claw*).
4. B. expansum.
5. B. gracillimum.
6. B. parallelum.

Genus 2. ÆTHIOPUS (αιθυια, *fulica*, and πους).

1. *Æ.* Lyellianus.
2. *Æ.* minor.

GROUP II.

Genus 3. STEROPEZOUM (Στεροπης and ζωον).

1. S. ingens.
2. S. elegans.
3. S. elegantius.

Genus 4. ARGOZOUM (Αργηζ and ζωον).

1. A. Redfieldianum.
2. A. dispari-digitatum.
3. A. pari-digitatum.
4. A. minimum.

Genus 5. PLATYPTERNA (πλατυζ and πτερνα).

1. P. Deaniana.
2. P. tenuis.
3. P. delicatula.

GROUP III.

Genus 6. ORNITHOPUS (ορνιζ and πουζ).

1. O. Adamsanus.
2. O. gallinaceus.
3. O. gracilior.
4. O. loripes.
5. O. rectus.*

GROUP IV.

Genus 7. POLEMARCHUS (πολεμαρχοζ).

1. P. gigas.

Genus 8. PLECTROPUS (πλεκτρον and πουζ).

1. P. minitans.
2. P. longipes.

Genus 9. TRIÆNOPUS (τριαινα and πουζ).

1. T. Baileyanus.
2. T. Emmonsianus.

* Discov ered (as also *Harped actylus rectus*, p 167) while this paper was passing through the press. Hence the number of species in this synopsis (fifty-one), exceeds by two the number stated at the beginning of this memoir.

Genus 10. HARPEDACTYLUS (αρπη and δακτυλοζ).
1. H. gracilis.
2. H. concameratus.
3. H. rectus.*

Appendix to this Group.
Genus 11. TYPOPUS (τυποζ and πουζ).
l. T. abnormis.

GROUP V. (BIPEDAL BATRACHIANS ?)
Genus 12. OTOZOUM (Ωτοζ and ζωον).
l. O. Moodii.
Genus 13. PALAMOPUS (παλαμη and πουζ).
1. P. Dananus.

GROUP VI. (QUADRUPEDAL BATRACHIANS.)
Genus 14. THENAROPUS, *King* (Θεναρ and πουζ).
1. T. heterodactylus.
Genus 15. ANOMŒPUS (ανομοιοζ and πουζ).
1. A. scambus.
2. A. Barrattii.
Genus 16. ANISOPUS (ανισοζ and πουζ).
1. A. Deweyanus.
2. A. gracilis.
Genus l7. HOPLICHNUS (οπλη and ιχνοζ).
1. H. quadrupedans.

GROUP VII. (LACERTILIANS ?)

Genus 18. MACROPTERNA (μακροζ and πτερνα).

1. M. rhynchosauroidea.
2. M. recta.
3. M. divaricans.

Genus 19. XIPHOPEZA (ξιφοζ and πεζα).

1. X. triplex.

GROUP VIII. (CHELONIANS.)

Genus 20. ANCYROPUS (αγκυρα and πουζ).

1. A. heteroclitus.

Genus 21. HELCURA (ελκω and ουρα).

1. H. littoralis.

GROUP IX. (ANNELIDS OR MOLLUSCS.)

Genus 22. HERPYSTEZOUM (ερπυστηζ and ζωον).

1. H. Marshi.
2. H. minutum.

GROUP X.

Genus 23. HARPAGOPUS (αρπαγη and πουζ).

1. H. giganteus.
2. H. Hudsonius.
3. H. dubius.

I now proceed to describe in a systematic manner the above groups, genera, and species. Their affinities to existing animals will be pointed out, so far as they can be ascertained.

GROUP I. STRUTHIONIDÆ.

Animal vertebrated, bipedal, tridactylous, pachydactylous.

Genus 1. BRONTOZOUM.

Foot tridactylous, pachydactylous, tubercular-clawed; inner toe shortest; all of them directed forward. Phalangeal expansions on the inner toe, two; on the middle toe, three; on the outer toe, four; corresponding to the number of phalanges, except the distal expansion, which was probably made by the two extreme phalanges. Lower extremity of the tarso-metatarsal bone double-headed; rarely making a distinct impression through the cushion beneath. Cushion sloping upwards posteriorly. Claws on the lateral toes a little outside of their axes; on the middle toe, a little towards its inner side.

Species 1. BRONTOZOUM GIGANTEUM. (Pl. 1. Fig. 1.)

Ornithichnites giganteus, Am. Journal of Science, Vol. XXIX., Plate 1; and Buckland's Bridgewater Treatise, Plate 26[b].

Ornithoidichnites giganteus, Final Report on the Geology of Massachusetts, Plate 36, fig. 18.

Nos. 38-43, 128, 149, 150, 151, of specimens in the Cabinet of Amherst College.

Divarication of the lateral toes, 40°; of the inner and middle toes, 20° to 25°; of the outer and middle toes, 15°. Length of the middle toe, 12.5 inches; of the inner toe, 10 inches; of the outer toe, 12.5 inches; of the foot, 14 to 18 inches; of the step, 3 to 6 feet. Width of the toes, 2 to 3 inches; of the posterior part of the foot, 6.5 inches. Length of the claw, 1.75 inch. Distance between the tips of the lateral toes, 12

inches; between the tips of the outer and middle toes, 7 to 8 inches; between the inner and middle toes, 7.45 inches. Length of the middle toe beyond the lateral toes, 5.5 inches. Length of the proximal phalanx of the inner toe, 3.7 to 3.8 inches; of the penultimate and ultimate phalanges united, 3.7 to 4.7 inches; of the proximal phalanx of the middle toe, 2.8 to 4 inches; of the second phalanx, 3 to 3.1 inches; of the penultimate and ultimate phalanges united, 2.3 to 2.9 inches; of the proximal phalanx of the outer toe, 3.1 to 3.5 inches; of the second, 2.8 to 3.2 inches; of the third, 2 to 2.1 inches; of the penultimate and ultimate phalanges united, 2.3 to 2.5 inches. Angle between the line of direction and the axis of the foot, as the animal walked, 5° to 10°. Distance of the centre of the heel from the line of direction, 2 to 3 inches. Toes nearly straight; middle one slightly curved inwards. Claws nearly straight, and only slightly deflexed. Integuments of the under side of the foot papillose and striated. Animals gregarious. Track shown of the maximum size, with some of the striæ and papillæ, on Plate 1, fig. 1.

Remarks. — This enormous animal, whose feet were four or five times larger than those of the ostrich, seems to have been the most common of those whose tracks have been impressed upon the sandstone of the Connecticut valley; for its tracks are more abundant than those of almost any other species. They must have been the giant rulers of that valley. Their gregarious character appears from the fact, that, at some localities (Northampton, &c.), we find parallel rows of tracks a few feet distant from one another, and that, too, oblique somewhat to the line of coast at the time.

Localities. — Between the bridges over Connecticut and Deerfield Rivers, in the northeast part of Deerfield; at the Horse Race, in Gill; at Northampton, Chicopee Falls, Enfield Falls, and Wethersfield.

Species 2. BRONTOZOUM SILLIMANIUM (Pl. III. Fig. 2.)

Ornithoidichnites tuberosus in part, and *O. cuneatus*, of Mass. Geol. Report, Plate 37, fig. 21, and Plate 38, fig. 22.

Ornithoidichnites Sillimani, Transactions of Association of Amer. Geol., p. 256.

Nos. 44, 47-52, 55, 56, 90, 126, 138, 144, 149, 173, 185, 186, 206, 209, 234, in Cabinet.

Divarication of the lateral toes, 30° to 40°; of the inner and middle toes, 20° to 30°; of the outer and middle toes, 10° to 20°. Length of the middle toe, 6 inches; of the inner toe, 4.4 inches; of the outer toe, 5.5 inches; of the foot, 8 inches; of the step, 18 to 20 inches; of the claw, 1 inch. Distance between the tips of the lateral toes, 5 inches; between the tips of the inner and middle toes, 4 inches; between the tips of the outer and middle toes, 3.5 inches. Projection of the middle toe beyond the lateral ones, 3 inches. Width of the toes, 1 to 1.9 inch. Length of the proximal phalanx of the inner toe, 0.9 to 1.6 inch; of the penultimate and ultimate phalanges united, 0.8 to 1.3 inch; of the proximal phalanx of the middle toe, 0.9 to 1.5 inch; of the second, 1 to 1.6 inch; of the penultimate and ultimate phalanges united, 0.8 to 1.7 inch; of the proximal phalanx of the outer toe, 0.7 to 0 9 inch; of the second phalanx, 0.7 to 0.8 inch; of the third, 0.6 to 1 inch; of the penultimate and ultimate phalanges united, 0.8 to 1.5 inch. Extremity of the tarso-metatarsal bone with two condyles for articulation with the toes. Axis of the foot nearly coincident with the line of direction. Claws nearly straight, and only slightly deflexed from the axis of the toes. Tracks shown, of the natural size, on Plate 3, fig. 2, which exhibits also an impression of the double-headed extremity of the tarso-metatarsal bone; copied from a specimen from South Hadley.

Remarks. — This species varies considerably in size, and its tracks are quite abundant at Turner's Falls and Northampton, and are found also at Wethersfield, Portland, and Middletown. It has also been found at Pompton, in New Jersey, by W. C. Redfield, Esq. (Am. Jour. Sci., Vol. XLIV. p 134, and XLV. p. 315), and is the only species of this genus found out of the valley of Connecticut River. It is respectfully dedicated to Dr. Benjamin Silliman, of New Haven.

On Plate 24, fig. 5, is an outline of an interesting slab, less than two feet in diameter, discovered by Mr. Plinius Moody, in the north part of South Hadley, and deposited by him in Amherst College. It contains 20 tracks of this species on that small surface, in relief, many of them very distinct, brought to light by the action of water; the track being so much concreted as not to be washed away nor disintegrated. The tracks are not all on one layer.

Species 3. BRONTOZOUM LOXONYX. (Pl. II. Fig. 1, 2.)

Ornith ichnites tuberosus in part, Am. Jour. Sci., Vol. XXIX. p. 318.

Ornithoidichnites tuberosus in part, Mass. Geol. Report, Plate 37, fig. 20.

Nos. 44-46, 53, 54, 187-190, in Cabinet.

Divarication of the lateral toes, 25° to 30°; of the inner and middle toes, 15° to 20°; of the middle and outer toes, 10°. Length of the middle toe, 6 inches; of the inner toe, 4.4 inches; of the outer toe, 5.5 inches; of the foot, 8 inches; of the claw, 1 inch; of the step, 30 inches. Distance between the tips of the lateral toes, 5.75 inches; between the tips of the inner and middle toes, 4 inches; between the tips of the middle and outer toes, 4 inches. Projection of the middle toe beyond the lateral

ones, 3 inches. Width of the toes, 1 to 1.9 inch. Length of the proximal phalanx of the inner toe, 1.6 inch; of the second and third phalanges, 1.6 inch; of the first of the middle toe, 1.6 inch; of the second , 1.7 inch; of the last two, l.4 inch; of the first of the outer toe, 1 inch; of the second, 1. 3 inch; of the third, 1.2 inch; of the last two, 1.5 inch. Toes straight; claws abnormal (bent) , making an angle with the axis of the toes of from 30° to 40°. Axis of the foot and line of direction nearly coincident. Tracks shown, of the natural size, on Plate 2, fig. 1, from Mount Holyoke; and fig. 2, from Turner's Falls, which specimen was destitute of claws and less divaricate than fig. 1, but shows the phalangeal impressions very distinctly.

Localities. — Mount Holyoke, Northampton, Wethersfield, Turner's Falls, Horse Race, and South Hadley.

Remarks. — I have found more difficulty in fixing upon the distinctive characters of this and the species which precedes and follows it, than in respect to almost any other species founded on footmarks, because they seem to pass more or less into one another. Yet one sees that the footmarks could not have been made by the same species at different ages of growth . The present species is distinguished from the preceding by its larger size, the more massive character of the foot, and by an unusually, oblique direction to the claws. It is also rather less divaricate. The oblique direction of the claws (from which the specific name is derived) may not be constant. It is quite obvious in the specimen from which Plate 2, fig. 1, was taken, as well as in all the specimens from the same locality, although these are few. That locality is a remarkable one, namely, the west precipitous side of Mount Holyoke, twenty rods north of Titan's Piazza, where the gray micaceous slate crops out below the trap, and only a few feet

below the latter occur the tracks. This is the only spot where footmarks are found in this valley beneath the trap; and it probably, though not necessarily, indicates an earlier existence of the animals than in those cases where the tracks lie above the trap.

Species 4. BRONTOZOUM EXPANSUM. (Pl. III. Fig. 1.)

Ornithoidichnites expansus, Mass. Geol. Rep., Plate 38, fig. 23.
Nos. 44, 59, 207, in Cabinet.

Divarication of the lateral toes, 50° to 70°; of the inner and middle toes, 25°; of the middle and outer toes, 30°. Length of the middle toe, 4.6 inches; of the inner toe, 3.2 inches; of the outer toe, 4.9 inches; of the claw, 1.1 inch; of the foot, 6 to 7 inches; of the step, 25 inches. Distance between the tips of the lateral toes, 6 inches; between the tips of the inner and middle toes, 4.2 inches; between the middle and outer toes, 3.4 inches. Projection of the middle toe beyond the lateral ones, 2.4 inches. Width of the toes, one inch to one and a half. Length of the proximal phalanx of the inner toe, 1.3 inch; of the last two, 1.2 inch; of the first on the middle toe, 1.4 inch; of the second, 1.3 inch; of the last two, 1.3 inch; of the first on the outer toe, 1.6 inch; of the second, 1.2 inch; of the third, 0.9 inch; of the last two, 1.3 inch. Toes straight; claws normal; that is, only slightly deflexed from the axis of the toes. Track shown, of the natural size, on Plate 3, fig. 1.

Remarks. — This species has a more massive foot than the B. Sillimanium; its divarication is greater, and its middle toe shorter. Yet it is not always easy to distinguish the two species. They occur at the same localities, but the former is much the more common.

Species 5. BRONTOZOUM GRACILLIMUM. (Pl. II. Fig. 3.)

Ornithoidichnites gracillimus. Am. Jour. Sci., Vol. XLVII., Plate 3, fig. 4.

Nos. 89, 129, 130, 134, 135, 158, 167, in Cabinet.

Divarication of the lateral toes, 50°; of the inner and middle toes, 25°; of the middle and outer toes, 25°. Length of the middle toe, 2.2 inches; of the inner toe, 1.7 inch; of the outer toe, 2 inches; of the claw, 0.4 inch; of the foot, 2.5 inches; of the step, 7 to 8 inches. Distance between the tips of the lateral toes, 1.9 inch; between the tips of the inner and middle toes, 1.2 inch; between the tips of the outer and middle toes, 1.35 inch. Projection of the middle toe beyond the lateral ones, 0.9 inch. Width of the toes, 0.3 to 0.5 inch. Length of the proximal phalanx of the inner toe, 0.5 to 0.6 inch; of the last two, 0.4 to 0.5 inch; of the first on the middle toe, 0.5 to 0.6 inch; of the second, 0.4 to 0.5 inch; of the last two, 0.3 to 0.4 inch; of the first on the outer toe, 0.45 inch; of the second, 0.4 inch; of the third, 0.45 inch; of the last two, 0.6 inch. Toes straight; claws slightly abnormal. Angle between the line of direction and the axis of the foot, 0° to 10°. Distance of the heel from the line of direction, 0.8 inch. Track shown, of the natural size, on Plate 2, fig. 3.

Localities. — Turner's Falls, Chicopee Falls, Wethersfield.

Species 6. BRONTOZOUM PARALLELUM. (Pl. III. Figs 3, 4.)

Figured and described in Am. Journal of Science, Vol. IV., New Series, p. 50.

Nos. 137, 234, in Cabinet.

Divarication of the lateral toes, 15° to 20°; of the inner and middle toes, 5° to 6°; of the outer and middle toes, 8° to 15°.

Length of the middle toe, 2 to 3 inches; of the inner toe, 1.5 to 2 inches; of the outer toe, 1.8 to 2.3 inches; of the claw, 0.4 inch; of the foot, 3 to 3.5 inches; of the step, 13 to 24 inches. Distance between the tips of the lateral toes, 1.5 to 1.6 inch; between the inner and middle toes, 1.7 inch; between the outer and middle toes, 1.6 inch. Projection of the middle toe beyond the lateral ones, 1.4 inch. Width of the toes, 0.4 to 0.6 inch. Length of the proximal phalanx of the inner toe, 0.8 inch; of the last two, 0.9 inch; of the first on the middle toe, 0.8 inch; of the second, 0.8 inch; of the last two, 0.8 inch; of the first on the outer toe, 0.55 inch; of the second, 0.4 inch; of the third, 0.4 inch; of the last two, 0.55 inch. Toes straight; claws somewhat abnormal. Axis of the foot and line of direction entirely coincident. Track shown, of the natural size, on Plate 3, figs. 3 and 4. Fig. 4 was copied from a specimen from South Hadley, and shows the impression of the double-headed extremity of the tarso-metatarsal bone, behind the phalangeal impressions.

Localities. — Turner's Falls, South Hadley.

Remarks. — Distinguished from all other species by the less divarication of the outer toes, and the great length of the step. I have reason to suppose that its most usual step was almost two feet. This would make its leg nearly four feet long; which is greater than that of the red flamingo.

Affinities of the Group. — The alternation of right and left feet proves the animals to have been bipeds. The number and position of the toes, but more eminently the number of phalanges in the several toes, ally the animals strongly to birds. The want of a hind toe, and the great length of most of the steps, ally them to Grallæ. The great thickness of the toes, and the great size of the feet, in some instances, taken in connection with the fact, that

the Struthionidæ have that low organization which might have enabled them to live almost as early as reptiles, renders it not improbable that these birds belonged to that family.

Though several facts as above stated afford a presumption that these animals were birds, yet the new developments that have come to my knowledge on this subject have left that opinion to rest mainly on one argument, namely, the number of phalanges in the toes; which, if we admit two phalanges to have made but one tubercul ar impres sion at the extrem ities of the toes, corres pond to the feet of birds, and to those of no other animals. I should once have relied much on the mere fact that these animals were bipeds, to prove their ornithic type, taking existing animals as the basis of judgment. But, as I shall show farther on, we now know that some of these biped animals were probably batrachians, - certainly not birds. The trifid charac ter of the toes in front is another character which in existing animals is confined to birds, with two or thr ee uni mport ant exc eptio ns. But , in one of the spe cies to be described in this paper, we have a distinct tridactyle character to the fore foot, and yet we can prove beyond all questi on that it belonged to a quadruped. Upon the whole, though the evidence of the ornithic character of this group is narrowed down, it is still firm and substantial

SUB-GROUP.

Characters. — Toes and claws winged. Other characters the same as the general group.

Genus II. ÆTHYOPUS.

Foot tridactylous, expanded, winged: phalangeal impressions in

the track shallow. (Other characters the same as those of the Brontozoum, except in respect to the extremity of the tarso-metatarsal bone, whose character in this genus has not been observed.)

Species 1. *Æthyopus Lyellianus*. (Pl. IV. Fig. 1.)

Ornithoidichnites Lyellii, Transactions of Assoc. Amer. Geologists, Plate 11, fig. 1.

Nos. 57, 58, in Cabinet.

Divarication of the lateral toes, 35°; of the inner and middle toes, 15°; of the middle and outer toes, 20°. Length of the middle toe, 6.4 inches; of the inner toe, 4.2 inches; of the outer toe, 5.2 inches; of the claw, 1 inch; of the foot, 7 to 9 inches. Distance between the tips of the lateral toes, 4.8 inches; between the inner and middle toes, 4.1 inches; between the outer and middle toes, 3.9 inches. Projection of the middle toe beyond the lateral ones, 3.3 inches . Width of the toes, 1.1 to l.8 inch. Length of the proximal phalanx of the inner toe, 1.6 inch; of the last two phalanges, 1.8 inch; of the first on the middle toe, 1.8 inch; of the second, 1.8 inch; of the last two, 1.7 inch; of the first on the outer toe, 1 2 inch; of the second, 1.2 inch; of the third, 1 inch; of the last two, 1.5 inch. Toes straight; flat beneath, winged. Claws winged, broad, unusually lateral in their origin. Track shown, of the natural size, on Plate 4, fig. 1.

This species is dedicated to Charles Lyell, Esq., of London, whose researches in respect to fossil footmarks have been very important.

Remarks. — This remarkably distinct species has been found only at Turner's Falls, and in single detached specimens; so that the length of the step has not been ascert ained. As to the possib ility of its being the *Brontozoum loxonyx*, see my remarks following the next species.

Species 2. *Æthyopus minor*. (Pl. IV. Fig. 2, 3.)

Ornithoidichnites fulicoides, Trans. Assoc. Amer. Geol., Plate 11, fig. 4.

Nos. 60-62, 130, 136, 137, 159, 209, in Cabinet.

Divarication of the lateral toes, 50° to 70°; of the inner and middle toes, 20° to 30°; of the middle and outer toes, 30° to 40°. Length of the middle toe, 3.2 inches; of the inner toe, 2.5 inches; of the outer toe, 2.9 inches; of the foot, 3.5 to 4 inches; of the step, 8 to 10 inches; of the claw, 0.7 inch. Distance between the tips of the lateral toes, 3.3 inches; between the inner and middle toes, 1.9 to 2 inches; between the middle and outer toes, 2.5 inches. Projection of the middle toe beyond the lateral ones, 1.5 inch. Width of the toes, 0.65 to 0.87 inch. Length of the first phalanx on the inner toe, 1.2 inch; of the last two, 0.5 inch; of the first on the middle toe, 1 inch; of the second, 0.5 inch; of the last two, 0.7 inch; of the first on the outer toe, 0.8 inch; of the second, 0.7 inch; of the third, 0.6 inch; of the last two, 0.5 inch. Toes straight, winged: claws normal, winged. Angle of the axis of the foot from the line of direction, from 5° to 10°; sometimes outward, and sometimes inward. Distance between the heel and the line of direction, 1.25 inch. Track shown, of the natural size, on Plate 4, figs. 2 and 3, which differ chiefly in size.

Localities. — Turner's Falls and South Hadley.

Remarks. — There is one supposition which would make the distinction between Brontozoum and Æthyopus an accidental circumstance. Mud, when trodden upon, may be in so plastic a state, that deep impressions made upon it would be partially filled by the gravity of the surrounding particles. Yet a superficial impression might remain, say of the foot of an animal, and this, becoming hardened, might present the appearance of winged toes. Of the

first species I have only a few specimens; yet they do not appear as if thus altered from a track of the *Brontozoum loxonyx*, which most resembles this in shape. The phalangeal impressions are distinct, and the mud must have been a fine, tenacious red clay, such as has left us in other species the most perfect tracks; even in some instances, the papillæ and striæ of the skin. The *Æthyopus minor* is a common track, though impressions of its claws are not often well exhibited. Yet when they are shown, they seem to have been produced by a marginal wing. The evidence of a wing along the toes is less obvious in this species. But, upon the whole, I have only slight doubts that the feet of these animals (birds) were winged.

Numerous rows of the tracks of this species are represented on Plate 20, fig. 10, and Plate 23, fig. 3, which give the outlines of slabs (the first in my collection, and the other in that of Mr. Marsh), containing tracks of other species of animals; two quadrupeds at least, the Anisopus and Helcura. Plate 24, fig 3, is the outline of a small slab in Mr. Marsh's collection, remarkable for the great distance of the right and left tracks from the line of direction. Yet that they were made by right and left feet is evident from the number of phalangeal impressions on the toes. It seems difficult to suppose that it is not a distinct species from the A. minor; although that species commonly walked with feet wide apart.

Affinities of the Sub-Group. — The resemblance between the tracks of these animals and the feet of the *Fulica Americana*, or Coot, and of the Grebe or Dob Chick, *Podiceps Carolinensis*, is striking; and since other considerations (especially the number of phalanges) ally them to birds, it seems reasonable to conclude that the animals which made these tracks were closely allied to the Podicepidæ.

Table of the Ratio of the several Characters in the Species of this Group. — It will afford the zoölogist and comparative anatomist a better means of judging of the grounds on which the foregoing species have been proposed, to present at a glance, so far as it can be done in figures, the relations between the several characters in different species. I hope in this way to satisfy naturalists, that such differences in the tracks could not have belonged to mere varieties as to age or mode of progression, nor have resulted from the character of the mud, but must have required different species of animals to produce them. In other words, I hope to show that these differences are quite as great as they are between the tracks of different living species. In constructing the table, I have taken 100 as the highest number in the preceding details of the characters, and calculated the proportion which the same character in the other species bears to this maximum. It may happen, as in the second column, that a character is at a maximum in several species.

Table 1

	Divarication of			Length of							Distance				Length of the phalanges of									Ratio between the length of the foot and the step.
	The lateral toes.	The inner and middle.	The middle and outer.	The middle toe.	The inner.	The outer.	The foot.	The step.	The claw.	Middle toe beyond the rest.	Between the lateral toes.	Between the inner and middle.	Between the middle and outer.	Width of the toes.	The inner toes.			The middle toes.			The outer toes.			
B. giganteum	50	60	43	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	3.4
B. sillimanium	44	100	43	48	44	44	50	38	57	55	42	54	47	56	46	36	35	43	46	24	23	40	46	2.4
B. loxonyx	34	80	29	48	44	44	50	56	57	55	48	54	53	56	43	38	47	56	53	30	43	60	62	3.7
B. expansum	75	100	86	37	32	40	40	46	63	44	50	57	45	50	35	29	41	43	50	48	40	45	54	3.8
B. gracillimum	75	100	71	18	17	16	16	14	23	16	16	16	18	16	11	12	14	13	15	14	13	22	25	3
B. parallelum	22	22	33	20	18	16	20	34	23	26	12	23	21	20	21	21	24	26	32	17	13	20	23	5.8
Aeth. lyellianus	50	60	57	51	42	42	50		57	60	40	55	52	56	43	43	53	60	65	37	40	50	62	
Aeth. minor	100	100	100	26	25	23	24	17	40	28	28	27	33	28	33	33	27	26	27	24	23	30	21	2.4

GROUP II.

Characters. — Tridactylous, leptodactylous, bipedal, vertebrated.

Genus I. STEROPEZOUM

Toes somewhat keel-shaped; the middle and inner ones curved towards the line of direction; the outer one slightly bent from that line. Heel distinct and large; leaving an impression on mud of radiating ridges and furrows, sloping upwards very gradually behind, more abruptly before, leaving a ridge on the track, at least as high as the general surface, between the heel and the toes, which also slope upwards posteriorly. This ridge, however, has usually a depression in it, connecting the heel and the outer toe. But, upon the whole, we infer that the foot arches upwards between the toes and the heel, leaving, however, a slight ridge along its outer part. Bottom of the heel a little elevated above that of the toes.

Remark. — Of the nature of that structure of the heel, which produces on the track radiating ridges, somewhat resembling fine ripple-marks, I feel in doubt, yet am inclined to believe them the result of rugosities, or striæ and ridges on the heel.

Species 1. STEROPEZOUM INGENS. (Pl. V. Fig. 1.)

Ornithichnites ingens, Am. Jour. Science, Vol. XXIX. p. 319.
Ornithoidichnites ingens, Mass. Geol. Rep., Plate 40, fig. 27.
Nos. 63- 66 in Cabinet.

Divarication of the lateral toes, 60°; of the inner and middle toes, 35°; of the middle and outer toes, 25°. Length of the middle toe, 13 inches; of the inner toe, 9.75 inches, of the outer toe, 10.25 inches; of the heel, 10 inches; of the foot, 23 to 25 inches; of the step, 40 to 72 inches, of the middle toe beyond the lateral

ones, 4.5 inches. Width of the foot where the toes are articulated to the heel, 1.5 inch; of the heel in its widest part, 8 inches. Distance between the tips of the lateral toes, 9.5 inches; between the inner and middle toes, 6.7 inches; between the tips of the middle and outer toes, 6.3 inches. Versed sine of inward curvature in the middle toe, 0.7 inch; in the inner toe, 0.5 inch. Track shown, of the natural size, on Plate 5, fig. 1.

Remarks. — The only locality with which I am acquainted, of the tracks of this remarkable species, is at the Horse Race in Gill, whence I have obtained only one well-characterized specimen. But I measured its dimensions from several specimens in the rock there, so as to feel confident that I have not overrated them; and yet they are of a very extraordinary character. The animal, however, could not have been as large as the *Brontozoum giganteum*, already described, or the *Otozoum Moodii*, yet to be described.

Species 2. STEROPEZOUM ELEGANS. (Pl. V. Fig. 2.)

Ornithichnites diversus, Am. Jour. Science, Vol. XXIX. fig. 22.
Ornithoidichnites elegans, Mass. Geol. Report, Plate 41, fig. 28.
Nos. 67, 68, 70 - 72, in Cabinet.

Divarication of the lateral toes, 60° to 65°; of the inner and middle toes, 35°; of the middle and outer toes, 30°. Length of the middle toe, 4.4 inches; of the inner toe, 2.3 inches; of the outer toe, 2.8 inches; of the heel, 2.2 inches; of the foot, 6 to 7 inches; of the step, 12 to 21 inches; of the middle toe beyond the lateral ones, 2.4 inches. Width of the foot at the roots of the toes, 1 inch; of the heel, 2 inches. Distance between the tips of the lateral toes, 3 inches; between the inner and middle toes, 2.8 to 3.1 inches; between the middle and outer toe, 2.4 to 2.8 inches. Versed sine of inward curvature in the inner toe, 0.15 inch; of the

middle toe, 0.35 inch; of the outer toe, outward, 0.2 inch. Track shown, of the natural size, on Plate 5, fig. 2.

Localities. — Marsh's Quarry, Montague; north part of Montague; two miles south of Turner's Falls; and Horse Race, Gill.

Species 3. STEROPEZOUM ELEGANTIUS. (Pl. V. Fig. 3)

Ornithoidichnites elegantior, Mass. Geol. Rep., Plate 42, fig. 30.

Ornithichnites diversus, β. *platydactylus*, Am. Jour. Sci., Vol. XXIX. p. 3l9.

Nos. 74- 76, 79, in Cabinet.

Divarication of the lateral toes, 70°; of the inner and middle toes, 30°; of the middle and outer toes, 40°. Length of the middle toe, 2 inches; of the inner toe, 1.1 inch; of the outer toe, 1.3 inch; of the heel, 1 inch; of the foot, 7 inches; of the step, 5.5 inches to 9 inches; of the middle toe beyond the others, 1.2 inch. Distance between the tips of the lateral toes, 1.5 inch; between the outer and middle toes, 1.4 inch; between the inner and middle toes, 1.4 inch. Width of the foot at the roots of the toes, 0.4 inch. Track shown, of the natural size, on Plate 5, fig. 3.

Localities. — Montague, Marsh's Quarry; Horse Race, Gill; and South Hadley.

Remarks. — I acknowledge it to be quite possible that the tracks of this species may have been made by the young of *S. elegans*. Yet the table of ratios annexed to this group will show quite a difference, in some respects, between them, besides their size.

Genus II. ARGOZOUM.

Digitigrade, sometimes nearly plantigrade, tridigitate. Toes curved; the lateral ones mostly outwards, somewhat keel-shaped; leptodactylous; vertebrated.

Remarks. — I acknowledge it to be possible that a distinct heel may belong to this genus, although my specimens do not show it. In that case, the first specie s, *A*. *Redfie ldianum*, would not differ enough from the *Steropezoum ingens* to be separated from it, although some of its characters do not well agree with that species. But as I have seen quite a number of specimens of the tracks of most of the species of this genus, and no very distinct heel is visible, although some of the impressions are quite deep, I group them under a distinct genus; and if that should fail, yet all the species will maintain their ground as distinct species of *Steropezoum*, except the first.

Species 1. ARGOZOUM REDFIELDIANUM. (Pl. VI. Fig. 1.)

Ornithoidichnites Redfieldii, Am. Jour. Science, Vol. XLVII., Plate 3, fig. 1.

Nos. 145, 146, 149, in Cabinet.

Divarication of the lateral toes, 75°; of the inner and middle toes, 30°; of the middle and outer toes, 45°. Length of the middle toe, 12 inches, of the inner toe, 8 inches; of the outer toe, 9.5 inches; of the claw, 2 inches; of the foot, 12.5 inches; of the step, 30 inches. Distance between the tips of the lateral toes, 12 inches; between the inner and middle toes, 7.8 inches; between the middle and outer toes, 9 inches. Length of the middle toe beyond the others , 6 inches . Versed sine of the inward curvat ure of the middle toe, 0.7 inch. Track shown, of the natural size, on Plate 6, fig. 1.

Locality. — Chicopee Falls, on hard, quartzose, and sometimes calcareous, gray sandstone.

Dedicated to my friend, William C. Redfield, Esq., of New

York, whose labors in geology, as well as in meteorology, have inspired the highest respect.

Remarks. — This is the only leptodactylous species on whose tracks I have been able to discover a claw, though I can not doubt its existence on them all; but it did not make an impression on the mud distinct from the toe. In the present species it is only the claw, and not the phalangeal impressions, that are exhibited, although these also were probably made, but were too slight to be retained.

This, also, is the only species with whose tracks I have discovered coprolites. At Chicopee Falls, where alone this species has been found, I have obtained several specimens of these bodies. These have been analyzed by Dr. S. L. Dana, as already stated; and the results afford one of the most curious examples of the application of chemistry to geology which the records of those sciences contain.

Species 2. ARGOZOUM DISPARI-DIGITATUM. (Pl. VI. Fig. 3.)

Ornithoidichnites macrodactylus, Mass. Geol. Report, Plate 43, fig. 35.

Nos. 69, 73, 91-94, in Cabinet.

Divarication of the lateral toes, 40° to 55°; of the inner and middle toes, 18° to 30°; of the middle and outer toes, 20° to 25°. Length of the middle toe, 5.3 inches; of the inner toe, 2.8 inches; of the outer toe, 3.2 inches; of the foot, 5 to 6 inches; of the step, 15 inches. Distance between the tips of the lateral toes, 2.2 to 3 inches; between the inner and middle toes, 2.1 to 2.8 inches; between the outer and middle toes, 2 to 3.4 inches. Projection of the middle toe beyond the others, 1.3 to 2.4 inches. Angle be-

twe en the axi s of the foo t and the lin e of dir ectio n, 0°. Dis tance of the heel from do., 0.5 inch. Track shown, of the natural size, on Plate 6, fig. 3.

Localities. — Wethersfield and Chicopee Falls.

Species 3. ARGOZOUM PARI-DIGITATUM . (Pl. VI. Fig. 4, 5.)

Ornithichnites minimus, Am. Jour. Science, Vol. XXIX.

Ornithoidichnites isodactylus, Mass. Geol. Report, Plate 45, figs. 38, 39.

Nos. 98 - 100, 229, in Cabinet.

Divarication of the lateral toes, 80° to 90°; of the inner and middle toes, 40°; of the middle and outer toes, 40° to 50°. Length of the middle toe, 1.5 to 1.8 inch; of the inner toe, 1.1 to 1.3 in ch; of th e ou ter to e, 1. 1 to 1. 3 in ch. Le ngth of th e fo ot, 1. 5 to 2 inches; of the step, 10 to 12 inches (?); of the middle toe beyond the others, 0.7 to 0.9 inch. Distance between the tips of the lateral toes, 1.8 inch; between the inner and middle toes, 1.1 inch; between the outer and middle toes, 1.4 inch. Toes nearly straight. Angle between the axis of the foot and the line of direction, 20°. Track shown, of the natura l size, on Plate 6, figs. 4 and 5; the latter, perhaps, a little distorted.

Localities. — Horse Race and Turner's Falls in Gill, and Wethersfield.

Species 4. ARGOZOUM MINIMUM. (Pl. VI. Fig. 6.)

Ornithoidichnites minimus, Mass. Geol. Report, Plate 15, fig. 41.

Nos. 85 and 106, in Cabinet.

Divari cation of the latera l toes, 90°; of the inner and middle toe s, 50° ; of the out er and mid dle toe s, 40° . Len gth of the mid - dle toe, 0.85 inch; of the inner toe, 0.6 inch; of the outer toe,

0.7 inch. Length of the foot, 0.9 inch; of the step, 3.2 inches; of the middle toe beyond the others, 0.35 inch. Distance between the tips of the lateral toes, 1 to 1.2 inch; between the inner and middle toes, 0.6 to 0.7 inch; between the outer and middle toes, 0.6 to 0.7 inch. Angle between the axis of the foot and the line of direction, 10°. Track shown, of the natural size, on Plate 6, fig. 6.

Locality. — Wethersfield, at the Cove; on red shale.

Remarks. — Since the discovery of the *Macropterna rhynchosauroidea*, I have been in considerable doubt whether the above species should not be referred to it. Certainly the two have been confounded. But I have a few specimens of the *Argozoum minimum* quite distinct, which, as yet, I cannot regard as a Macropterna, and therefore shall let this species remain for the present.

Genus V. PLATYPTERNA.

Heel very broad, as well as the foot at the roots of the toes. Toes slender; for the most part curved. Feet plantigrade.

Remarks. — This elegant genus is distinguished by the unusual breadth of the posterior part of the foot, including the heel; and yet, on many specimens of its tracks, there is no appearance of a heel. It is wanting, also, in the curved or angular space between the toes and the heel which belongs to the genus *Steropezoum*. In most of the specimens, the impression of the heel is rounded posteriorly; but in the *P. tenuis* the heel disappears so gradually, by an upward slope of the foot, that its exact termination on the stone is marked with difficulty. The first species may be only the *Ornithopus gallinaceus*, wanting in the hind toe, and were not some of my specimens of *O. gallinaceus* deeply impressed upon the stone, I should be led to conclude them identical.

Species 1. PLATYPTERNA DEANIANA. (Pl. VII. Fig. 1.)

Ornithoidichnites Deanii, Mass. Geol. Report, Plate 42, figs 31, 32, and Plate 44, fig. 37.

Nos. 78 - 83, 96, in Cabinet.

Divarication of the lateral toes, 70°; of the inner and middle toes, 45°; of the middle and outer toes, 25°. Length of the middle toe, 3 inches; of the inner toe, 1.5 inch; of the outer toe, 1.8 inch; of the heel, 1. 1 to 1. 2 inch; of the foot, 4 to 4. 5 inches; of the step, 9 to 12 inches; of the middle toe beyond the rest, 1.8 inch. Width of the heel, 0.9 to 1.2 inch; at the place of insertion of the toes, 1 inch. Distance between the tips of the lateral toes, 2 to 2.5 inches; between the inner and middle toes, 2.1 to 2.15 inches; between the outer and middle toes, 2 to 2.35 inches. Versed sine of the curvature of the inner toe, inwards, 0.17 inch; of the middle toe, inwards, 0.12 inch; of the outer toe, outwards, 0.22 inch. Track shown, of the natural size, on Plate 7, fig. 1.

Locality. — Wethersfield, at the Cove; on red shale.

This species is dedicated to Dr. James Deane, of Greenfield, who first called my attention to the subject of footmarks, and who subsequently investigated it with much success.

Species 2. PLATYPTERNA TENUIS. (Pl. VII. Fig. 2, 3.)

Ornithoidichnites tenuis, Mass. Geol. Report, Plate 43, figs. 33, 34.

Nos. 84 - 87, 208, in Cabinet.

Divarication of the lateral toes, 45° to 60°; of the inner and middle toes, 20° to 30°; of the middle and outer toes, 25° to 30°. Length of the middle toe, 2 inches; of the inner toe, 1 inch; of the outer toe, 1. 3 inch; of the heel, 0. 6 inch; of the foot, 2. 1 to 2.7 inches; of the step, 7 (?) inches. Width of the heel, 0.6 inch.

Distance between the tips of the lateral toes, 1.1 to 1.7 inch; between the inner and middle toes, 1.1 to 1.4 inch; between the outer and middle toes, 1 to 1.4 inch. Length of the middle toe beyond the others, 0.9 to 1.1 inch. Track shown, of the natural size, on Plate 7, figs. 2 and 3; there being a slight difference between them.

Locality. — Wethersfield, at the Cove; on red shale.

Species 3. PLATYPTERNA DELICATULA. (Pl. VII. Fig. 4.)

Ornithoidichnites delicatulus, Mass. Geol. Report, Plate 45, fig. 40.

Nos. 103, 104, in Cabinet.

Divarication of the lateral toes, 40°; of the inner and middle toes, 22°; of the middle and outer toes, 18°. Length of the middle toe, 1.1 inch; of the inner toe, 0.65 inch; of the outer toe, 0.75 inch; of the heel, 0.4 inch; of the foot, 1.5 inch; of the step, 3 inches; of the middle toe beyond the rest, 0.5 inch. Width of the heel, 0.35 inch; of the foot at the roots of the toes, 0.25 inch. Distance between the tips of the lateral toes, 0.6 inch; between the inner and middle toes, 0.6 inch; between the outer and middle toes, 0.55 inch. Toes slightly curved. Track shown, of the natural size, on Plate 7, fig. 4.

Locality. — Wethersfield, at the Cove; on red shale.

Affinities of the Group. — The biped character of the animals and their tridactyle feet would seem, were we to judge by living animals, to ally them to birds; while the deficiency of the hind toe would lead us to regard most of them as Grallatores. The inference of Dr. Dana, also, from the coprolites of one species, is that they were dropped by such omnivorous birds as those which produce the guano. I shall show in this paper, however, that biped

batrachians once lived, as well as tridactyle quadrupeds, - tridactyle at least on the fore foot.

Table of the Ratio between the several Characters of Group II., on a Scale of 100.

GROUP III.

Toes four; three pointing forward; the hind toe lying on the inside of the foot and on a prolongation backward of the outer toe.

Genus VI. ORNITHOPUS.

Characters the same as for the Group.

Species 1. ORNITHOPUS ADAMSANUS. (Pl. VII. Fig. 5.)

Ornithoidichnites Danæ, Am. Jour. Science, Vol. XLVII., Plate 4, fig. 5.

No. 125 in Cabinet.

Divarication of the lateral toes, 100°; of the inner and middle toes, 40°; of the middle and outer toes, 60°; of the middle and hind toes, 140°. Length of the middle toe, 6.5 inches; of the

Table 2

	Divarication of			Length of							Distance between			Versed sine of			Width of		
	The lateral toes.	The inner and middle.	The middle and outer.	The inner toe.	The middle toe.	The outer toe.	The foot.	The step.	Middle toe beyond the rest.	The heel.	The tips of the lateral toes.	The inner and middle.	The outer and middle.	The inner toe.	The middle toe.	The outer toe.	The heel.	The foot at the roots of the toes.	Ratio between the length of the foot and the step.
Steropezoum ingens	67	70	56	100	100	100	100	100	75	100	80	81	70	100	100		100	100	2.3
" *elegans*	70	70	67	24	34	27	27	21	40	22	25	36	29	30	50	50	25	67	2.5
" *elegantius*	78	60	90	11	15	13	10	11	20		12	18	15					27	2.2
Argozoum redfieldianum	84	60	100	82	92	93	52	54	100		100	100	100		100				2.4
" *dispari-digitatum*	53	48	49	29	41	31	23	27	30		22	28	30						2.5
" *pari-digitatum*	94	80	100	12	13	12	7	20	12		15	14	15						5.5(?)
" *minimum*	100	100	90	6	9	6	4	6	6		9	8	8						3.5
Platypterna deaniana	78	90	56	15	23	17	19	19	30	12	18	27	24	34	10	55	11	67	2.5
" *tenuis*	59	50	60	10	15	13	10	12	16	6	12	17	13				8	40	2.9
" *delicatula*	44	45	40	7	8	7	6	5	8	4	5	8	6				4	17	2

inner toe, 4.2 inches; of the outer toe, 5.2 inches; of the hind toe, 3 inches. Length of the heel, 6 inches (?). Width of the heel, 3.5 inches; of the foot at the roots of the toes, 2.2 inches. Length of the middle toe beyond the others, 4.3 inches. Distance between the tips of the lateral toes, 7 inches; between the inner and middle toes, 4.5 inches; between the outer and middle toes, 6.5 inches; between the middle and hind toes, 11 inches. Track shown, of the natural size, on Plate 7, fig. 5.

Locality. — Montague City, a few rods east of the canal, on the road to Boston.

Remark. — This is a somewhat doubtful species. The single specimen obtained I could not refer to any known species, and therefore have dedicated it to Professor C. B. Adams, of Amherst College. The hind toe is not very distinct. The heel, or rather the tarsal bone, seems to have sloped upwards at a small angle.

Species 2. ORNITHOPUS GALLINACEUS. (Pl. VIII. Fig. 1.)

Ornithoidichnites tetradactylus, Mass. Geol. Report, Plate 46, fig. 42.

Nos. 112-117, 172, 174, in Cabinet.

Divarication of the lateral toes, 60° to 80°; of the inner and middle toes, 35°; of the middle and outer toes, 45°; of the middle and hind toes, 140°. Length of the middle toe, 2.75 inches; of the inner toe, 1.5 inch; of the outer toe, 1.8 inch; of the hind toe, 1.3 inch; of the foot, exclusive of the hind toe, 2.5 to 3 inches; of the step, 7 inches, of the middle toe beyond the others, 1.5 inch. Distance between the tips of the lateral toes, 2.37 inches; between the inner and middle toes, 1.9 inch; between the outer and middle toes, 1.8 inch; between the middle and hind toes, 4.2 inches. Foot plantigrade. Toes nearly straight. Track shown, of the natural size, on Plate 8, fig. 1.

Localities. — Horse Race, Gill; Chicopee Falls; and Wethersfield, at the Cove.

Remarks. — By comparing Plate 7, fig. 1, with Plate 17, fig. 4, leaving out the hind toe of the latter, the force of the remark already made, that the *Platypterna Deaniana* may be only the *Ornithopus gallinaceus* divested of the hind toe, will be appreciated. And we know that the hind toe frequently disappears.

Species 3. ORNITHOPUS GRACILIOR. (Pl. VIII. Fig. 2.)

Ornithoidichnites gracilior, Mass. Geol. Rep., Plate 46, fig. 43.
Nos. 118,119, 208, in Cabinet.

Divarication of the lateral toes, 75° to 90°; of the inner and middle toes, 40°; of the outer and middle toes, 35° to 50°; of the middle and hind toes, 110° to 130°. Length of the middle toe, 1.5 inch; of the inner toe, 1.1 inch, of the outer toe, l.1 inch. Hind toe digitigrade, articulated high upon the tarsus; length of the same from the roots of the toes, 0.8 inch; of the part that impresses the ground in walking, 0.3 to 0.5 inch. Middle toe rather keel-shaped. Toes nearly straight. Length of the foot, excluding the hind toe, 1.4 to 1.7 inch; of the middle toe beyond the rest, 0.7 inch. Distance between the tips of the lateral toes, 1.7 inch; between the inner and middle toes, 1.05 inch; between the middle and outer toes, 1.3 inch; between the middle and hind toes, 2 inches. Track shown, of the natural size, on Plate 8, fig. 2.

Locality. — Wethersfield.

Species 4. ORNITHOPUS LORIPES. (Pl. VIII. Fig. 3.)

Ornithoidichnites divaricatus, Mass. Geol. Rep., Plate 44, fig. 36.
Nos. 95, 97, 101, 102, 121, 143, in Cabinet.

Divarication of the lateral toes, 100°; of the inner and middle toes, 50°; of the middle and outer toes, 50°; of the middle and hind toe, 120°. Length of the middle toe, 5 inches; of the inner toe, 3.75 inches; of the outer toe, 4 inches; of the foot, 6.5 to 7 inches; of the heel, 2 inches; of the hind toe, 2.75 inches; of the step, 16 to 23 inches; of the middle toe beyond the rest, 2.5 inches. Distance between the tips of the lateral toes, 5.7 inches; between the inner and middle toes, 3.9 inches; between the middle and outer toes, 3.9 inches; between the middle and hind toes, 6.8 inches. Versed sine of the backward curvature of the hind toe, 0.2 inch; of the inward curvature of the inner toe, 0.4 inch; of the same in the middle toe, 0.6 inch; of the same in the outer toe, 0.2 inch. Angle between the axis of the foot and the line of direction, 10° inwards. Distance of the middle of the heel from the line of direction, 3 inches. Track shown, of the natural size, on Plate 8, fig. 3.

Localities. — Horse Race, southwest part of Montague; Chicopee Falls; Cabotville; Northampton; Wethersfield.

Remarks. — I am so well satisfied that the track which I described in the Massachusetts Geological Report as the *Ornithoidichnites divaricatus*, having only three toes, is the same as that made by the *Ornithopus loripes*, that I have united them. For when the fourth toe is left out of the account, they do not seem distinct; and that toe, so frequently wanting, I do not regard as sufficient to characterize a species.

Plate 24, fig. 4, is copied and reduced from a specimen in my cabinet obtained at Marsh's Quarry in Montague. It will give a good idea of the relative situation of the feet when the animal walked.

Species 5. ORNITHOPUS RECTUS. (Pl. V. Fig. 4.)

Nos. 244, 245, in Cabinet.

Divarication of the front lateral toes, 75° to 80°; of the inner and middle toes, 40°; of the middle and outer toes, 40°; of the inner and hind toes, 40° to 60°. Length of the hind toe, 1.8 inch; of the inner front toe, 2.7 inches; of the middle front toe, 3.5 inches; of the outer toe, 2.9 inches; of the middle toe beyond the rest, 1.4 inch; of the foot, 4.5 inches; of the step, 18 inches. Heel rather broad, and extending back farther than the hind toe. Distance between the tips of the hind toe and the middle front toe, 4 inches, between the second and middle toes, 2.2 inches; between the middle and outer toes, 2.4 inches; between the second and outer toes, 3.6 inches; between the rows of tracks, 7 inches. Axis of the foot nearly coincident with the line of direction. Track shown, of the natural size, on Plate 5, fig. 4.

Locality. — Horse Race, Gill; at the quarry, three miles above Turner's Falls; on gray micaceous sandstone.

Remarks. — This species was discovered while this paper was passing through the press. The quite distinct specimens on which it is founded were presented to me by Mr. Ptolemy P. Severance, who has charge of the quarries and public works at Turner's Falls. I was in doubt whether to refer this species to *Ornithopus* or *Plectropus*; but the shortness of the heel and the nearness of the roots of the hind toe to the roots of the others have led me to place it as a fifth species of the former. In the great distance between the tracks of the right and left foot, it differs from all other species except the *Harpedactylus concameratus*; and one cannot but inquire whether possibly the animal was not a quadruped, moving forward like the Proteus, as described in another part of this paper. At present, however, the evidence is very slight of a quadrupedal char-

acter in this animal . The hind toe, it will be seen, stands at nearly right angles to the axis of the foot; not on a posterior prolongation of the outer front toe, as is usual in four-toed living birds, and in most species of *Ornithopus*.

Affinities of the Group. — The same characters which ally the last group to birds exist in this also. We have, in addition, a hind toe, situated as in many of the four-toed birds; so that its impression on mud lies on a posterior prolongation of the outer toe. Furthermore, in one species at least (the *O. gracilior*), we have proof that the hind toe was articu lated high upon the tarsus, so that only its extremity reached the ground, as is the fact with many birds. So that, in the present group, the relations to birds are stronger than in any of the other leptodactylous species. We have proof that some fossil animals, with tridactylous feet, were quadrupeds , and probab ly some bipeds were batrac hians; but I know of no example in living or fossil nature in which a biped with four toes, situated as in this group, was any thing else than a bird.

Table of the Ratio between the several Characters of this Group, on a scale of 100.

	Divarication of				Length of								Distance between				Versed sine of			Width of		
	The lateral toes.	The inner and middle.	The outer and middle.	The middle and hind.	The inner toe.	The middle toe.	The outer toe.	The hind toe.	The foot.	The step.	Middle toe beyond the rest	The heel.	The tips of the lateral toes.	The inner and middle.	The outer and middle.	The middle and hind.	Of the inner toe.	Of the middle toe.	The outer toe.	The heel.	The foot at the roots of the toes.	Ratio between the length of the foot and the step.
Ornithopus adamsanus	100	80	100	100	100	100	100	100			100	100	100	100	100	100	0	0	0	100	100	
" *gallinaceus*	76	70	75	100	36	42	35	43	41	36	33		34	42	28	38	0	0	0		23	2.5
" *gracilior*	82	80	71	86	26	23	21	27	24		15		24	23	20	18	0	0	0			
" *loripes*	100	100	82	86	89	77	77	92	100	100	56	33	81	87	60	62	100	100	10	43	68	2.9
" *rectus*	77	57	83	75	64	54	56	60	82	90	42		50	55	43						44	4

GROUP IV.

Feet tetradactylous, plantigrade; three of the toes directed forward, and the fourth situated far back on the heel, making various angles with the axis of the foot. Heel large or long, consisting sometimes of the whole tarsus.

Genus VII. POLEMARCHUS.

Heel very large and rounded, making an impression as deep as the toes. Three slender toes directed forward, the hind toe situated far back on the heel, and at right angles to the axis of the foot.

Species 1. POLEMARCHUS GIGAS. (Pl. IX. Fig. 1.)

Sauroidichnites polemarchius, Mass. Geol. Report, Plate 35, fig. 17.

Nos. 34-36, in Cabinet.

Divarication of the lateral toes, 45°; of the inner and middle toes, 20°; of the middle and outer toes, 25°; of the middle and fourth toes, 80°. Length of the middle toe, 11.2 inches; of the inner toe, 8.5 inches; of the outer toe, 8.3 inches; of the hind toe, 2.5 inches; of the heel, 3.8 inches; of the middle toe beyond the rest, 3.2 inches; of the foot, 15 inches; of the step, 48 inches. Width of the heel, 3.9 inches; of the foot at the roots of the toes, 2.5 inches. Distance between the tips of the lateral toes, 6.6 to 8.7 inches; between the inner and middle toes, 4 to 4.6 inches; between the middle and outer toes, 5.5 to 7.5 inches; between the middle and hind toe, 13 inches. Fourth toe straight. Versed sine of the inward curvature of the inner toe, 0.45 inch; of the inward curvature of the middle toe, 0.9 inch; of the inward curva-

ture of the outer toe, 0.3 inch. Foot plantigrade. Toes very slender. Track shown, of the natural size, on Plate 9, fig. 1.

Localities. — Chicopee Falls, in the bed of the river; and at a quarry one mile south of Cabotville.

Remark. — I have not met with a sufficient number of these tracks in place to be sure that they were not made by a quadruped.

Genus VIII. PLECTROPUS.

Heel elongated, apparently extending to the tarsal joint, quite narrow, making an impression as deep as the toes with its anterior part. Fourth toe procee ding at right angles from the heel behind the roots of the toes, resembling the spur on some of the gallinaceous birds.

Species 1. PLECTROPUS MINITANS. (Pl. IX. Figs. 2, 3.)

Sauroidichnites minitans, Mass. Geol. Report, Plate 33, fig. 11.

Nos. 17 - 23, 153, in Cabinet.

Divarication of the lateral toes, 87° to 95°; of the inner and middle toes, 37° to 42°; of the middle and outer toes, 45° to 60°; of the middle and hind toes, 90° to 110°. Length of the middle toe, 2.5 to 3.8 inches; of the inner toe, 1.7 to 2.6 inches; of the outer toe, 1.8 to 2.5 inches ; of the hind toe, 0.9 inch; of the heel, 1 to 2 inches; of the foot, 3.5 to 6 inches; of the step, 15 to 17 inches. Width of the heel, 0.4 to 0.5 inch; of the foot at the roots of the front toes, 0.4 inch. Distance between the tips of the lateral toes, 2.7 to 3.7 inches; between the inner and middle toes, 1.6 to 2.6 inches; between the outer and middle toes, 2.4 to 2.9 inches; between the middle and hind toes, 3.3 to 4.8 inches. Length of the middle toe beyond the rest, 1.5 to 2 inches. Versed sine of the inward curvature of the middle toe, 0.15 inch; of the outward curva-

ture of the outer toe, 0.1 inch. Heel sloping upwards posteriorly, in a gradual manner, so as to leave an impression on the mud a greater or less distance. Feet for the most part plantigrade. Distance between the roots of the three forward toes and the hind toe, 0.7 to 0.9 inch. Track shown, of the natural size, on Plate 9, figs. 2, 3.

Localities. — Chicopee Falls, one mile south of Cabotville; and at Wethersfield.

Remarks. — The singular manner in which the hind toe on the track of this and the following species, from being on the upper layer at right angles with the heel, changes in passing downwards, so as to correspond almost with that of *Ornithopus gallinaceus,* has been already noticed in describing the tenth general character. This fact shows us that little dependence can be placed upon this character; and it approximates two species of tracks, which, at first view, seem very much unlike, namely, *Ornithopus gallinaceus* and *Plectropus minitans*.

Species 2. PLECTROPUS LONGIPES. (Pl. VIII. Fig.4; Pl. X. Fig. l-3.)

Sauroidichnites minitans, Mass. Geol. Rep., Plate 33, fig. 12.

Nos. 24-26, 154, 155, 163, 164, 171, in Cabinet.

Divarication of the lateral toes, 70° to 75°; of the inner and middle toes, 30° to 37°; of the middle and outer toes, 40° to 45°; of the middle and hind toes, 90° to 100°. Length of the middle toe, 2.1 to 3.5 inches; of the inner toe, 1.4 to 2 inches; of the outer toe, 1.7 to 2.5 inches; of the hind toe, 0.6 to 1 inch; of the heel, 2.6 to 5.7 inches; of the foot, 6 to 9 inches; of the step, 14 to 17 inches. Width of the heel, 0.3 inch; of the foot at the roots of the front toes, 0.4 inch. Distance between the tips of the lateral toes, 2.2 to 2.6 inches; between the inner and middle toes, 1.4 to 1.9 inch; between the outer and middle toes, 1.6 to

2.3 inches; between the middle and hind toes, 3.3 to 4.7 inches. Distance between the roots of the front toes and the root of the hind toe, 0.8 to 1.3 inch. Length of the middle toe beyond the rest, 1 to 1.6 inch. Toes slightly curved; the two front inner ones inward, and the outer one outward. Axis of the foot corresponding nearly with the line of direction. The whole length of the tarsal bone reaches the ground usually in walking. Track shown, of the natural size, on Plate 8, fig 4, and Plate 10, figs. 1, 2, 3.

Localities. — Wethersfield, at the Cove, on gray shale, or micaceous sandstone, at Turner's Falls, and Cabotville.

Remarks. — Nearly all the facts within my reach would indicate that this animal was a biped. Yet the long heel and side toe, so like a lacertilian, have long led me to suspect it might be a quadruped. I have sometimes found two tracks almost in the same spot, as is common with quadrupeds. But still the most instructive case of this kind, already referred to under the third general character, does not confirm this supposition. By a careful dissection of No. 171 in my cabinet, I found, on three successive layers of the rock, three impressions so unlike as to perplex the most practised eye, but I think I now understand them. The uppermost layer presents a track as exhibited on Plate 10, fig. 1, having five toes in front and one articulated to the tarsus, or tarso-metatarsus. The lowest layer, represented on Plate 10, fig. 3, shows five toes most symmetrically arranged, and scarcely exciting a suspicion that there could be two tracks. But I felt quite confident that existing animals would not allow us to give six toes to the foot of any biped or quadruped; and therefore I ventured, at the risk of spoiling the specimen, to cleave it asunder once more; when I was presented with the outline shown on Plate 10, fig. 2, which seems to me to solve the enigma to a considerable extent. It shows, in my

opinion, the impression of two feet nearly in the same spot, one of them a right foot, and the other a left. If they were those of a quadruped, however, they ought to be both right or both left. I regard the toes *a, b, c,* as belonging to the fore foot, and *d* as its fourth or lateral toe; while *e, f, g,* are the three front toes of the hind foot, and *h* is its hind toe, which, on this layer, is much more oblique to the heel than on the upper layer, Plate 10, fig. 1, as I have observed to be the case in other instances, and which I impute to a slight onward movement in the mud, as the track was filled up. I at first regarded this specimen as a distinct species from the *P. longipes.* But the resemblance is too close between them to allow of a separation. The dimensions of the two tracks on Plate 10, fig. 2, are, however, considerably different, as the following statement of their dimensions will show:—

Fore foot. — Divarication of the lateral toes, 75°; of the inner and middle toes, 35°; of the outer and middle toes, 40°; of the middle and hind toes, 70°. Length of the middle toe, 2.8 inches; of the inner toe, 1.6 inch; of the outer toe, 1.8 inch; of the hind toe, 1 inch. Distance between the tips of the lateral toes, 2.4 inches; between the inner and middle toes, 1.8 inch; between the outer and middle toes, 2.1 inches; between the middle and hind toes, 3.5 inches. Length of the middle toe beyond the rest, 1.6 inch. Toes somewhat bent.

Hind foot. — Divarication of the lateral toes, 80°; of the inner and middle toes, 40°; of the outer and middle toes, 40°; of the middle and hind toes, 115°. Length of the middle toe, 2.2 inches; of the inner toe, 1.5 inch; of the outer toe, 1.7 inch; of the hind toe, 0.7 inch. Distance between the tips of the lateral toes, 2.2 inches; between the inner and middle toes, 1.4 inch; between the

outer and middle toes, 1.6 inch; between the middle and hind toes, 3.3 inches. Toes slightly curved.

It is clear, I think, from the angles of divarication of the forward toes, as well as from the length of the toes and the position of the lateral or hind toes, that the front track of this specimen must have been made by a left foot, and the other by a right foot; although I feel a little doubt whether the toe *d* is the hind toe of the fore foot, as it only shows its extremity. The hind foot, as appears from the above measurements, is smaller than the fore foot; which is not usual in batrachians or lacertilians. Upon the whole, I cannot make out this track to be of quadrupedal origin, and yet its general character is such as to leave me still in doubt whether the animal was not a quadruped.

One other specimen of the tracks of this species (No. 163 of Cabinet), split twice asunder, shows the forms delineated on Plate 15, figs. 17-19. Here it is not obvious that two tracks are united. Indeed, had not the case above given furnished the clew, we should not suspect from this specimen that more than one track existed. The occurrence of two specimens of these double tracks strengthens the suspicion, that the animal that made them (*Plectropus longipes*) was a quadruped.

Genus IX. TRIÆNOPUS.

Feet tridactyle in front, plantigrade; divarication small: toes very slender; hind toe proceeding from the extremity, or near the extremity, of the heel. Heel very slender. Gregarious.

Remark. — The distinction between this and the preceding genus is not striking, and perhaps not permanent. It consists in the much more slender and delicate character of the whole foot, and in the position of the fourth toe. But I have some reason to suspect

that the species of *Triænopus* may be quadrupeds, or rather that there is but one species of this genus, and that a quadruped, with feet quite unlike. For, in several cases, I find two tracks occupying almost exactly the same place, and pointing in the same direction, as has been shown in the case of *Plectropus longipes*. But the tracks of *Triænopus* are extremely crowded together; and although more perfect than any others I have ever found, yet I have not been able to trace out consecutive tracks. So brittle is the beautiful red shale on which they are imprinted, that it is rare to be able to obtain specimens more than a foot square.

Species 1. TRIÆNOPUS BAILEYANUS. (Pl. X. Fig. 4.)

Sauroidichnites Baileyi, Mass. Geol. Report, Plate 32, figs. 8, 9.

Nos. 13-16, 161, 162, 165, 166, 168, 169, 175, 178, 179, 212, in Cabinet.

Divarication of the lateral toes, 35° to 40°; of the inner and middle toes, 15° to 20°; of the middle and outer toes, 15° to 20°; of the middle and hind toe, 30° to 40°. Length of the middle toe, 2.5 to 3.3 inches; of the inner toe, 1.6 to 2.2 inches; of the outer toe, 2 to 2.5 inches; of the hind toe, 0.7 to 0.9 inch; of the heel, 1.4 to 2 inches; of the foot, 4 to 4.9 inches; of the step, 7 inches (?); of the middle toe beyond the rest, 1.5 inch. Distance between the roots of the forward toes and that of the hind toe, about 1 inch; between the tips of the lateral toes, 1 to 1.8 inch; between the inner and middle toes, 1.1 to 1.6 inch; between the outer and middle toes, 1.3 to 1.7 inch; between the middle and hind toe, 3.2 to 3.7 inches. Extremity of the heel adhering to the mud, so that when the former was lifted up, the latter followed, forming a ridge. Behind this ridge we sometimes find what seems a continuation of the heel backward; or, more probably, a hind toe, sometimes more

than an inch long, shown by dotted lines on Plate 15, figs. 10 and 11. Toes and heel nearly straight and very narrow. Width of the foot at the roots of the toes, 0.3 inch; of the heel, 0.2 inch. Track shown, of the natural size, on Plate 10, fig. 4.

Remarks. — The changes of form in the track of this species on successive layers of rock are instructive, and have already been in part described under the third general character. Plate 15, fig. 10, shows the track on the highest layer of No. 175 (Cabinet); fig. 11 shows the second track, half an inch lower; fig. 12, the third track, one quarter of an inch lower; and fig. 13, the fourth impression, one third of an inch lower. On the upper layers the rock is broken off, so as not to show the extremities of all the toes; but lower down they are all exhibited, both from their becoming shorter, and from the manner in which the mud was silted into the impression, so as not to fill perpendicularly, but obliquely.

The species is dedicated to Professor J. W. Bailey, of West Point, the eminent microscopist.

Plate 19, fig. 6, shows the tracks, on a specimen from Wethersfield (No. 169, Cabinet), of this and the following species, reduced three times from the natural size. They are in relief; and on the other side of the specimen (which is an inch and a half thick), they are much more numerous, so numerous, indeed, that individual tracks can scarcely be traced out. Yet in all these cases, the tracks point nearly in the same direction; as is the case with almost all the specimens from that remarkable locality, which leads to the inference that the animals were gregarious.

Locality. — Wethersfield, at the Cove; on beautiful red shale.

Species 2. TRIÆNOPUS EMMONSIANUS. (Pl. X. Fig. 5.)

Sauroidichnites Emmonsii, Mass. Geol. Report, Plate 31, figs. 5 - 7.

Nos. 7-12, 157, 160, 162, 165, l69, 177, in Cabinet.

Divarication of the lateral toes, 50°; of the inner and middle toes, 25°; of the middle and outer toes, 25°; of the middle and hind toes, 115°. Hind toe proceeding from the extremity of the heel. Length of the middle toe, 2. 3 to 3 inches; of the inner toe, 1.5 to 2 inches; of the outer toe, 1.5 to 2.2 inches; of the hind toe, 0.7 to 1 inch; of the heel, 0.3 to 0.5 inch; of the middle toe beyond the rest, 1.1 inch; of the foot, 2.8 to 3.6 inches. Distance between the tips of the lateral toes, 1.5 to 2 inches; between the inner and middle toes, 1.1 to 1.5 inch; between the middle and outer toes, 1.3 to 2 inches; between the middle and hind toes, 2.9 to 3.9 inches. Heel 0.2 inch wide; at the roots of the front toes, 0.4 inch. Versed sine of the inward curvature of the inner toe, 0.15 inch; of the same in middle toe, 0.1 to 0.15 inch; of outer toe, outwards, 0.05 inch. Track shown, of the natural size, on Plate 10, fig. 5.

Locality. — Wethersfield, at the Cove; on red shale, intermingled with the last species.

This species is dedicated to Professor Ebenezer Emmons, of Albany.

No. 7 (Cabinet) furnishes us with an instructive example of a change of form in the track of this species, as it appears on successive layers of little more than an inch in thickness. Plate 15, fig. 14, shows the track on the uppermost layer; fig. 15, on the second; and fig. 16, on the lowest.

Remarks. — Although my specimens of the tracks of this and the preceding species are more numerous than of any other, and most of them as perfect impressions as can be made on a plastic material, I have not been able to ascertain the length of the step, nor, in fact, to satisfy myself whether the animal was a biped or a

quadruped. The shale on which they occur is so brittle that it is difficult to obtain a slab more than a foot long, and then the tracks are so numerous that their interference obscures the characters. When I first opened the rocks at this spot, ten years ago, these points probably might easily have been settled; but I was not then aware of their importance. I strongly suspect that the tracks of the two species of *Tr iæno pus* may be only those of the hind and fore feet of a lizard. I have several specimens, in which two tracks occur almost in the same place, as already fully described.

Genus X. HARPEDACTYLUS.

Leptodactylous; three to four-toed. Toes all curved inward, like sickles.

Species 1. HARPEDACTYLUS GRACILIS. (Pl. XIV. Fig. 2.)

Sauroidichnites tenuissimus, Mass. Geol. Report, Plate 34, fig. 13.
Nos. 27 - 30, in Cabinet.

Divarication of the outer of the three front toes, 70°; of the inner and middle toes, 33°; of the middle and outer toes, 35°; of the fourth or hind toe and the outer front toe, 55°. Length of the inner front toe, 1.9 inch; of the middle toe, 2.2 inches; of the outer toe, 1.8 inch; of the fourth or hind toe, 0.9 inch; of the heel, 1.6 inch; of the foot, 3.7 inches; of the step, 8 inches; of the middle front toe beyond the rest, 0.8 inch. Distance between the tips of the lateral front toes, 2.2 inches; of the inner and middle toes, 1.25 inch; of the outer and middle toes, 1.5 inch; of the hind and middle toes, 2 inches; between the roots of the front toes and the origin of the fourth toe, 0.7 inch. Width of the heel, 0.2 inch. Tarsal joint lifting up

the mud as the animal walked. Toes all curved inward. Versed sine of the hind toe, 0.12 inch; of the inner front toe, 0.17 inch; of the middle toe, 0.13 inch; of the outer toe, 0.2 inch. Angle between the axis of the foot and the line of direction very large. Axis of the heel prolonged strikes the tip of the outer toe. Middle front toe making an angle with that axis of 40°. Inner toe making a similar angle equal to 70°. Fourth toe making, an angle equal to 60°. Toes, particularly the posterior, extremely narrow. Track shown, of the natural size, on Plate 14, fig. 2, copied from a quite perfect specimen in Mr. D. Marsh's cabinet, lately found by him at Turner's Falls. Plate 20, fig. l, shows two tracks, in their normal position, from the same locality, reduced from their natural size three times.

Localities. — Turner's Falls, Horse Race, and Wethersfield.

Remarks. — Although I described this species in my Report on the Geology of Massachusetts, yet so defective were my specimens, that I despaired of giving it a place in this paper, until the discovery of the specimens from which the preceding figures were drawn. One cannot look at these, without feeling a strong impression that the animal will prove to be a quadruped; and facts which I have yet to mention, as to the small fore feet of some animals having often made only a slight impression on mud, lead to the suspicion that such may be discovered in connection with these. If, indeed, Plate 14, figs. 4 and 5, sketched from a specimen presented to me by Dr. Deane, and found at Turner's Falls, belongs to this species, as I rather presume it may, it shows us the hind and fore feet.

Species 2. HARPEDACTYLUS CONCAMERATUS. (Pl. XIV. Fig. 3.)

No. 180 in Cabinet.

Tridigitate. Divarication of the lateral toes, 60°; of the inner

and middle toes, 25°; of the outer and middle toes, 35°. Length of the middle toe (measured on the chord), 3.2 inches; of the inner toe, 2 inches; of the outer toe, 1.6 inch; of the middle toe beyond the rest, 2.2 inches. Distance between the tips of the lateral toes, 3.5 inches; between the inner and middle toes, 1.7 inch; between the middle and outer toes, 3.4 inches. Versed sine of the inward curvature of the inner toe, 0.3 inch; of the middle toe, 0.6 inch. Outer toe straight. Width of the curved ridge between the toes and heel (the space between the dotted line and the heel, in Plate 14, fig. 3,), 0.3 to 0.6 inch; the length of the same (which is the width of the foot at the roots of the toes), 2.2 inches. Length of the heel (*breadth* literally,), 1.2 inch. Breadth of do., 2 inches. Length of the foot, 4.7 inches; of the step, 8 to 12 inches, if considered a biped. Foot vaulted, so as to leave a ridge between the toes and the heel, and hence the specific name. Axis of the foot very much turned inward towards the line of direction. Distance from that line, 5 inches. Track shown, of the natural size, on Plate 14, fig. 3.

Remarks. — The specimen, Plate 14, fig. 3, from which most of the above description was taken, is a very perfect one, from Turner's Falls, presented to me by Mr. Ptolemy P. Severance. But just as I was sending this paper to the press (April 27th), my attention was called to a slab of ten tracks in a row, or rather two rows, lying in the sidewalk in Greenfield Street, in front of the residence of Franklin Ripley, Esq. It was from the Horse Race, and is a gray micaceous sandstone. I at once recognized these tracks as essentially corresponding with those of the *H. concameratus*. They are distinguished from all others by the axis of the foot turning so much inward toward the line of direction, by the great distance of the middle of the heel from that line (5 inches), and by

the sickle shape of the inner toes especi ally. One can hardly doubt, on inspecting the specimen sketched on Plate 24, fig. 6, reduced 12 diameters, that the animal was a biped; yet the inquiry arises, whether it may not have been a quadruped with feet placed like those of the Proteus, exhibited on Plate 19, fig. 3. This is possible; but the very nearly exact alternation of the tracks in the two rows seems hardly consistent with such a supposition. If we could discover a small fore foot with each large one, such an alternation would be natural; but no trace of such tracks can be seen. And, upon the whole, my present conviction is, that we must regard the animal as a biped, with short legs and a wide body, walking much like the common goose. Had I discov ered this slab earlie r, I should probably have separated this species from *Harpedactylus*; but as the thing now stands, such a change is difficult, and perhap s it is not import ant. I am glad to be able to give a sketch of the slab in this paper, althou gh the indivi dual tracks are not laid down with quite so much accuracy as I could have wished.

Species 3. HARPEDACTYLUS RECTUS. (Pl. V. Fig. 5.)

Divarication of the lateral toes, 32° to 38°; of the inner and middle toes, 10° to 15°; of the middle and outer toes, 25° to 30°. Length of the inner toe, 2.6 inches; of the middle toe, 3.75 inches; of the outer toe, 2.5 inches ; of the middle toe beyond the rest, 1.5 inch; of the foot, 4 inches at least; of the step, 5.5 inches . Heel nearly 2 inches broad; length not determined. Distance between the tips of the inner and middle toes, 1.5 to 2 inches; between the middle and outer toes, 2 to 2.5 inches; between the lat eral toe s, 2.2 5 to 3 inc hes; bet ween the row s of tra cks mad e by the right and left foot, 3.5 inches. Axis of the foot turned inward a few degrees towards the line of direction. Track shown,

of the natural size, on Plate 5, fig. 5; and a row of the tracks, reduced to one sixth the natural size, is shown on Plate 24, fig. 7.

Locality. — Turner's Falls, Gill, at the quarry, eighty rods above the cataract.

Remarks. — The specimen from which this species has been described was in the possession of Mr. Ptolemy P. Severance, but what is to be its ultimate destination is not yet known. A sketch of it, accurately reduced, is given on Plate 24, fig. 7. The species is distinguished from all others by the long and delicate toes, in connection with an elliptical heel, whose posterior part is not well marked, but which appears to me to approach nearly to that of *Harpedactylus concameratus*; and therefore I have placed this species under that genus, though the specific name *rectus*, as applied to the toes, seems almost to contradict the generic name. It differs from other species, also, by the toes pointing so much inward towards the line of direction, and also in the shortness of the step compared with the length of the foot, which is more remarkable than in any species hitherto discovered, the ratio between them being only 1.37. Yet the nine steps shown on Plate 24, fig. 7, although somewhat broken, prove conclusively what is the length both of the foot and the step. I have a suspicion that it was a web-footed animal, but no positive evidence. This species was discovered while this paper was passing through the press.

Affinities of the Group. — The probable biped character of most of the species, and the trifid character of the front part of the foot, are presumptions in favor of their being birds. On the other hand, the curved and slender character of most of the toes, the large or long tarsus, forming the heel, and the articulation of the hind toe, when present, so far back upon the tarsus, assimilate them to

lizards, whose feet certainly have a general resemblance to the tracks of these animals. On the other hand, the resemblance between the front part of the foot of the genus *Triænopus* and that of certain birds is very striking, as the sketches on Plate 20, copied from Gray's *Genera of Birds*, subfamily Columbinæ, will show. Fig. 2 represents the foot of the *Lopholaimus antarcticus*; figs. 3 and 4, the feet of *Cathartes fœtens*; and fig. 5, the foot of a species of *Gryphus*. But the fact is, these are birds which for the most part never walk upon the ground, and certainly never upon a muddy shore; so that we may be sure that this accidental resemblance does not indicate any real affinity. Upon the whole, I am more inclined to refer this group to the lacertilian tribe than to birds, although the evidence does not seem very decided.

Table of the Ratio between the several Characters of this Group, on a Scale of 100.

Note. — The three species of *Harpedactylus* are omitted in the above table, because they are so obviously unlike the other species that minute comparisons seem unnecessary.

	Divarication of				Length of								Distance between				Versed sine of the curve			Width of		
	The lateral toes.	The inner and middle.	The outer and middle.	The middle and hind.	The inner toe.	The middle toe.	The outer toe.	The hind toe.	The foot.	The step.	Middle toe beyond the rest.	The heel.	The tips of the lateral toes.	The inner and middle.	The outer and middle.	The middle and hind.	Of the inner toe.	Of the middle toe.	The outer toe.	The heel.	The foot at the roots of the toes.	Ratio between the length of the foot and the step.
Polemarchus gigas	49	51	48	70	100	100	100	100	20	100	100	90	100	100	100	100	100	100	100	100	100	3.2
Plectropus minitans	100	100	100	87	31	27	25	36	62	33	56	36	42	49	40	30		17	33	12	16	3.4
" *longipes*	74	37	81	83	20	25	25	32	100	31	41	100	32	37	29	30				8	16	2.1
Triaenopus baileyanus	40	20	33	31	22	26	26	32	13	14?	47	40	18	32	23	26				4	12	
" *emmonsianus*	55	27	48	10	21	24	22	36	43		34	10	24	30	26	26	33	13	16	5	16	

APPENDIX TO GROUP IV.

Remarks. — Some general resemblances between the foot of the following genus and those of the preceding genera of this group have led me to place it in an appendix, though very probably it may prove to have very different affinities.

Genus XI. TYPOPUS.

Foot plantigrade, except the middle toe, which is strikingly digitigrade; trifid; toes leptodactylous. Heel a prolongation backward of the outer toe; yet, from the anterior extremity of this, a ridge extends nearly at right angles, which appears to form a basis for the insertion of the other toes.

Remarks. — If I had not very distinct tracks of this species, I should not attempt to describe it, it is so anomalous and unlike existing nature. The lateral character of the heel is one peculiarity. But the ridge on the foot, running obliquely from this to the roots of the inner toe, is more peculiar; seeming, in fact, to be only a curved continuation backward of that toe. I have been, indeed, in doubt whether to consider it as a heel, or that and the toe as one crooked toe. But the middle toe seems to have been articulated to this ridge, though high up, leaving a cavity between. Hence I have, upon the whole, regarded this ridge as a part of the heel. That part of the heel which is a continuation backward of the outer toe might be considered a hind toe, were not its width and bluntness, as seen on the tracks, more characteristic of a heel.

Species 1. TYPOPUS ABNORMIS. (Pl. X. Fig. 6.)

Sauroidichnites abnormis, Am. Jour. Science, Vol. XLVII., Plate 3, figs, 6, 7, 8.

Nos. 131 - 133, in Cabinet.

Divarication of the lateral toes, 35°; of the inner and middle toes, 20°; of the middle and outer toes, 15°. Length of the middle toe, so far as it usually impresses the ground in walking, l.9 inch; whole length of do., 2.8 inches; of the inner toe, 1.3 inch; of the outer toe, 1.8 inch; of the part of the heel running directly backward, 0.7 inch; of the lateral part, 2 inches; of the foot, 4 inches; of the step, 18 inches; of the middle toe beyond the rest, 1.4 inch. Width of the heel, 0.2 to 0.3 inch; of the foot at the roots of the toes, 2.2 inches. Distance between the tips of the lateral toes, 2.8 inches; between the inner and middle toes, 1.8 inch; between the middle and outer toes, 2 inches. Axis of the left foot turned inward from the line of direction, 15°; of the right foot, 30°. Distance of the axis of the foot from the line of direction, 2.5 inches. Right foot shown, of the natural size, on Plate 10, fig. 6. Plate 19, fig. 7, shows three tracks in their normal position, one sixth of the natural size (linear measure), sketched from a slab in the cabinet of Mr. Dexter Marsh.

Locality. — Turner's Falls.

Plate 15, fig. 2, is copied from a very distinct specimen of footmarks from Wethersfield, and seems to approach the *Typopus* in form, though a distinct species. But I hesitate to describe it as such, because, being near another track, its form may have been altered, and I have only one specimen.

Remarks. — All the specimens yet found show the extraordinary fact, that the right foot has a divergence of 15° more than the other from the line of direction; and especially the specimen in Mr. Marsh's collection, from which Plate 19, fig. 7, was copied. This surely cannot be natural, if the animal was a biped; for nature, with few exceptions, constructs pairs of organs alike. What

improbability is there in the supposition, that the animal which made the tracks at the locality (Turner's Falls) had one of its legs (the right) broken, and that it subsequently united in a wrong position?

Affinities of the Genus. — The biped character of the animal and its trifid toes afford a presumption that it was a bird; yet the great peculiarity of its feet would rather lead us to suspect that it might have been a saurian or batrachian.

GROUP V. BIPEDAL BATRACHIANS?

Toes four, directed forward, or obliquely forward. Bipedal.

Genus XII. OTOZOUM.

Tetradactylous; pachydactylous; *lobopedate*; plantigrade. Toes all directed forward; the inner one shortest; the second next longer; the third longest of all, the fourth but little shorter; all making distinct phalangeal impressions on mud, the inner toe most distinctly; three are made by the inner toe, four by the second, and three by the two outer toes. Two bones of the metacarpus (?), articulated to the phalanges of the two outer toes, make a distinct impression. Cushion beneath the carpus rounded beneath, and sloping upward posteriorly.

Species 1. OTOZOUM MOODII. (Pl. XII. Fig. 1.)

American Journal of Science, Vol. IV., New Series, p. 55.

No. 234, in Cabinet.

Divarication of the outer toes, 35°; of the inner and second toes, 15°; of the outer and third toes, 12°; of the two middle toes, 5°. Length of the inner toe, 8.5 inches; of the second toe,

10.25 inches; of the third toe, 8 inches; of the outer toe, 8.5 inches; of the foot, 20 inches; of the step, about 3 feet. Distance between the extremities of the outer toes, 1.3 inch; of the inner and second toes, 6.5 inches; of the second and third, 3.4 inches; of the third and fourth, 2.7 inches. Width of the toes, 2 to 3.3 inches. Length of the phalanges of the inner toe, — proximal phalanx, 3 inches; the second, 2 inches; the third, 3.4 inches (?): of the second toe, — the proximal, 2.4 inches; the second, 2.5 inches; the third, 2.9 inches; the fourth, 2.6 (?) inches: of the proximal metacarpal bone of the third and fourth toes, 3.5 inches; of the second do., 4 inches: of the first phalanx of the third toe, 2 inches; of the second, 2 inches; of the distal, 3.8 (?) inches: of the outer toe, — the proximal, 1.6 inch; the second, 1.6 inch; the distal, 5.4 inches (?). Divarication of the axes of the feet and the line of direction, 15°. Distance of the middle of the heel from the line of direction, 2.5 inches. Integuments of the bottom of the feet rugose and irregularly papillose. Track shown, of the natural size, with the papillose impressions, on Plate 12, fig. 1.

Locality. — South Hadley, near the house of Pliny Moody, Esq., by whom it was discovered and preserved, and the specimen, the only one known, deposited in the cabinet of Amherst College, where it is numbered 234. Mr. Moody was the first person in the Connecticut valley who recognized the fossil footmarks found there as those of birds; having spoken, more than forty years since, of those on No. 61 of my cabinet as made by "poultry," or by "Noah's raven." Hence it has seemed to me but justice that his name should be attached to this most remarkable species.

Affinities of the Genus. — Its biped character is evident from

the sketch (Plate 12, Fig. 2), which is copied from the only slab yet found with the tracks of this animal. The number of toes directed forward, and especially the number of phalangeal impressions, forbid us to class it among birds. There is, however, some resemblance between its foot and that of a frog in an embryotic state; and such analogies are important, because the adult developments of the early geological periods correspond best to the embryo structure of living animals. Hence there is at least a probability, that this animal was a biped batrachian, and what a monster, with feet 20 inches long and 12 wide! No such biped batrachians, indeed, now live; but some exist with only two feet. For an animal so large, its tracks are more nearly in a right line than we should expect, and its steps shorter; an indication of short legs.

In the *American Journal of Science*, Vol. IV. of the New Series, I have given full details respecting this track and its affinities. But I do not judge it expedient to repeat them all here. And yet so remarkable an animal - the most extraordinary of all those discovered by their tracks - could not properly be passed in silence in an attempt to give a monograph of this subject. Although a sketch of the slab containing the tracks of this species is given in that work, yet I have thought its exhibition here would be appropriate; and it is accordingly given on Plate 12, fig. 2, reduced eighteen diameters. It contains four tracks of the *Otozoum*, of which *A* is the most perfect. The two rows of tracks, *a*, *a*, &c., *b*, *b*, &c., belong to the *Brontozoum parallelum*; besides which a large part of the surface is covered with rain-drops in relief, as are all the tracks.

Genus XIII. PALAMOPUS.

Bipedal; tetradactylous; toes all directed forward, spreading moderately; leptodactylous; essentially plantigrade.

Species 1. PALAMOPUS DANANUS. (Pl. XI. Figs. 1, 2.)

No. 149 in Cabinet.

Angle between the inner and second toes, 25°; between the second and third, 30°; between the third and fourth, 15°; between the inner and outer, 67°. Length of the inner toe, 2 inches; of the second, 2.5 inches; of the third, 4.7 inches; of the outer, 2.3 inches; of the third or longest toe beyond the others, 2.7 inches. Distance between the tips of the first and second toes, 2.4 inches; between the second and third, 3.4 inches; between the third and fourth, 3 inches; between the outer ones, 4.7 inches. Length of the heel, 3.7 inches; breadth behind, 2 inches; wider before. Probably web-footed. Length of the foot, 8.5 inches; of the step, 21 inches. Axis of the foot and line of direction coincident.

Remarks. — The above dimensions were measured from Plate 11, fig. 1. Fig. 2, which is the next track on the only slab of this species yet discovered, appears to have been somewhat distorted by a subsequent track of *Brontozoum giganteum* on the same stone. It is possible, however, that this was not the cause of the difference between them.

This track was discovered by Mr. William S. Clarke, of the Senior Class in Amherst College, on the railroad, in the southeast part of Northampton. It is dedicated to S. L. Dana, M. D., LL. D., of Lowell.

Affinities of the Genus. — The resemblance between the tracks of this genus and the feet of some living batrachians is rather

striking. Some of the Ranidæ have only four toes on their fore feet. Now, as we have evidence of the probable existence, during the triassic period, of the biped batrachian *Otozoum*, we may, with no little probability, refer the *Palamopus* to the same tribe, until proof shall he obtained of its quadrupedal character. The *P. Dananus* is the only fossil animal in New England whose tracks decidedly indicate webbed feet.

GROUP VI. QUADRUPEDAL BATRACHIANS.

Quadrupeds, with 4 to 5 blunt pachydactylous toes, and webbed feet, especially the fore feet. Heels broad and irregular. Impression of the toes on the mud uniform through their entire length (i.e. not showing phalangeal enlargements). Rudiment of a sixth toe on the hind foot, and of a fifth toe on the fore feet (?).

Genus XIV. THENAROPUS, *King*.

Figured and described by Dr. King, in American Journal of Science, Vol. XIVIII. p. 348.

Description the same as that of the Group.

Species 1. THENAROPUS HETERODACTYLUS, *King*.
(Pl. XVI. Figs. 1, 2.)

No. 191 in Cabinet.

Fore foot. — Toes four, with the rudiment of a fifth (?) on the inside, shown on the track by a protuberance. Divarication of the lateral toes, 90°; of the inner and second toes, 20°; of the second and third, 30°; of the third and fourth, 40°. Length of the inner toe beyond the web, 1.2 inch; of the second toe, 1.4 inch; of the third, 1.5 inch; of the fourth, 1.1 inch; of the foot,

4.2 inches. Rudiment (?) of the fifth toe shown by a protuberance on the inside of the heel. Breadth of the heel, or hind part, 2.7 inches; of the toes, from 0.6 to 0.9 inch. Distance from tip to tip of the lateral toes, 4.5 inches; of the first and second, 1.5 inch; of the second and third, 1.8 inch; of the third and fourth, 2 inches. Toes blunt. Angle between the axis of the foot (a line drawn from the extremity of the heel to the middle point between the second and third toes) and the line of direction, 35°.

Hind foot. — Five toes, with the rudiment of a sixth (?) on the inside. Divarication of the outer toes, 75°; of the inner and second, 15°; of the second and third, 20°; of the third and fourth, 10°; of the fourth and fifth, 28°. Length of the inner toe beyond the web, 1.6 inch; of the second, 1.8 inch; of the third, 2.4 inches; of the fourth, 3.1 inches; of the fifth, 0.9 inch; of the foot, 5.5 inches; of the step, 9 to 16 inches. Distance between the hind and fore feet on the same side, 0 to 1 inch. Angle of the axis of the hind foot with the line of direction, 0° to 30°; usually coincident. Distance between the two rows of tracks, 6 to 8 inches; between the tips of the lateral toes, 4 inches; between the first and second, 1.2 inch; between the second and third, 1.5 inch; between the third and fourth, 1.2 inch; between the fourth and fifth, 3.2 inches. Width of the heel, about 2.2 inches. Tracks of the fore and hind foot shown, of the natural size, in a normal position, on Plate 16, figs. 1, 2.

Remarks. — The tracks of this animal were first described by Dr. Alfred T. King, in *the Proceedings of the Academy of Natural Sciences, Philadelphia*, for November and December, 1844, and in the *American Journal of Science*, Vol. XLVIII., p. 348 They occur in Westmoreland county, Pennsylvania, in the rocks of the coal formation, about 800 feet below its top. The sketch, Plate 16,

figs 1, 2, of the natural size, representing a hind and fore foot, is copied from a very distinct specimen, sent me by Dr. King. The above description has been derived chiefly from the same slab, No. 191 of my Cabinet. On that slab are several mud veins, some of which proceed directly from the tips of the toes This is, in fact, just what we might expect from the desiccation of the mud; though, to an unpractised eye, it might throw doubt over the whole subject.

Affinities of the Genus. —The anatomist cannot examine the tracks of this animal, or the sketches which I have given, without at once perceiving their resemblance to those of some living batrachians . Their semi-palmate character, the number and bluntness of the toes, and deficiency of claws, the want of phalangeal impressions, the relative length of the toes, the supposed rudiments of an additional toe, bear a striking analogy to the feet of the *Hyla Seurii* and *H. Gaimardi*, for instance, figured in the *Dict. Class. d'Hist . Nat.*, Plate 125. Even the relative length of the toes is the same, the outer toe but one being the longest. The *Thenaropus*, however, did not move by leaps; but as a tortoise; and it is possible that it might have been a chelonian. More probably, however, it was a batrachian; and being, with the exception of an unknown reptile discovered in the carboniferous rocks of Nova Scotia by Mr. Logan, the only example of vertebral animals so low in the series of rocks, it possesses a peculiar interest.

Genus XV. ANOMŒPUS.

Hind feet plantigrade, three-toed (four-toed?); all the toes pointing forward. Heel long, extending to the tarsal joint. Fore foot quinquefid, digitigrade. All the toes pachydactylous, and making phalangeal impressions.

Remarks. — The second species of this genus was described by me in 1840, in my Massachusetts Report, with figures, (Plate 48, figs. 44, 45,) under the name of *Sauroidichnites Barrattii.* The evidence then discovered did not prove it to be a quadruped, although I strongly suspected this must be the case. The other species, the *A. scambus*, was first described by Dr. Deane, as a quadruped, in the *American Journal of Science*, Vol. XLIX. p. 80, and re-described in the same work, New Series, Vol. III. p. 78. Dr. Deane, however, has represented the hind leg as wanting altogether in a foot, and the lower leg as doubled down upon the long tarsus, or heel; and he supposes that from the animal's "peculiar organization, one set of feet did not touch the earth" (*American Journal of Science*, Vol. XLIX. p. 80). Having carefully examined the original specimen from which his drawings and description were taken, belonging to T. Leonard, Esq., of Greenfield, as well as others in Mr. Marsh's cabinet and in my own, I cannot doubt that the hind foot is most distinctly represented in nearly every case, as I have shown it on Plate 13, figs. 1 and 3, and on Plate 21, fig. 1, and on Plate 21, fig. 3, though as to the fourth toe I am not certain; and the heel of the hind foot has sometimes a peculiarity of structure, which might readily suggest the idea of the lower leg folded upon the tarsus; but I am not prepared thus to explain the slight longitudinal ridges we sometimes find upon it. But, however that may be, I cannot doubt that the hind foot had three stout, very distinct toes, very much resembling some of the tridactyle feet already described; for I find them on nearly every specimen I have seen; and although we might say of one instance, that the heel happened to come in contact with a track of *Brontozoum* directly before it, we cannot thus explain the numerous cases exhibited upon the plates above referred to; the originals of which

may be seen in the possession of Mr. Leonard, Mr. Marsh, or myself, by naturalists who would make sure of the correctness of my delineations. I will add, however, that the examination of the characters of this genus has cost me more labor and perplexity than that of any other described in this paper; and it would not be strange, if different observers should not entirely agree as to some of the features of its tracks.

Species 1. ANOMŒPUS SCAMBUS. (Pl. XIII. Figs. 1 - 6.)

Am. Jour. of Science, Vol. XLIX. p. 80, and Vol. III. p. 78, New Series.

Hind foot. — Pachydactylous; three-toed (four-toed?). Divarication of the lateral toes, 45° to 50°; of the inner and middle toes, 20° to 25°; of the middle and outer toes, 20°. Toes usually nearly straight, but sometimes curved. Heel 4.2 inches long, expanding towards the posterior part. Lower leg above the tarsal joint sometimes making an impression on mud (see Pl. 13, fig. 4). Phalangeal impressions on mud three (?) by the inner toe, 0.7, 0.7, 0.8 inch, respectively; three by the middle toe, 1.1, 1, 0.7 inch; and five by the outer toe, 0.8, 0.8, 0.6, 0.6, 0.6 inch. Lateral distance between the extremity of the heels in the two tracks, 4 to 5.8 inches. Angle between the axis of the foot and the line of direction, 0° to 20°. Distance between the tips of the lateral toes, 2.7 inches; between the inner and second toes, 1.9 inch; between the second and third, 1.8 inch. Projection of the middle toe beyond the rest, 1.2 inch. Length of the middle toe, 3.2 inches; of the inner toe, 2.4 inches; of the outer toe, 3.3 inches; of the foot, 6 to 8 inches; of the step, usually about 9 inches.

Fore feet. — Quinquefid, pachydactylous; digitigrade. Divarication of the outer toes, excluding the hind toe, 75° to 90°; of

the inner and second toes, 20° to 35°; of the second and third, 10° to 25°; of the third and fourth, 30° to 45°; of the middle and hind toes, 90° to 100°. Length of the inner toe, 1 inch; of the second, 1.3 inch; of the third, 1.5 inch; of the fourth, 1.2 inch; of the hind toe, 1 inch. Number of phalangeal impressions made by the inner toe, two, 0.4, 0.3 inch, respectively; by the second, three (?), 0.3, 0.3, 0.3 inch; by the third, four, 0.4, 0.3, 0.3, 0.3 inch; by the fourth, three, 0.4, 0.4, 0.3 inch; by the hind toe, two, 0.4, 0.4 inch. Angle between the axis of the foot and the line of direction, 25° to 50°. Distance of the middle of the heel from the line of direction, 2 inches. Track of the hind foot, of natural size, shown on Plate 13, fig. 1; of the fore foot, on fig. 2. The hind foot, also, is shown on fig. 3, with perhaps a fourth toe. Figs. 4, 5, and 6 are also tracks of this or an allied species; the toes on the hind foot being more or less indistinct, and the leg above the tarsal joint making an impression on fig. 4.

Locality. — Turner's Falls, Gill.

Remarks. — The great difficulty of ascertaining the characters of this species, and the paucity of specimens, have made it necessary to give numerous sketches, some of which have been already referred to. Plate 21, fig. 1, is a true copy, reduced to one sixth of the natural size, of a slab four feet by two, belonging to T. Leonard, Esq., which that gentleman has very liberally allowed me to study and to copy. Upon it may be seen one row of seven or eight tracks of a *Brontozoum*, probably *B. gracillimum*; two parallel trails of a tortoise, the *Helcura littoralis*, to be described on a subsequent page; several insulated tracks, perhaps of *Brontozoum*, and also of the present species of *Anomœpus*, both hind and fore feet. The impressions *a* and *b*, of hind feet, and *c* and *d*, of fore feet, are the most interesting, because they appear to have been made

by the animal when at rest upon all its feet, and certainly look like the imprints of a frog, scarcely less than a foot in diameter; or, possibly, a tortoise.

In order to show how great changes of tracks frequently occur on layers of rock only an inch apart, I have given, on Plate 21, fig. 2, the under side of the above slab, belonging to Mr. Leonard. Scarcely one of these tracks corresponds to those upon the upper side of the slab. Only one example of a track of *Anomœpus* occurs, though some of the other trifid feet may be the toes of the hind foot of that animal. We see, also, three tracks of what is probably the *Ornithopus gallinaceus*.

Plate 20, fig. 3, is copied from a slab in Mr. Marsh's collection, reduced to one third of its natural size. It seems to show a succession of the tracks of *Anomœpus scambus*, the last four very similar to those upon Plate 21, fig. 1; that is, they seem to have been made by the animal when sitting upon its haunches. Yet the left-hand hind track is greatly injured by another track of an animal moving in an opposite direction; and the three fragments of toes near it look like the fore feet of the *Anomœpus*. If so, the heel of the hind feet did not reach the surface.

Plate 20, fig. 9, is a sketch, reduced three times, from a small slab presented me by Dr. Deane. It exhibits several tracks, more or less perfect, very similar to those of the slabs above described. In two cases, at least, on this slab, we seem to have little else but the impression of the heel, with a part of the lower leg (*a* and *b*). Yet a little in advance of *a*, we have impressions (*c*), indistinct I admit, of a sort that reminded me of the feet of certain batrachians; for example, the *Anolis Edwardsii*, of whose feet I have given a sketch on Plate 20, fig. 7, copied from Griffith's Cuvier, Vol. IX. p. 228. Yet I am by no means confident that I rightly

understand this case. But the statement may lead others, who have better opportunity, to reach the truth. The imprints of the fore feet on this slab, Plate 20, fig. 9, do not well correspond with those of the *Anomœpus scambus*, as given on the other drawings; and I am not without suspicion that it shows us tracks, not only specifically, but even generically, different from the *Anomœpus scambus*. I might add, that the term *scambus* (crooked leg) was derived from this slab, and may prove inappropriate to the species.

Plate 13, fig. 3, is copied from No. 170 of my cabinet. I cannot resist the impression that it has a fourth toe, as represented, though the specimen is not one of the most distinct. It shows, also, a rather remarkable ridge, common in this species, represented by a dotted line; the specimen appearing somewhat as if two heels lay side by side. I am not prepared to explain it; nor can I admit that it results from an impression of the leg above the tarsal joint.

Species 2. ANOMŒPUS BARRATTI. (Pl. XIV. Fig. 1.)

Sauroidichnites Barrattii, Mass. Geol. Report, Plate 30, fig. 1.

Nos. 1, 139, in Cabinet.

Hind foot. — Five-toed; plantigrade: toes pachydactylous, clawed, curved. Heel long. Divarication of the outer toes, 95° to 130°; of the inner and second, 20° to 45°; of the second and third, 40° to 50°; of the third and fourth, 30° to 40°; of the fourth and fifth, 10° to 20°. Length of the inner toe, 1.2 to 1.8 inch; of the second, 1.5 to 2 inches; of the third, 2 to 2.4 inches; of the fourth, 2 to 2.1 inches; of the fifth, 1.4 to 1.7 inch; of the heel to the tarsal joint, 4.5 (?) inches; of the foot, 7.5 inches. Versed sine of curvature in the middle toe, 0.4 inch; in the fourth,

0.15 inch. Length of the step, 11 to 14 inches. Leg above the tarsal joint often making an impression in walking, several inches in length, which forms an angle with that of the long tarsus, of about 35°, indicating a sprawling mode of progression, as is shown on Plate 14, fig. 1.

Fore feet. — Very similar to those of the first species; but my specimens of these are too imperfect for description.

Localities. — Plate 20, fig. 6, was taken from a specimen presented me by Dr. Barratt, of Middletown, to whom the species is dedicated, because discovered by him. (See *Mass. Geol. Report*, Vol. II. p. 477.) The specimen from which the sketch, Plate 14, fig. 1, is taken, was found at Marsh's Quarry, in Montague, but was much injured before I found it. I feel confident, however, that the dotted lines represent it as it was originally, although that part of the specimen is wanting. The five toes on the hind foot of this species clearly distinguish it from the *Anomœpus scambus.* When I described the tracks of this species in the *Massachusetts Geological Report*, I had no certain evidence of its quadrupedal character, though strongly suspecting it to have been made by a quadruped.

Genus XVI. ANISOPUS.

Quadrupedal; hind feet nearly twice as long as the fore ones, and considerably wider. Both hind and fore feet four-toed. In walking, the hind foot was brought up nearly into the place of the fore one. Tracks but a little to the right and left of the line of direction. Foot pachydactylous.

Species 1. ANISOPUS DEWEYANUS. (Pl. XVI. Figs. 5, 6.)

Sauroidichnites Deweyi, Trans. Assoc. Amer. Geologists, Plate 11, fig. 9.

Nos. 37, 136, in Cabinet.

Hind foot. — Pachydactylous. Divarication of the lateral toes, 45°; of the inner and second, 20°; of the second and third, 10°; of the third and fourth, 10°. Length of the inner toe, 0.5 inch; of the second, 0.7 inch; of the third, 0.8 inch; of the fourth, 0.5 inch. Breadth of the foot from tip to tip of the outer toes, 1.4 inch; from first to second, 0.6 inch; from second to third, 0.45 inch; from third to fourth, 0.4 inch; at the roots of the toes, 1.2 inch. Length of the heel, 0.9 inch; of the foot, 1.7 inch; of the step, 7 to 7.5 inches; the same for the fore feet. Track of the fore foot usually a little inside of the hind one. Angle between the axis of the foot and the line of direction, to the right and left, 15° to 40°. Distance of the middle of the heel from the line of direction, 0 to 1.5 inch. Width of the toes, 0.2 to 0.3 inch.

Fore foot. — Divarication of the toes the same as in the hind foot. Length of the inner toe, 0.2 inch; of the second, 0.5 inch; of the third, 0.6 inch; of the fourth, 0.35 inch. Breadth from tip to tip of the lateral toes, 0.7 inch; from the first to the second, 0.25 inch; from the second to the third, 0.25 inch; from the third to the fourth, 0.3 inch. Length of the foot, 0.6 inch. Position of the foot, in regard to the line of direction, the same as the hind feet. Width of the toes, 0.1 to 0.2 inch. Track shown, of the natural size, fore and hind feet, on Plate 16, figs. 5, 6, from different specimens.

This species is dedicated to my early friend, Rev. Chester Dewey, LL D., of Rochester.

Remarks. — This was the first animal whose tracks were recognized as those of a quadruped, in the valley of Connecticut River. I first described them in my Report on the Geology of Massachusetts, from a specimen from Middletown, on which the inner toe

had been worn off, and I then supposed that a three-toed animal must be a biped. I suggested, however, their resemblance in other respects to those of a marsupial quadruped, but left the case unexplained. This was in 1840. At the meeting of the Geological Association in Boston, in 1842, I described the same track, from a specimen discovered by Dr. Deane, and presented to me, under the name of *Sauroidichnites Deweyi*. This description, with a drawing, was published in the Transactions of the Association, and I there stated that "this is the first example in which any of the numerous tracks upon the sandstone of. the Connecticut valley were made by a quadruped." Dr. Deane, in 1845, published a drawing and description of the same specimen, as containing the tracks of a quadruped. But the discovery of still better specimens, from one of which (No. 136 of my cabinet) Plate 22, Fig. 1, was copied exactly, gives us a clearer insight into the character of the animal, especially as to its mode of progression. We can see on that drawing, that the feet on the right side of the animal uniformly pointed a little to the right, and those on the left to the left; and that it must have advanced by regular steps, like a common mammiferous quadruped. The slab on which this row of tracks occurs is represented on Plate 20, fig. 10. On it are four rows of *Æthyopus minor,* and two tracks of *Helcura littoralis.* Plate 23, fig. 3, shows another slab in Mr. Marsh's cabinet, with tracks of *Anisopus*.

Species 2. ANISOPUS GRACILIS. (PI. XVI. Figs. 3, 4)

Nos. 141, 158, in Cabinet. Numerous specimens in Mr. Marsh's cabinet.

Hind foot. — Divarication of the lateral toes, 40°; of the inner and second, 15°, of the second and third, 10°; of the third and

fourth, 15°. Length of the inner toe, 0.4 inch; of the second, 0.6 inch; of the third, 0.9 inch; of the fourth, 0.7 inch. Distance from tip to tip of the outer toes, 0.75 inch; of the inner and second, 0.3 inch; of the second and third, 0.25 inch; of the third and fourth, 0.25 inch. Breadth of the posterior part, 0.5 inch; of the toes, about 0.1 inch. Length of the foot, 0.9 inch; of the step, 5.7 inches. Angle between the line of direction and the axis of the foot, 20°. Feet on the right side of the animal diverging to the right; those on the left side to the left.

Fore foot. — Divarication of the toes the same as in the hind feet. Axis of the fore foot essentially parallel to that of the hind foot. Track of the fore foot a little nearer to the line of direction than that of the hind foot, and just in advance of the latter. Length of the inner toe, 0.2 (?) inch; of the second, 0.4 inch; of the third, 0.55 inch; of the fourth, 0.4 inch. Distance from tip to tip of the outer toes, 0.4 inch; of the inner and second, 0.2 inch; of the second and third, 0.15 inch; of the third and fourth, 0.25 inch. Width of the toes (average), 0.08 inch. Length of the foot, 0.55. Track shown, of the natural size, both hind and fore feet, and in a normal position with respect to each other, on Plate 16, figs. 3, 4.

Remarks. — One of the most distinct of my specimens indicates a very short fifth toe on the outside of the foot, as is shown on Plate 16, fig. 4. But I am not confident whether such is the case, and therefore omit it in the description. This species is distinguished from the previous one, by being more slender and delicate in all its parts. It occurs at Turner's Falls.

Plate 22, fig 2, is a sketch of two tracks of the hind and fore feet, copied from No. 158 of the Cabinet, and reduced to one third of its natural size. For so small an animal, the length of the step is very great.

Genus XVII. HOPLICHNUS.

Feet hoof shaped; producing a track like a horseshoe. Quadrupedal; hind and fore feet of nearly equal size.

Species 1. HOPLICHNUS QUADRUPEDANS. (Pl. XVI. Figs. 7, 8.)

Nos. 181 - 183, in Cabinet

Anterior part of the foot semicircular, or forming a portion of a circle. Impression very much resembling a horseshoe. Diameter, 1.5 to 2.2 inches. Middle of the foot extending, when the animal was walking, from one to five inches to the right and left of the line of direction. Track shown, of the natural size, on Plate 16, figs. 7, 8.

Locality. — Turner's Falls, at the Ferry, on the Gill side of the river; on coarse micaceous sandstone.

Remarks. — The sketches on Plate 16, figs. 7 and 8, give the shape of the depression in this track; but no toes are visible. It is possible that the surface on which they occur was a little below where the animal trod, and that the layer of rock above would have shown the toes. It is possible, also, that a slight movement of the sand, after the imprint was made, might have obliterated the toes; yet no reason can be given why in that case the impression should have been left so uniformly of a circular form. The specimens, however, do show a slight ridge in some cases, extending backward from the track, as if a gentle current had slightly moved the sand. But there can be no doubt that this animal is generically different from any other described in this paper; for the fore and hind feet are nearly of equal size, and more nearly circular than any other species. The sketch, on Plate 22, fig. 3, taken from No. 181 of my cabinet, will satisfy any one acquainted with ichnology, that

these tracks were made by a quadruped; because we find two tracks near each other, succeeded by a long interval, and these in two rows. The sketch is reduced four times, but is an exact copy of the original. Those acquainted with the history of fossil footmarks will recognize the tracks of this species as identical with those described by Dr. Cotta, in 1839, in Saxony; sketches of which are given in the *American Journal of Science*, Vol. XXXVIII. p. 255. The only difference is, that ours are more perfectly rounded. Dr. Cotta regards the extremity of the arch as the ends of two toes, making the animal bidigitate. But our specimens make it more probable that those extremities were the posterior part of the foot, and that the toes were in front, and very short. He likewise could not find any succession of tracks; but our specimens, although not showing all we could wish, make it extremely probable that the tracks had a quadrupedal origin; and hence the specific name.

Affinities of the Group. — I have already said enough, I trust, as to the relations of the first genus (*Thenaropus*) to batrachians, and even to the Ranidæ. The relations of the second genus (*Anomœpus*) may be a little more doubtful. The sprawling character of its hind feet, so as to bring even the lower leg upon the ground, corresponds better to some chelonians than to batrachians. Yet the position of the feet, as shown on Plate 2l, figs. l and 3, when the animal was at rest, corresponds so nearly to that of the Ranidæ, that I think we may safely refer it to that tribe. Such a position of the animal looks as if it moved by leaps, like the common frog. But it is a large animal to advance in this manner; I mean, large among batrachians; nor do the drawings, Plate 20, fig. 9, and Plate 21, fig. 3, confirm this impression. If so large an animal had advanced by leaps, is it possible that we should not meet with

some cases in which the foot slid forward as it came to the ground, with such a *vis a tergo* as its weight would give? Yet the impressions of its feet are as distinct and undisturbed, as if they had been each one put down with the nicest care. I hesitate, therefore, to assert that leaping was the animal's mode of progression.

The form of the feet, and the number and position of the toes, as well as the broad posterior part of the foot, seem to ally the genus *Anisopus* to batrachians. But what living batrachian places its feet in walking as did these fossil species? It is, indeed, quite remarkable. Although the feet were of very unequal size, yet it would seem from Plate 22, fig. 1, that it walked very much like such quadrupeds as the cat, the dog, and the fox; that is, the tracks vary but little from a right line; nor is the axis of the foot turned much aside from the line of direction. Indeed, its mode of walking was much more like that of a mammiferous quadruped, with long, perpendicular legs, than like that of sprawling reptiles. I have almost persuaded myself that these animals are marsupial quadrupeds. For we know that this tribe did exist in the oolitic period, and would it be strange, if they should be shown to have appeared one geological period earlier, that is, in the triassic period? The presumption, however, from the general analogies of fossil nature is, that they were batrachians; but if they were so, their structure must have been quite peculiar. For the present, however, I leave them among the batrachians. By comparing their tracks with those of the Proteus, given on Plate 19, fig. 3, the form of the toes will be seen to be quite similar; but how different the mode of progression!

As to the *Hoplichnus*, its mode of walking must have been similar to that of quadrupeds; but since we know as yet so little

of its characters, I leave it with the batrachian tribe, on the ground of general analogies only.

GROUP VII. LACERTILIANS?

Quadrupedal; fore feet much the smaller. Toes varying from three to five. Heel very long.

Genus XVIII. MACROPTERNA.

Hind feet four-toed; fore feet three to four-toed. Heel long, especially upon the hind feet. Fore feet usually digitigrade, and much smaller than the hind ones. Hind feet usually plantigrade.

Species 1. MACROPTERNA RHYNCHOSAUROIDEA. (Pl. XV. Fig. 9.)

Ornithoidichnites Rogersi, Trans. Am. Geol. Assoc., Plate 11, fig. 7.

Ornithoidichnites minimus, in part, Mass. Geol. Report, Plate 45, fig. 41, and Plate 42, fig. 30.

Nos. 77, 105, 107 - 110, 120, 148, 184, 233, in Cabinet.

Hind feet. — Tetradactylous, leptodactylous. Divarication of the toes, excluding the short one behind, 80°; of the inner and middle toes, 30°; of the middle and outer toes, 50°. Length of the middle toe, 0.7 inch; of the inner toe, 0.45 inch; of the outer toe, 0.5 inch, of the fourth or hind toe, 0.25 (?) inch; of the foot, 1.8 inch; of the step, 3.8 to 5.5 inches; of the heel, 1.2 inch. Width of do., which is uniform throughout, 0.15 inch. Angle made by the axis of the foot with the line of direction, 10° to 50°. Distance of the end of the heel from that line, 0 to 1 inch. Position of the axis of the foot in successive steps, nearly parallel. Distance from tip to tip of the lateral front toes, 0.75 inch; from

the inner to the second toe, 0.5 inch; from the second to the third, 0.55 inch; from the third to the fourth, 0.4 inch (?).

Fore feet. — Tridactylous. Divarication of the toes essentially as in the hind feet. Length of the middle toe, 0.4 inch; of the inner toe, 0.3 inch; of the outer toe, 0.25 inch; of the heel, 0.25 inch; of the foot, 0.6 inch. Position of the axis of the foot and distance from the line of direction, same as in the hind feet. Distance from tip to tip of the lateral toes, 0.5 inch; of the inner and middle toes, 0.3 inch; of the middle and outer toes, 0.3 inch. A track of the hind foot is always preceded by one of the fore foot, distant usually a little more than an inch. A track of a hind and a fore foot, in their normal position, is shown on Plate 15, fig. 9.

Remarks. — The track of this remarkable animal was long mistaken by me for that of *Argozoum minimum*, and was supposed to be that of a biped, probably a bird. But the discovery of the long heel, and the almost constant occurrence of a large and small track together, showed that it was of quadrupedal origin. It is possible, indeed, that what I call a heel may be a hind toe running directly backwards, as is seen in some birds, and as the track of such lizards as the *Phyllurus Cuvieri* and *Milii* would exhibit. (See *Dictionnaire Classique d'Histoire Nat.*, Plate 120.) But its great length on the hind feet makes it more probably, in these tracks, an imprint of the tarsal bone. The specimens from which Plate 22, figs. 4, 5, were sketched were obtained from Wethersfield. That from which fig. 6 was taken was from the north part of South Hadley; and is given in my Geological Report on Massachusetts, Plate 42, fig. 30, as a track of *Argozoum minimum*. Since on this specimen no marks of the heel are visible, the resemblance of the tracks to those of that biped is very striking; and has led me into some doubt whether the *Argozoum minimum* be not

in fact a digitigrade impression of the *Macropterna*. But since the toes of the former are much more divaricate and curved than those of the latter, I do not give in to this opinion, and have retained the former as a species. The specific name of the *Macropterna* is founded upon the fact that the *rhynchosaurus*, according, to Mr. Ward, had but three toes in front, although a saurian lizard. Although the fore foot frequently shows a heel, I have found one on the hind foot in only two instances. Yet they are very distinct examples; though I cannot understand why it should not be shown in other cases, where the foot made as deep an impression. But I have seen too many similar omissions in other tracks, whose characters are well known, to be surprised at it.

The fourth toe on the hind foot I have found in only one instance; and in that case only the extremity of the toe reached the ground; this may explain why it left an impression so seldom. The specimen is so distinct, that I can hardly doubt the existence of such a toe on the animal.

The figures of this species, on Plate 22, are all copied from specimens, and are reduced to one third of the natural size.

Locality. — Wethersfield, on red shale; also at the Horse Race, in Gill, on fine gray micaceous sandstone; and at South Hadley, on gray micaceous sandstone.

Species 2. MACROPTERNA RECTA. (Pl. XV. Fig. 6.)

Sauroidichnites palmatus, Mass. Geol. Report, Plate 34, fig. 16.

Nos. 31 - 33, in Cabinet.

Hind foot. — Tetradactylous, leptodactylous, plantigrade. Divarication of the outer toes, 75° to 80°; of the inner and second, 10°; of the second and third, 30° to 35°; of the third and fourth, 35°. Length of the inner toe, 0.9 inch; of the second, 1.25 inch;

of the third, 1.6 inch; of the outer, 1.1 inch; of the heel, 1.4 inch. Width of the heel, 0.3 to 0.5 inch. Length of the foot, 3 inches; of the step, 7.7 inches. Distance between the tips of the lateral toes, 1.6 to l.8 inch; between the inner and second, 0.7 inch; between the second and third, 0.9 inch; between the third and fourth, 1.2 inch. Axis of the foot nearly coincident with the line of direction. Toes nearly straight.

Fore foot. — Tetradactylous, leptodactylous, imperfectly plantigrade. Divarication of the lateral toes, 100°; of the inner and second, 30°; of the second and third, 35°; of the third and fourth, 35°. Length of the inner toe, 0.25 inch; of the second, 0.4 inch; of the third, 0.9 inch; of the fourth, 0.7 inch; of the heel, 0.5 inch. Width of the heel, 0.8 inch (*length*, literally). Distance between the tips of the lateral toes, l.2 inch; between the first and second, 0.3 inch; between the second and third, 0.7 inch; between the third and fourth, 0.6 inch. Axis of the foot nearly coincident with the line of direction. Toes somewhat curved inward. Distance between the tracks (that is, between the tip of the middle toe behind and the heel of the fore foot), 0 to 1 inch.

Locality. — Horse Race, Gill; on gray micaceous sandstone

Remarks. — The specimen from which the above description was taken is the same as that from which I drew up my description of the *Sauroidichnites palmatus* of the Massachusetts Geological Report. I then regarded the animal as a biped, though suspecting it might turn out to be a quadruped. That conjecture has been verified in a rather singular manner. Very recently, as the specimen would not split well, I attempted to grind down its upper surface upon a grindstone. This brought to light a part of two smaller and similar tracks, a little in advance of the larger ones; which I conceive to settle the question as to their quadrupedal origin. It

also brough t to view a long heel on the hind foot. Of the fore foot I had insulated and perfect specimens, from which the sketch, Plate 15, fig. 6, was taken. Plate 22, fig. 6, shows the position and charac ter of all the tracks on the slab, the front ones being no w in a gr ea t me as ure gr ou nd aw ay . Th is di sc ove ry re nd ers it necessary to remove this species from the genus *Palamopus,* wh ic h is su pp ose d to be co mp ose d of bi pe ds. It ap pr oac he s so near the *Macrop terna* in its genera l charac ter, that I place it the re pro visio nally . Yet bot h fee t hav e fou r toe s; but it wou ld not be strang e if the other specie s of this genus should be found to hav e a sho rt toe on the for e fee t; so tha t I do not thi nk thi s fact a suffic ient reason for referr ing the *M. recta* to anothe r genus. There is somewhat the appearance of a toe runnig obliquely backwards from the end of the heel of the hind foot, where are placed dotted lines on Plate 15, fig. 6. But I am not sure of it, and, besides, it seems to be on the outside of the heel, which is a presumption against its being a toe; as the hind toe usually proceeds from the inside of the heel.

Species 3. MACROPTERNA DIVARICANS. (Pl. XV. Fig. 7.)

Fine specimens in the cabinet of Mr. Dexter Marsh in Greenfield, and in that of Professor Shepard in Amherst College.

Hind feet. — Tetrad actylous. Divari cation of the outer toes, 90° to 100°; of the inn er and sec ond, 25°; of the sec ond and third, 35°; of the third and fourth, 32°. Length of the inner toe, 0.45 inch; of the second, 0.6 inch; of the third, 0.7 inch; of the fourth , 0.6 inch; of the heel, 1.2 inch; of the foot, 1.9 inch; of the step, 3.3 inches. Heel somewhat wedge-shaped, varying in wi dth fr om 0. 2 to 0. 6 in ch . Di stan ce fr om ti p to ti p of th e lateral toes, 1.3 inch; from the inner to the second toe, 0.55 inch;

from the second to the third, 0.6 inch; from the third to the fourth, 0.5 inch. Angle between the axis of the foot and the line of direction, 0° to 80°. Toes all turned outward; much spreading. Feet turned outward. Distance of the heel from the line of direction, 0 to 1.1 inch.

Fore feet. — Pentadactylous. Divarication of the outermost of the four front toes, 125°; of the inner and second, 50°; of the second and third, 50°; of the third and fourth, 25°. Length of the inner toe, 0.25 inch; of the second, 0.45 inch; of the third, 0.4 inch; of the fourth, 0.3 inch; of the fifth, 0.1 inch; of the foot, 0.6 inch. Foot digitigrade. More distant from the line of direction in walking than the hind toe, but less divaricate. Track from 0 to half an inch in advance of the hind foot. Tracks of both feet, of the natural size, and in normal position, shown on Plate 15, fig. 7.

Locality. — Turner's Falls; below the Falls, on the Gill side.

Remarks. — The first specimen of this species, discovered by Mr. Marsh and now in his cabinet, exhibits only the hind toes. As soon as I saw it, I recognized it as nearly related to the *Sauroidichnites palmatus* of my Massachusetts Report, and probably identical with it; although I had then no certain evidence that any of them were quadrupeds, as we had then on the specimen only an alternation of the right and left hind foot, as shown on Plate 19, fig. 5, which is a copy of the slab above referred to in Mr. Marsh's cabinet, reduced to one third of its natural size. When, however, I discovered the small tracks connected with the large ones of *Macropterna recta* (*S. palmatus*), I hastened to Greenfield to reexamine Mr. Marsh's specimen, in the hope of finding there also the fore foot. To my surprise and gratification, I found that he had obtained from a new locality, below Turner's Falls, most beau-

tiful specimens of this species, with the small fore foot as distinct as the hind one. One of these specimens is sketched on Plate 22, fig. 8, reduced three times. It was, however, only on a fine specimen in Professor Shepard's cabinet that I have discovered a fifth toe on the fore foot, too distinct to be doubted. I am still somewhat suspicious that this and the preceding species (*M. recta*) may turn out to be the same; although the latter is a good deal larger, the toes much straighter (hence the specific name), and, if I have not mistaken the character of the fore foot, this also differs a good deal, having a large heel. Both these species differ from the *M. rhynchosauroidea*, by having a quite different heel, and four or five toes, instead of three, on the fore foot.

Plate 22, fig. 10, is a sketch, of the natural size, of two rows of tracks on a slab in Mr. Marsh's collection. The fore tracks are much better developed than the hind ones. They appear to be the smallest of all tracks yet discovered. If they are the *M. divaricans*, they must have been made by the young of that species.

Genus XIX. XIPHOPEZA.

Tetradactylous: three toes directed forward; the fourth being a prolongation backward of the outer toe. Heel stout, expanding posteriorly. Hind and fore feet unequal, resembling three swords, or daggers, in a complex sheath.

Species 1. XIPHOPEZA TRIPLEX. (Pl. XV. Fig. 8.)

Specimens in the cabinet of Mr. Dexter Marsh.

Hind feet. — Three toes directed forward. Divarication of the outer toes, 80° to 90°; of the inner and middle, 40°; of the middle and outer, 50°; of the middle and hind, 130°; of the hind and outer, 180°. Length of the inner forward toe, 0.8 inch; of

the middle, 1.5 inch; of the outer, 1.1 inch; of the hind, 0.5 inch; of the heel, 1.2 inch; of the foot, 2.6 inches; of the step, 2.5 to 3.5 inches; of the middle front toe beyond the rest, 0.6 inch; Greatest width of the heel, near its posterior part, 0.45 inch; near the roots of the toes, 0.2 inch; between the tips of the lateral forward toes, 1.5 inch; between the inner and middle, 1 inch; between the middle and outer, 1.1 inch. Axis of the foot nearly parallel to the line of direction. Distance of the axis of the foot from that line, 1.4 inch.

Fore feet. — Much smaller than the hind feet; but only a few of the toes can be seen upon the specimens yet found of the tracks, — certainly not more than three. Enough, however, is seen to show the quadrupedal character of the animal. On Plate 22, fig. 9, copied from a slab in Mr. Marsh's cabinet, and reduced three times, we see the hind feet arranged in two nearly parallel rows, with traces of a few of the fore feet in such a position as we should expect in the tracks of a quadruped. The hind foot, of the natural size, with a part of the fore foot, is shown on Plate 15, fig. 8.

Locality. — Turner's Falls, on the Gill shore, below the Falls; on very soft gray micaceous sandstone.

Remarks. — Excluding the heel, the hind foot of this animal corresponds almost exactly to the *Ornithopus gallinaceus*, though smaller. But the heel and its quadrupedal character make it very distinct. Yet if the *Ornithopus Adamsanus* shall be found to be a quadruped, it will form a gigantic species of this genus; and perhaps it ought to b¢ placed here now, since we have no evidence that it is not a quadruped, and its large heel certainly makes it probable that it is. The tracks of this species, and also those of the *Macropterna divaricans* and *Harpedactylus gracilis*, were very recently discovered by Mr. D. Marsh, a little below Turner's Falls,

in Gill, where the highly inclined shales are laid bare. Mr. Marsh has generously allowed me to take sketches from his specimens, and to give the species scientific names; although he expects to give a popular description of them, in the *American Journal of Science*, before the publication of this paper.

Among Mr. Marsh's specimens, found at the above-named locality, is one of which a sketch of two rows of tracks, reduced three times, is given on Plate 23, figs. 1 and 2. I cannot satisfactorily refer this track to any known species, though perhaps it may belong to the one last described; that is, an impression considerably below the layer on which the animal trod. It is chiefly remarkable for the axis of the foot being turned so much inward, towards the line of direction, and for the wire-like fineness of the extremities of the toes. But the different tracks are so unlike and so imperfect, that I conclude they are a good deal altered from the original, and prefer not to describe them as a new species.

Affinities of the Group. — One cannot look at the succession of tracks and the form of the feet in this group, as exhibited upon the accompanying drawings, and much less upon the originals, without being struck with their resemblance to the feet and the tracks of small Lacertilia. The number of toes, indeed, corresponds perhaps more nearly to certain batrachians, say the *Salamandridæ* and *Sirenidæ*, which very commonly have only four toes, at least on the fore feet. But the long heel corresponds better to the lizards; and, upon the whole, I incline to consider them as such. And yet it is extremely difficult to decide between these two classes. There is one fact, especially, in respect to the first two species of *Macropterna*, that does not well correspond to either tribe. I mean the small deviation of the animal's feet to the right and the left of the line of direction. What living Lacertilia or

Batrachia would walk so nearly in a right line? Yet the tracks of *Xiphopeza* and the *Macropterna divaricans* show sprawling legs, like existing, lizards. Most of the fossil animals, also, brought up the hind foot in walking more nearly into the place vacated by the fore foot than existing lizards or batrachians do. It would seem as if these animals must have had longer and more upright legs than any of these tribes now alive. This is, however, less the case in the present group than in some of Group VI. I ought to add, that there is one living species of salamander, and perhaps more, with feet exceedingly like those of the *Macropterna rhynchosauroidea*; namely, with four toes on the hind feet, and three on the fore feet. This is the *Salamandre de Trois Doigts* of Sonnini and Latreille, from whose work on reptiles the outline of this animal, given on Plate 20, fig. 8, was copied. Yet how much more sprawling and divaricate must be the tracks of this animal than those of the *Macropterna* !

GROUP VIII. CHELONIANS.

Quadrupedal; fore feet less than the hind ones. Animal with sprawling or trailing legs.

Genus XX. ANCYROPUS.

Hind feet the larger, three leptodactylous toes in front, and one proceeding from the posterior part of the heel. Toes on the fore foot, three in front; perhaps one behind. Heels before and behind, long and crooked. Toes of both feet much curved outward. Tracks in two parallel rows. Feet slightly resembling an anchor, and hence the name.

Species 1. ANCYROPUS HETEROCLITUS. (Pl. XV. Figs. 3 - 5.)

Sauroidichnites heteroclitus and *Jacksoni*, Mass. Geol. Report, Plate 30, figs. 2 and 3.

Nos. 2 - 6, 130, 156, in Cabinet.

Hind foot. — Heel 1.5 inch long, 0.7 inch wide. Length of the inner toe, 0.4 inch; of the second, 0.6 inch; of the third, 0.5 inch; of the hind toe, 0.5 inch; of the foot, 3 inches; of the step, from 4.5 to 5.5 inches. Versed sine of the outward curvature of the toes, from 0.4 to 0.7 inch, making them very crooked. Distance from tip to tip of the lateral toes, 0.9 inch; of the inner and second, 0.45 inch; of the second and third, 0.45 inch; of the middle front and the hind toes, 1.8 inch. Heel at its posterior extremity adhering to the mud so as to raise a singular conical eminence (shown in the drawings), as it was lifted up. Tracks in two rows, from 6 to 7 inches apart; the toes turned outward, and the axis of the foot parallel to the line of direction.

Fore foot. — Heel 1.8 inch long, and 0.3 inch broad; crooked; the hind part turned towards the line of direction, opposite to that of the toes. Length of the inner toe, 0.3 inch; of the middle, 0.4 inch; of the outer, 0.35 inch. Perhaps a fourth toe on the inner side of the heel. Distance from tip to tip of the lateral toes, 0.5 inch; of the inner and second, 0.3 inch; of the second and third, 0.25 inch. Curvature of the toes the same as on the hind foot. Tracks of both the hind and fore feet shown, of the natural size, on Plate 15, figs. 3 - 5; the last two being of the hind foot.

Remarks. — Until recently I had found only insulated tracks of this genus, and I described the hind and fore feet as distinct species (*Geological Report*, p, 478, Plate 30, figs. 2 and 3). The discovery of the specimen of tracks from which Plate 19, fig. 4, was sketched, however, although quite imperfect, reveals the true char-

acter of the animal, and also the reason why some of the tracks were much narrower than others, namely, that one is the fore foot and the other the hind foot. It is quite possible, I think, that there may be four toes in front, certainly on the hind foot, which I take to be the largest, according to a general rule. Plate 15, fig. 5, copied from a track found at Wethersfield, so much resembles the others, that I do not separate them, although the former shows four distinct toes in front.

On Plate 19, fig. 4, one of the tracks seems to have a fourth toe proceeding from the outside of the heel. This is not quite certain, though I have endeavoured to copy the specimen. The inner hind toe, also, is wanting on that specimen. But it is not perfect enough to found any important conclusions upon it, save that it shows the manner in which the animal walked.

Genus XXI. HELCURA.

Quadrupedal; tail and feet trailing upon the ground.

Species 1. HELCURA LITTORALIS. (Pl. XV. Fig. 1.)

No. 136 in Cabinet. Specimens also in Mr. Marsh's cabinet.

Feet from 1.5 to 2.5 inches long, and from half an inch to an inch wide; tracks somewhat acuminate, as if the foot trailed on lifting it up, and the trail continuing often interruptedly to the next track. A similar trail, also, seems to have been made by the tail. Tracks somewhat in two rows; two tracks being usually near each other, and then a wider interval. Plate 15, fig. 1, is copied from No. 136, and represents a portion of the trail and tracks of this animal, of the natural size.

Remarks. — One cannot look upon the specimen (No. 136 of my cabinet) from which Plate 15, fig. 1, was copied, without being

struck with the resemblance to the trail of a tortoise upon mud. Yet after the animal passed, a thin layer of mud was deposited, after which other animals walked over it and a shower of rain fell upon it, so that the tracks of the *Helcura* are indistinct. The toes cannot be distinguished; nor can the successive tracks of the same foot be seen very certainly. I cannot, however, doubt that these trails were made by a chelonian, and by a different species from any other whose tracks I have met upon this sandstone. They have been found only at Turner's Falls. A second fine example may be seen in Mr. Marsh's collection, a sketch of which is given on Plate 23, fig. 3. Plate 21, fig. 1, shows also the trail of *Helcura.*

Affinities of the Group. — It seems unnecessary to add much to the preceding descriptions, to make it probable that the genera *Ancyropus* and *Helcura* were chelonians. No other animals that I know of would leave such footmarks and trails. The approximation of the tracks, as shown on Plate 19, fig. 4, shows that the Ancyropians moved forward very slowly, just as tortoises now do. Their tail and feet, also, were frequently trailed over the mud, as was done by the Helcurans. And if I have not mistaken the characters of these genera, the conclusion seems forced upon us that they were chelonians.

GROUP IX. ANNNELIDS OR MOLLUSCS

Track a curved or looped furrow, of various sizes.

Genus XXII. HERPYSTEZOUM.

Characters the same as those of the group.

Species 1. HERPYSTEZOUM MARSHII. (Pl. XVII. F;~. 1.)

Groove made by the progression of the animal, 0.2 inch wide. Shown, of the natural size, on Plate 17, fig. 1. Plate 23, fig. 4, shows another specimen, from Mr. Marsh's collection, greatly reduced.

Remarks. — This species was discovered at Turner's Falls, by Mr. Dexter Marsh, who, by indefatigable industry and tact, has obtained a very rich and valuable collection of the footmarks and other fossils of the Connecticut valley. Hence I have attached his name to this animal. This paper will testify, also, that he has discovered several other species described in it.

Species 2. HERPYSTEZOUM MINUTUM. (Pl. XVII. Fig. 2.)

Width of the groove made by the progression of the animal, 0.05 inch. Shown, of the natural size, on Plate 17, fig. 2.

Remarks. — The only difference between the two species of this genus consists in size, - that is, so far as we can judge from their track- way. Yet this difference is so great, that they must have been produced by different species. Both of them occur at Turner's Falls, on reddish shale.

Affinities of the Group. — The resemblance between the trackways of these animals and those of certain annelids, especially the common earthworm, upon mud, is very striking. That such was the origin of the figure 1, Pl. 17, I have little doubt. Fig. 2 is rather larger than the earthworm produces, and it might have been made by a small mollusc. I more incline, however, to refer it to the Annelata.

GROUP X.

Feet didactylous; toes unequal, in shape somewhat like the drag used in tilling land.

Genus XXIII. HARPAGOPUS.

Characters the same as those of the group.

Remarks. — I have hesitated long before referring the marks described under this group to the tracks of animals, because they differ so much from the feet of any animals with which I am acquainted. But there is so much uniformity among these impressions, that we must refer them to some common cause; some cause, too, that made an impression on the surface of mud, rather than to a body interposed between layers of mud; and I know of no agency, but the feet of animals, that could have made such impressions. Moreover, we do know of some living animals (as the crustaceans), that have didactylous feet. Heteroclitic, then, as these markings are, I must refer them to the tracks of animals, till proved to be something else.

Species 1. HARPAGOPUS GIGANTEUS. (Pl. XVIII. Fig. 1.)

Nos. 137, 152, in Cabinet.

Divarication of one pair of toes, 15°; of the other, 25°. Length of the longest toe in one pair, 10.5 inches; of the shortest do., 7 inches; of the longest in the other pair, 1.3 inches; of the shortest do., 5 inches (as far as it reached the ground). Thickness of the toes, 1.4 to 1.7 inch. Feet pointing in nearly opposite directions. One foot shown, of the natural size, on Plate 18, fig. 1. On Plate 23, fig. 5, is a reduced copy of the slab, showing both feet, and also a row of the tracks of *Brontozoum parallelum* and *Æthyopus minor.*

Remarks. — It may seem an insuperable objection to considering the sketches of Pl. 23, fig. 5, as the feet of the same animal, that they point in opposite directions. But a reference to the feet of some reptiles will show that such would be the tracks which they would make. Plate 23, fig. 6, is an outline of the *Algyra barbarica*, copied from Griffith's Cuvier, Vol. IX. p. 212. Of a similar character is the outline on Plate 23, fig. 7, of the *Salamandra Beecheyi*, copied from the *Zoölogy of Beechey's Voyage*, Plate 31, fig. 3.

I would not intimate that the *Harpagopus giganteus* was a batrachian or lacertilian; for I have no evidence of another set of tracks corresponding to those sketched on Plate 23, fig. 4. Indeed, I know of no living animal whose feet correspond to these impressions. Yet some crustaceans have bifurcated extremities; as was the case with some encrinites. Then one cannot but think, in this connection, of the ichthyopodulites of Dr. Buckland, or petrified track-ways of certain ambulatory fishes, whose fins struck the muddy bottom.

Locality. — Turner's Falls, where it was obtained by Mr. Marsh; and he has specimens in his cabinet.

Species 2. HARPAGOPUS HUDSONIUS. (Pl. XVIII. Fig. 2.)

No. 127 in Cabinet.

Rows of tracks two, parallel, about a foot apart; feet didactylous; toes diverging about 40°; unequal in length; blunt; length from 2 to 3.5 inches; the axis of the foot lying nearly at right angles to the direction in which the animal moved. One foot of two toes shown, of the natural size, on Plate 18, fig. 2. Plate 24, fig. 1, shows a greatly reduced outline of a slab in my cabinet, taken from a sidewalk in New York.

Remarks. — These tracks occur in the Hamilton group of the Erie division of the New York system of rocks; and have been particularly described by me in Vol. XLVII. of the *American Journal of Science*, p. 314. I introduce this species here, because the tracks resemble in form the first species of this genus, although, if the animals that made them were similar, they must have been widely separated in age. I am unable to trace out any satisfactory affinities between the present species and any existing animals, although some crustaceans have extremities with a bifurcation similar to these tracks. On Plate 24, fig. 1, it will be seen that the tracks, or pairs of toes, are arranged somewhat in parallel lines.

Species 3. HARPAGOPUS DUBIUS. (Pl. XVIII. Fig. 3.)

Toes from one and a quarter to two and a quarter inches long, and half an inch wide, with rounded extremities; arranged somewhat on a line, across which the axis of the toes lies at an angle of about 50°. Impressions made by the toes shallow, yet distinct. Three impressions shown, of the natural size, on Plate 18, fig. 3.

Remarks. — The tracks of this species have less evidence of being those of an animal than the last, from the silurian rocks of New York. Still there is enough of general resemblance to the *H. Hudsonius*, especially in the form of the impressions and their arrangement along a line, to make it probable that both had a similar origin. This specimen was found by Dr. Deane, at Turner's Falls, and presented to me. I hope that time will throw more light upon it, as well as upon the other species of the genus. It has seemed to me that they exhibit too many evidences of organic origin to be passed in silence.

Conclusion. — I have thus presented the results of more than thirteen years' examination of an obscure and difficult branch of paleontology. In endeavouring to give definiteness and system to its materials, by an application of the laws of zoölogy and comparative anatomy, I know that I have undertaken a difficult task. It is no easy matter to restore animals from mere fragments of their skeletons; yet to recall them into existence from the evidence of their tracks must be still more perplexing. Hence I hope I may claim much indulgence from naturalists, in what they may regard as a bold attempt. Whether they admit my conclusions or not, I trust that they will see that this curious subject is making rapid progress. I had thought, long ago, that I had got nearly to the end of the chapter upon it, so far as the Connecticut valley is concerned. But within a year or two, and with comparatively feeble efforts, some of the most interesting and important of all the facts relating to footmarks have come to light, modifying considerably our previous conclusions, and giving us new and more remarkable insight into the former zoölogical condition of New England. It is no idle boast to say, that I have devoted much time, and labor, and thought, to these mementos of the races that, in the dawn of animal existence in the Connecticut valley, tenanted the shores of its rivers and estuaries. Whatever doubts we may entertain as to the exact place on the zoölogical scale which these animals occupied, one feels sure that many of them were peculiar and gigantic; and I have experienced all the excitement of romance, as I have gone back into those immensely remote ages, and watched those shores along which these enormous and heteroclitic beings walked. Now I have seen, in scientific vision, an apterous bird, some twelve or fifteen feet high, — nay, large flocks of them, — walking over the muddy surface, followed by many others of analogous character,

but of smaller size. Next comes a biped animal, a bird, perhaps, with a foot and heel nearly two feet long. Then a host of lesser bipeds, formed on the same general type; and among them several quadrupeds with disproportioned feet, yet many of them stilted high, while others are crawling along the surface, with sprawling limbs. Next succeeds the huge *Polemarch*, leading along a tribe of lesser followers, with heels of great length, and armed with spurs. But the greatest wonder comes in the shape of a biped batrachian, with feet 20 inches long. We have heard of the Labyrinthidon of Europe, — a frog as large as an ox; but his feet were only 6 or 8 inches long, — a mere pygmy compared with the *Otozoum* of New England. Behind him there trips along, on unequal feet, a group of small lizards and *Salamandridæ*, with trifid or quadrifid feet. Beyond, half seen amid the darkness, there move along animals so strange that they can hardly be brought within the types of existing organization. Strange, indeed, is this menagerie of remote sandstone days; and the privilege of gazing upon it, and of bringing into view one lost form after another, has been an ample recompense for my efforts, though they should be rewarded by no other fruit. But I will indulge the hope, that naturalists will not refuse them a name and a place on the register of pre-adamic existence.

** In order to bring the most important of these characters under the eye at a glance, I have collected them in the appended table. The numbers are the mean of those given in the detailed descriptions, where there is any variation in the characters. For an easy comparison of species, this table will be convenient. But as it will explain itself, further description is unnecessary.

A TABULAR VIEW

OF THE CHARACTERS OF THE TRACK-DISCOVERED ANIMALS OF THE UNITED STATES

		Divarication						Length												Distance						Versed sine				Width				
	Number of toes	Of the outer front toes.	Of the inner and second front toes.	Of the second and third front toes.	Of the third and fourth front toes.	Of the fourth and fifth front toes.	Of the hind toe and middle front toe.	Of the inner toe.	Of the second toe.	Of the third toe.	Of the phalangeal impressions of the inner toe.	Of the phalangeal impressions of the middle toe.	Of the phalangeal impressions of the outer toe.	Of the claw of the middle toe.	Of the fourth front toe.	Of the fifth front toe.	Of the hind toe.	Of the foot.	Of the step.	Of the heel.	Of the middle front toe beyond the rest.	Between the tips of the outer toes in front.	Between the tips of the inner and second front toes.	Between the tips of the second and third toes.	Do. the middle front and hind toe and the fourth front toe.	Between the tracks of the hind and fore feet.	Of the heel from the line of direction = the distance of the rows of tracks.	Of the inner toe.	Of the middle toe.	Of the outer toe.	Of the fourth toe.	Of the toes.	Of the heel.	Or. do. at the roots of the toes.	Angle between the axis of the foot and the line of direction.	Number of phalangeal impressions made by the toes, reckoning outwards.
Brontozoum.																																		
1. giganteum,	3	40	22	15				10	12.5	12.5	3.8-4.4	3.4-3-2.6	3.3-3.5-2.1-2.4	1.75				16	56		5.5	12	7.45	7.5			2.5					2.5				2-3-4
2. Sillimanium,	3	35	25	15				4.4	6	.5.	1.4-1.1	1.2-1.3-1.2	0.8-0.7-0.9-1.1	1				8	19		3	5	4	3.5								1.4				2-3-4
3. loxonyx,	3	28	17	10				4.4	6	5.5	1.6-1.6	1.6-1.7-1.4	1-1.3-1.2-1.5	1				8	30		3	5.75	4	4								1.4			35	2-3-4
4. expansum,	3	60	25	30				3.2	4.6	4.9	1.3-1.2	1.4-1.3-1.3	1.6-1.2-0.9-1.3	1.1				6.5	25		2.4	6	4.2	3.4								1.3				2-3-4
5. gracillimum,	3	50	25	25				1.7	2.2	2	0.5-0.4	0.5-0.4-0.4	0.45-0.4-0.45-0.6	0.4				2.5	7.5		0.9	1.9	1.2	1.35			0.8					0.4			5	2-3-4
6. parallelum,	3	17	55	12				1.8	2.5	2	0.8-0.9	0.8-0.8-0.8	0.55-0.4-0.4-0.55	0.4				3.2	18		1.4	1.5	1.7	1.6								0.5			0	2-3-4
Æthyopus.																																		
1. Lyellianus,	3	35	15	20				4.2	6.4	5.2	1.6-1.8	1.8-1.8-1.7	1.2-1.2-1-1.5	1				8			3.3	4.8	4.1	3.9								1.5				2-3-4
2. minor,	3	60	25	35				2.5	3.2	2.9	1.2-0.8	1-0.8-0.7	0.8-0.7-0.6-0.5	0.7				3.8	9		1.5	3.3	2	2.5			1.25					0.8			8	2-3-4
Steropezoum.																																		
1. ingens,	3	60	35	20				9.75	13	10.25								24	56	10	4.5	9.5	6.7	6.3				0.5	0.7				8	1.5			
2. elegans,	3	62	35	30				2.3	4.4	2.8								6.5	16	2.2	2.4	3	3	2.6				0.15	0.35	0.2			2	1			
3. elegantius,	3	70	30	40				1.1	2	1.3								2.5	7	1	1.2	1.5	1.4	1.4									2.5	0.4			
Argozoum.																																		
1. Redfieldianum,	3	75	30	45				8	12	9.5				2				12.5	30		6	12	7.8	9				0.7						0.4			
2. dispari-digitatum,	3	47	24	23				2.8	5.3	3.2								5.5	15		1.8	2.6	2.4	2.7			0.5								0		
3. pari-digitatum,	3	85	40	45				1.2	1.7	1.2								1.7	11		0.8	1.8	1.1	1.4											20		
4. minimum	3	90	50	40				0.6	0.85	0.7								0.9	3.2		0.35	1.1	0.7	0.6											10		
Platypterna.																																		
1. Deaniana,	3	75	45	25				1.5	3	1.8								4.3	10	1.2	1.8	2.3	2.1	2.2				0.17	0.12	0.22			1.2	1			
2. tenuis,	3	53	25	28				1	2	1.3								2.4	7(?)	0.6	1	1.4	1.2	1.3									0.6				
3. delicatula,	3	40	22	18				0.6	1.1	0.75								1.5	3	0.4	0.5	0.6	0.6	0.55									0.35	0.25			
Ornithopus.																																		
1. Adamsanus,	4	100	40	60			140	4.2	6.5	5.2							3			6(?)	4.3	7	4.5	6.5	11								3.5	2.2			
2. gallinaceus,	4	70	35	45			140	1.5	2.75	1.8							1.3	2.8	7		1.5	2.37	1.9	1.8	4.2												
3. gracilior	4	83	40	43			120	1.1	1.5	1.1							0.8	1.5		0.7	0.7	1.7	1.5	1.3	2											
4. loripes,	4	100	50	50			120	3.75	5	4							2.75	6.8	19	2	2.5	5.7	3.9	3.9	6.8		3	0.4	0.6	0.2	0.2			3	10		
Polemarchus.																																		
1. gigas,	4	45	20	25			80	8.5	11.2	8.3							2.5	15	48	3.8	3.2	7.6	4.3	6.5	13			0.5	0.9	0.3			3.9	2.5			
Plectropus.																																		
1. minitans,	4	90	40	50			100	2.2	3.1	2.1							0.9	4.7	16	1.5	1.8	3.2	2.1	2.7	4			0.15		0.1			0.45	0.4			
2. longipes,	4	72	32	40			95	1.7	2.8	2.1							0.8	7.5	15	4.2	1.3	2.4	1.7	1.9	4								0.3	0.4			
Triænopus.																																		
1. Baileyanus,	4	37	18	18			35	1.9	2.9	2.2							0.8	4.5	7(?)	1.7	1.5	1.4	1.3	1.5	3.5								0.2	0.4			
2. Emmonsianus,	4	50	25	25			115	1.8	2.7	1.9							0.8	3.2		0.4		1.8	1.3	1.7	3.4			0.15	0.12	0.05			0.2	0.4			
Harpedactylus.																																		
1. gracilis,	4	70	33	35			55	1.9	2.2	1.8							0.9	3.7	8	1.6	0.8	2.2	1.2	1.5	2			0.17	0.13	0.2	0.12		0.2			
2. concameratus,	3	60	25	35				2	3.2	1.6									1.2		2.2	3.5	1.7	3.4				0.3	0.6				2	2.2			
Typopus.																																		
1. abnormis,	3	35	20	15				1.3	2.8	1.8								4	18	2.7	1.4	2.8	1.8	2									0.25	2.2			
Otozoum																																		
1. Moodii,	4	35	15	5	12			8.5	10.25	8	3-2-3.4(?)	second toe 2.4-2.5-2.9-2.6(?)	third toe 2-2-3.8(?) outer toe 1.6-1.6-5.4(?)		8.5			20	36			13	6.5	3.4	2.7		2.5					2.7			15	3-4-3-3	
Palamopus.																																		
1. Dananus,	4	67	25	30	15			2	2.5	4.7					2.3		2	8.5	21	3.7	2.7	4.7	2.4	3.4	3								2	3			
Thenaropus.																																		
1. heterodactylus - hind ft.,	5	75	15	20	10	28		1.6	1.8	2.4					3.1	0.9		5.5	12.5			4	1.2	1.5	2	1	3.5						2.2		30	
fore ft.,	4	90	20	30	40			1.2	1.4	1.5					1.1			4.2				4.5	1.5	1.8	1.2							0.7	2.7	2.7	35	
Anomœpus.																																		
1. scambus - hind ft.,	4(?)	47	25	20				2.4	3.2	3.3	0.7-0.7-0.8	1.1-1-0.7	0.8-0.8-0.6-0.6-0.6					7	9	4.2	1.2	2.7	1.9	1.8			2.5								20	3-3-5
fore ft.,	5	87	27	17	40		95	1	1.3	1.5	0.4-0.3	0.3-0.3-0.3	0.4-0.3-0.3-0.3		1.2	1.2	1										2								35	2-3-4-3-2
2. Barrattii - hind ft.,	5	120	30	45	35	15		1.5	1.7	2.2					2.	1.6		7.5	12	1.5?									0.4		0.15						
fore ft.,	5																																			
Anisopus																																		
1. Deweyanus - hind ft.,	4	45	20	10	10			0.5	0.7	0.8					0.5			1.7	7	0.9		1.4	0.6	0.45	0.4		1.5					0.25		1.2	30	
fore ft.,	4	45	20	10	10			0.2	0.5	0.6					0.35			0.6				0.7	0.25	0.25	0.3							0.15			30	
2. gracilis - hind ft.,	4	40	15	10	15			0.4	0.6	0.9					0.7			0.9	5.7			0.75	0.3	0.3	0.25							0.1		0.5	20	
fore ft.,	5(?)	40	15	10	15			0.2?	0.4	0.55					0.4			0.55				0.4	0.2	0.15	0.25							0.08			20	
Hoplichnus.																																		
1. quadrupedans,																											3						1.9			
Macropterna.																																		
1. rhynchosauroidea - hind ft.,	4	80	30	50				0.45	0.7	0.5					0.25			1.8	4.6	1.2		0.75	0.5	0.55	0.4	1	1						0.15		30	
fore ft.,	3	80	30	50				0.3	0.4	0.25								0.6		0.25		0.5	0.3	0.3									0.15		30	
2. recta - hind ft.,	4	77	10	32	35			0.9	1.25	1.6					1.1			3	7.7	1.4		1.7	0.7	0.9									0.4			
fore ft.,	4	100	30	35	35			0.25	4	0.9					0.7					0.5		1.2	0.3	0.7		1							0.8			
3. divaricans - hind ft.,	4	95	25	35	32			0.45	0.6	0.7					0.6			1.9	3.3	1.2		1.3	0.55	0.6	0.5		0.6						0.4		40	
fore ft.,	5	125	50	50	25			0.25	0.45	0.4					0.3	0.1										0.5									
Xiphopeza.																																		
1. triplex - hind ft.,	4	90	40	50			130	0.8	1.5	1.1							0.5	2.6	3	1.2	0.6	1.5	1	1.1			1.4						0.45	0.2			
fore ft.,	4(?)																																			
Ancyropus.																																		
1. heteroclitus - hind ft.,	4							0.4	0.6	0.5							0.5	3	5	1.5		0.9	0.45	0.45	1.8		3.4	0.4	0.5	0.6			0.7		0	
fore ft.,	4(?)							0.3	0.4	0.35										1.8		0.5	0.3	0.25				0.4	0.5	0.6			0.8			
Harpagopus.																																		
1. giganteus,	2	15 to 25						5 to 7	10 to 13																							1.4 to 1.7			180	
2. Hudsonius,	2	40						2	3.5																		3							90		
3. dubius,																																		

The angular measures in the above table are given in degrees; the linear measures, in English inches and decimals of the same.

EXPLANATION OF THE PLATES.

N.B. — The tracks only of the species enumerated are represented.

Plate I.	Fig. 1.	Brontozoum giganteum.
II.	" 1, 2.	B. loxonyx.
	" 3.	B. gracillimum.
III.	" 1.	B. expansum.
	" 2.	B. Sillimanium.
	" 3, 4.	B. parallelum.
IV.	" 1.	Æthyopus Lyellianus.
	" 2, 3.	Æ. minor.
V.	" 1.	Steropezoum ingens.
	" 2.	S. elegans.
	" 3.	S. elegantius.
	" 4.	Ornithopus rectus.
	" 5.	Harpedactylus rectus
VI.	" 1.	Argozoum Redfieldianum.
	" 2.	A. dispari-digitatum.
	" 3, 4.	A. pari-digitatum.
	" 5.	A. minimum.
VII.	" 1.	Platypterna Deaniana.
	" 2, 3.	P. tenuis.
	" 4.	P. delicatula.
	" 5.	Ornithopus Adamsanus.
VIII.	" 1.	O. gallinaceus.
	" 2.	O. gracilior.
	" 3.	O. loripes.
	" 4.	Plectropus longipes.

Plate IX.	Fig.	1.	Polemarchus gigas.
	"	2, 3.	Plectropus minitans.
X.	"	1-3.	P. longipes, on different layers.
	"	4.	Triænopus Baileyanus.
	"	5.	T. Emmonsianus.
	"	6.	Typopus abnormis.
XI.	"	1.	Palamopus Dananus; left foot.
	"	2.	P. Dananus; right foot.
XII.	"	1.	Otozoum Moodii.
	"	2.	Slab, with four tracks of O. Moodii, several of Brontozoum, and rain-drops.
XIII.	"	1.	Anomœpus scambus; hindfoot.
	"	2.	A. scambus; fore foot.
	"	3.	A. scambus; hind foot, with perhaps four toes.
	"	4.	A. scambus? hind foot.
	"	5, 6.	A. scambus? fore feet.
XIV.	"	1.	A. Barrattii; left hind-foot.
	"	2.	Harpedactylus gracilis.
	"	3.	H. concameratus.
	"	4.	H. concameratus? hind foot ?
	"	5.	H. concameratus? fore foot?
XV.	"	1.	Helcura littoralis.
	"	2.	Typopus?
	"	3.	Ancyropus heteroclitus; fore foot.
	"	4, 5.	A. heteroclitus; hind foot.
	"	6.	Macropterna recta; hind and fore foot.
	"	7.	M. divaricans; hind and fore foot.
	"	8.	Xiphopeza triplex; hind and fore font.
	"	9.	Macropterna rhynchosauroidea; hind and fore foot.

Plate XV.	Fig.	10-13.	Triænopus Baileyanus, on successive layers of rock.
	"	14-16.	T. Emmonsianus, on successive layers.
	"	17-19.	Plectropus longipes, on successive layers.
XVI.	"	1.	Fore foot of Thenaropus heterodactylus.
	"	2.	Hind foot of the same.
	"	3, 4.	Hind and fore feet of Anisopus gracilis.
	"	5, 6.	Hind and fore feet of A. Deweyanus.
	"	7, 8.	Hoplichnus quadrupedans.
XVII.	"	1.	Herpystezoum Marshii.
	"	2.	H. minutum.
	"	3, 4.	Tracks of Platypterna Deaniana, on successive layers; fig. 3 being the highest.
XVIII.	"	1.	Harpagopus giganteus.
	"	2.	H. Hudsonius.
	"	3.	H. dubius
XIX.	"	1, 2.	Ideal tracks of a quadruped.
	"	3.	Tracks of the Banded Proteus.
	"	4.	Reduced sketch of tracks of Ancyropus heteroclitus.
	"	5.	Do. of Macropterna divaricans.
	"	6.	" Triænopus Baileyanus and Emmonsianus.
	"	7.	Typopus abnormis.
X.	"	1.	Tracks reduced of Harpedactylus gracilis.
	"	2.	Foot of Lopholaimus antarcticus.
	"	3, 4.	Foot of Cathartes fœtens.
	"	5.	Foot of a Gryphus.
	"	6.	Track reduced of Anomœpus Barrattii.
	"	7.	Feet of Anolis Edwardsii.

Plate XX.	Fig. 8.	Sketch of a Salamander, with three toes in front.
	" 9.	Slab reduced of Anomœpus scambus.
	" 10.	" " several species of animals.
XXI.	" 1.	" " tracks of Anomœpus scambus, &c., the upper side.
	" 2.	The under side of the same.
	" 3.	Slab of same species, the upper side.
XXII.	" 1.	Reduced slab of the tracks of Anisopus Deweyanus, upper side.
	" 2.	Do. of Anisopus gracilis, under side.
	" 3.	" Hoplichnus quadrupedans.
	" 4-6.	" Macropterna rhynchosauroidea.
	" 7.	" M. recta.
	" 8.	" M. divaricans.
	" 9.	" Xiphopeza triplex.
	" 10.	Slab, natural size, of Macropterna divaricans?
XXIII.	" 1, 2.	Slabs of an unknown species, reduced.
	" 3.	Reduced slab, showing various species from Mr. Marsh's cabinet (Æthyopus, Anisopus, and Helcura).
	" 4.	Herpystezoum Marshii, reduced.
	" 5.	Slab reduced of Harpagopus giganteus, Brontozoum parallelum, and Æthyopus minor.
	" 6.	Sketch of Algyra barbarica.
	" 7.	" Salamandra Beecheyi.
XXIV.	" 1.	Reduced slab of Harpagopus Hudsonius.
	" 2.	" " H. dubius.
	" 3.	" " Æthyopus minor.

Plate XXIV. Fig. 4. Reduced slab of Ornithopus loripes.
“ 5. Brontozoum Sillimanium
“ 6. Harpedactylus concameratus.
“ 7. H. rectus.

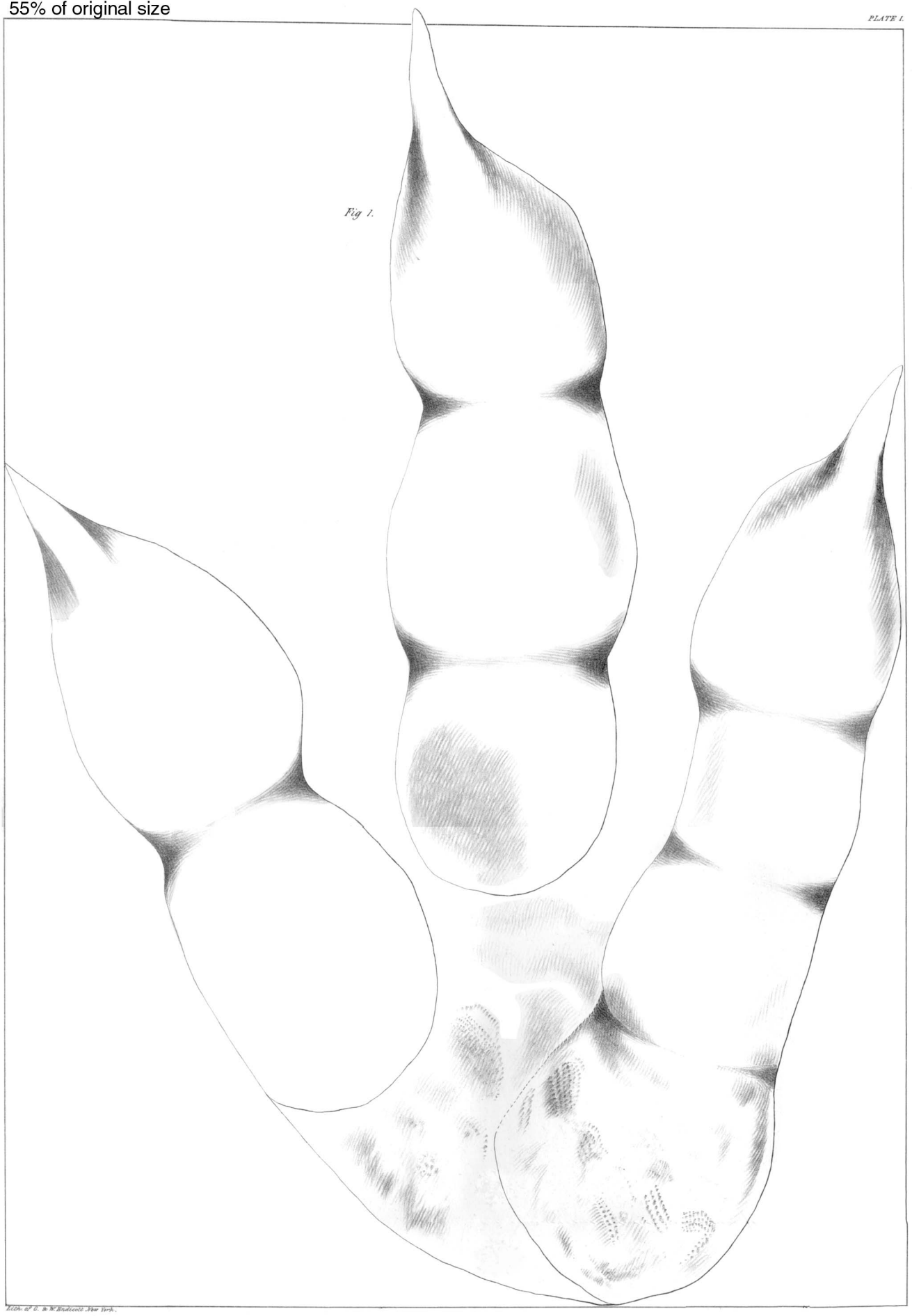
A TABULAR VIEW

OF THE CHARACTERS OF THE TRACK-DISCOVERED ANIMALS OF THE UNITED STATES.

		Divarication						Length											Distance					Versed Sine				Width			
	Number of toes.	Of the outer front toes.	Of the inner and second front toes.	Of the second and third front toes.	Of the third and fourth front toes.	Of the fourth and fifth front toes.	Of the hind toe and middle front toe.	Of the inner toe.	Of the second toe.	Of the third toe.	Of the phalangeal impressions of the inner toe.	Of the phalangeal impressions of the middle toe.	Of the phalangeal impressions of the outer toe.	Of the claw of the middle toe.	Of the fourth front toe.	**Of the fifth front toe.**	Of the hind toe.	Of the foot.	Of the step.	Of the heel.	Of the middle front toe beyond the rest.	Between the tips of the outer toes in front.	Between the tips of the inner and second front toes.	Between the tips of the second and third toes.	Do. the middle front and hind toe and the fourth front toe.	Between the tracks of the hind and fore feet.	Of the hind from the line of direction of the middle of the rows of tracks.	Of the inner toe.	Of the middle toe.	Of the outer toe.	Of the fourth toe.	Of the toes.	Of the heel.	Of do. at the roots of the toes.	Angle between the axis of the foot and the line of direction.	Number of phalangeal impressions made by the toes, reckoning outwards.
Brontozoum.																															
1. giganteum,	3	40°	22°	15				10	12.5	12.5	3.8–4.4	3.4–3–2.6	3.3–3.5–2.1–2.4	1.75			16	56.		5.5	12.	7.45	7.5			2.5					2.5			2–3–4
2. Sillimanium,	3	35	25	15				4.4	6.	5.5	1.4–1.1	1.2–1.3–1.2	0.8–0.7–0.9–1.1	1.			8.	19.		3.	5.	4.	3.5							1.4			2–3–4
3. loxonyx,	3	28	17	10				4.4	6.	5.5	1.6–1.6	1.6–1.7–1.4	1–1.3–1.2–1.5	1.			8.	30.		3.	5.75	4.	4.							1.4		35°	2–3–4
4. expansum,	3	60	25	30				3.2	4.6	4.9	1.3–1.2	1.4–1.3–1.3	1.6–1.2–0.9–1.3	1.1			6.5	25		2.4	6.	4.2	3.4							1.3			2–3–4
5. gracillimum,	3	50	25	25				1.7	2.2	2.	0.5–0.4	0.5–0.4–0.4	0.45–0.4–0.45–0.6	0.4			2.5	7.5		0.9	1.9	1.2	1.35			0.8				0.4		5	2–3–4
6. parallelum,	3	17	55	12				1.8	2.5	2.	0.8–0.9	0.8–0.8–0.8	0.55–0.4–0.4–0.55	0.4			3.2	18.		1.4	1.5	1.7	1.6							0.5		0	2–3–4
Æthyopus.																															
1. Lyellianus,	3	35	15	20				4.2	6.4	5.2	1.6–1.8	1.8–1.8–1.7	1.2–1.2–1–1.5	1.			8.			3.3	4.8	4.1	3.9							1.5			2–3–4
2. minor,	3	60	25	35				2.5	3.2	2.9	1.2–0.8	1–0.8–0.7	0.8–0.7–0.6–0.5	0.7			3.8	9.		1.5	3.3	2.	2.5			1.25				0.8		8	2–3–4
Steropezoum.																															
1. ingens,	3	60	35	20				9.75	13.	10.25							24.	56.	10.	4.5	9.5	6.7	6.3				0.5	0.7			8.	1.5		
2. elegans,	3	62	35	30				2.3	4.4	2.8							6.5	16.	2.2	2.4	3.	3.	2.6				0.15	0.35	0.2		2.	1.		
3. elegantius,	3	70	30	40				1.1	2.	1.3							2.5	7.	1.	1.2	1.5	1.4	1.4								2.5	0.4		
Argozoum.																															
1. Redfieldianum,	3	75	30	45				8.	12.	9.5				2.			12.5	30.		6.	12.	7.8	9.				0.7					0.4		
2. dispari-digitatum,	3	47	24	23				2.8	5.3	3.2							5.5	15.		1.8	2.6	2.4	2.7			0.5						0	
3. pari-digitatum,	3	85	40	45				1.2	1.7	1.2							1.7	11.		0.8	1.8	1.1	1.4									20	
4. minimum,	3	90	50	40				0.6	0.85	0.7							0.9	3.2		0.35	1.1	0.7	0.6									10	
Platypterna.																															
1. Deaniana,	3	70	45	25				1.5	3.	1.8							4.3	10.	1.2	1.8	2.3	2.1	2.2				0.17	0.12	0.22		1.2	1.		
2. tenuis,	3	53	25	28				1.	2.	1.3							2.4	7.(?)	0.6	1.	1.4	1.2	1.3								0.6			
3. delicatula,	3	40	22	18				0.6	1.1	0.75							1.5	3.	0.4	0.5	0.6	0.6	0.55								0.35	0.25		
Ornithopus.																															
1. Adamsanus,	4	100	40	60			140	4.2	6.5	5.2							3.		6.(?)	4.3	7.	4.5	6.5	11.							3.5	2.2		
2. gallinaceus,	4	70	35	45			140	1.5	2.75	1.8							1.3	2.8	7.		1.5	2.37	1.9	1.8	4.2									
3. gracilior,	4	83	40	43			120	1.1	1.5	1.1							0.8	1.5		0.7	0.7	1.7	1.5	1.3	2.								
4. loripes,	4	100	50	50			120	3.75	5.	4.							2.75	6.8	19.	2.	2.5	5.7	3.9	3.9	6.8		3.	0.4	0.6	0.2	0.2		3.	10	
Polemarchus.																															
1. gigas,	4	45	20	25			80	8.5	11.2	8.3							2.5	15.	48.	3.8	3.2	7.6	4.3	6.5	13.			0.5	0.9	0.3		3.9	2.5		
Plectropus.																															
1. minitans,	4	90	40	50			100	2.2	3.1	2.1							0.9	**4.7**	**16.**	**1.5**	**1.8**	**3.2**	**2.1**	**2.7**	**4.**			0.15		0.1		0.45	0.4		
2. longipes,	4	72	32	40			95	1.7	2.8	2.1							0.8	**7.5**	**15.**	**4.2**	**1.3**	**2.4**	**1.7**	**1.9**	**4.**							0.3	0.4		
Triænopus.																															
1. Baileyanus,	4	37	18	18			35	1.9	2.9	2.2							0.8	4.5	7.(?)	1.7	1.5	1.4	1.3	1.5	3.5							0.2	0.4		
2. Emmonsianus,	4	50	25	25			115	1.8	2.7	1.9							0.8	3.2		0.4		1.8	1.3	1.7	3.4			0.15	0.12	0.05		0.2	0.4		
Harpedactylus.																															
1. gracilis,	4	70	33	35			55	1.9	2.2	1.8							0.9	3.7	8.	1.6	0.8	2.2	1.2	1.5	2.			0.17	0.13	0.2	0.12	0.2			
2. concameratus,	3	60	25	35				2.	3.2	1.6									1.2		2.2	3.5	1.7	3.4				0.3	0.6				2.	2.2		
Typopus.																															
1. abnormis,	3	35	20	15				1.3	2.8	1.8								4.	18.	2.7	1.4	2.8	1.8	2.		.						0.25	2.2		
Otozoum.																															
1. Moodii,	4	35	15	5	12			8.5	10.25	8.	3–2–3.4(?)	Second toe. 2.4–2.5–2.9–2.6(?)	Third toe. 2–2–2.8 (?) Outer toe. 1.6–1.6–5.4(?)		8.5			20.	36.			13.	6.5	3.4	2.7		2.5					2.7		15	3–4–3–3
Palamopus.																															
1. Dananus,	4	67	25	30	15			2.	2.5	4.7					2.3		2.	8.5	21.	3.7	2.7	4.7	2.4	3.4	3.							2.	3.		
Thenaropus.																															
1. heterodactylus,	{ Hind ft., 5	75	15	20	10	28		1.6	1.8	2.4					3.1	0.9		5.5	12.5			4.	1.2	1.5	2.	1.	3.5							
	{ Fore ft., 4	90	20	30	40			1.2	1.4	1.5					1.1			4.2				4.5	1.5	1.8	1.2							0.7	2.2 2.7	2.7	30 35	
Anomœpus.	{ Hind ft., 4(?)	47	25	20				2.4	3.2	3.3	0.7–0.7–0.8	1.1–1–0.7	0.8–0.8–0.6–0.6–0.6					7.	9.	4.2	1.2	2.7	1.9	1.8			2.5						20	3–3–5
1. scambus,	{ Fore ft., 5	87	27	17	40		95	1.	1.3	1.5	0.4–0.3	0.3–0.3–0.3	0.4–0.3–0.3–0.3		1.2	1.2	1.									2.						35	2–3–4–3–2
2. Barratii,	{ Hind ft., 5	120	30	45	35	15		1.5	1.7	2.2					2.	1.6		7.5	12.	4.5?														
	{ Fore ft., 5																											0.4		0.15				
Anisopus.																															
1. Deweyanus,	{ Hind ft., 4	45	20	10	10			0.5	0.7	0.8					0.5			1.7	7.	0.9		1.4	0.6	0.45	0.4		1.5					0.25		1.2	30	
	{ Fore ft., 4	45	20	10	10			0.2	0.5	0.6					0.35			0.6				0.7	0.25	0.25	0.3							0.15			30	
2. gracilis,	{ Hind ft., 4	40	15	10	15			0.4	0.6	0.9					0.7			0.9	5.7			0.75	0.3	0.3	0.25							0.1		0.5	20	
	{ Fore ft., 5(?)	40	15	10	15			0.2?	0.4	0.55					0.4			0.55				0.4	0.2	0.15	0.25							0.08			20	
Hoplichnus.																															
1. quadrupedans,																										3.							1.9		
Macropterna.																															
1. rhyncho-sauroidea,	{ Hind ft., 4	80	30	50				0.45	0.7	0.5					0.25			1.8	4.6	1.2		0.75	0.5	0.55	0.4	1.	1.					0.15			30	
	{ Fore ft., 3	80	30	50				0.3	0.4	0.25								0.6		0.25		0.5	0.3	0.3								0.15			30	
2. recta,	{ Hind ft., 4	77	10	32	35			0.9	1.25	1.6					1.1			3.	7.7	1.4		1.7	0.7	0.9		1.						0.4				
	{ Fore ft., 4	100	30	35	35			0.25	4.	0.9					0.7					0.5		1.2	0.3	0.7								0.8				
3. divaricans,	{ Hind ft., 4	95	25	35	32			0.45	0.6	0.7					0.6			1.9	3.3	1.2		1.3	0.55	0.6	0.5		0.6					0.4		40		
	{ Fore ft., 5	125	50	50	25			0.25	0.45	0.4					0.3	0.1										0.5									
Xiphopeza.	{ Hind ft., 4	90	40	50			130	0.8	1.5	1.1							0.5	2.6	3.	1.2	0.6	1.5	1.	1.1			1.4					0.45	0.2		
1. triplex,	{ Fore ft., 4(?)																																	
Ancyrcpus.	{ Hind ft., 4							0.4	0.6	0.5							0.5	3.	5.	1.5		0.9	0.45	0.45	1.8		3.4	0.4	0.5	0.6		0.7		0	
1. heteroclitus,	{ Fore ft., 4(?)							0.3	0.4	0.35										1.8		0.5	0.3	0.25				0.4	0.5	0.6		0.8			
Harpagopus.																															
1. giganteus,	2	15 to 25					5 to 7	10 to 13																							1.4 to 1.7			180	
2. Hudsonius,	2	40					2	3.5																		3.							90	
3. dubius,																																		

The angular measures in the above table are given in degrees; the linear measures, in English inches and decimals of the same.

Fig 1.



Lith. of G. & W. Endicott New York.

Lith. of G. & W. Endicott New York

Lith of G & W. Endicott N. York.

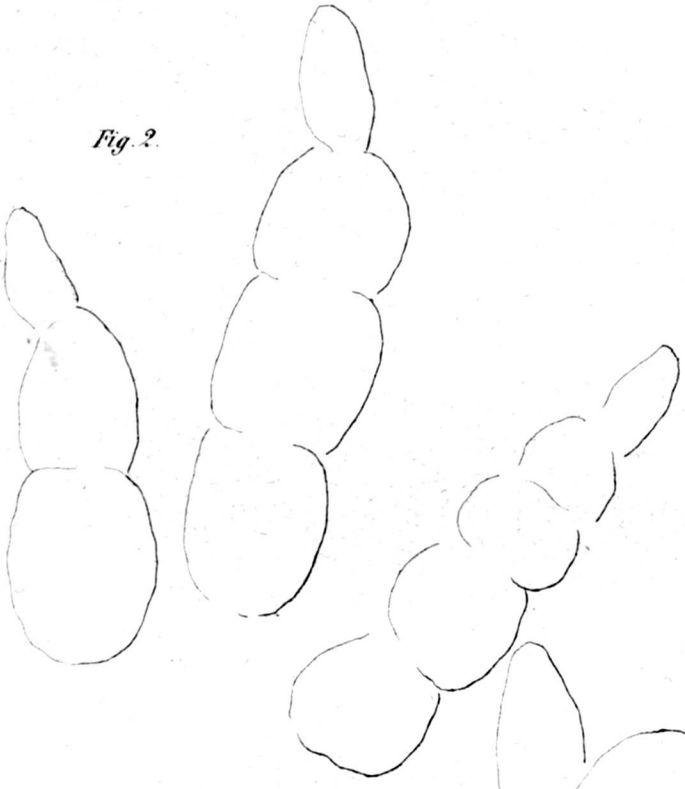


Fig. 2.

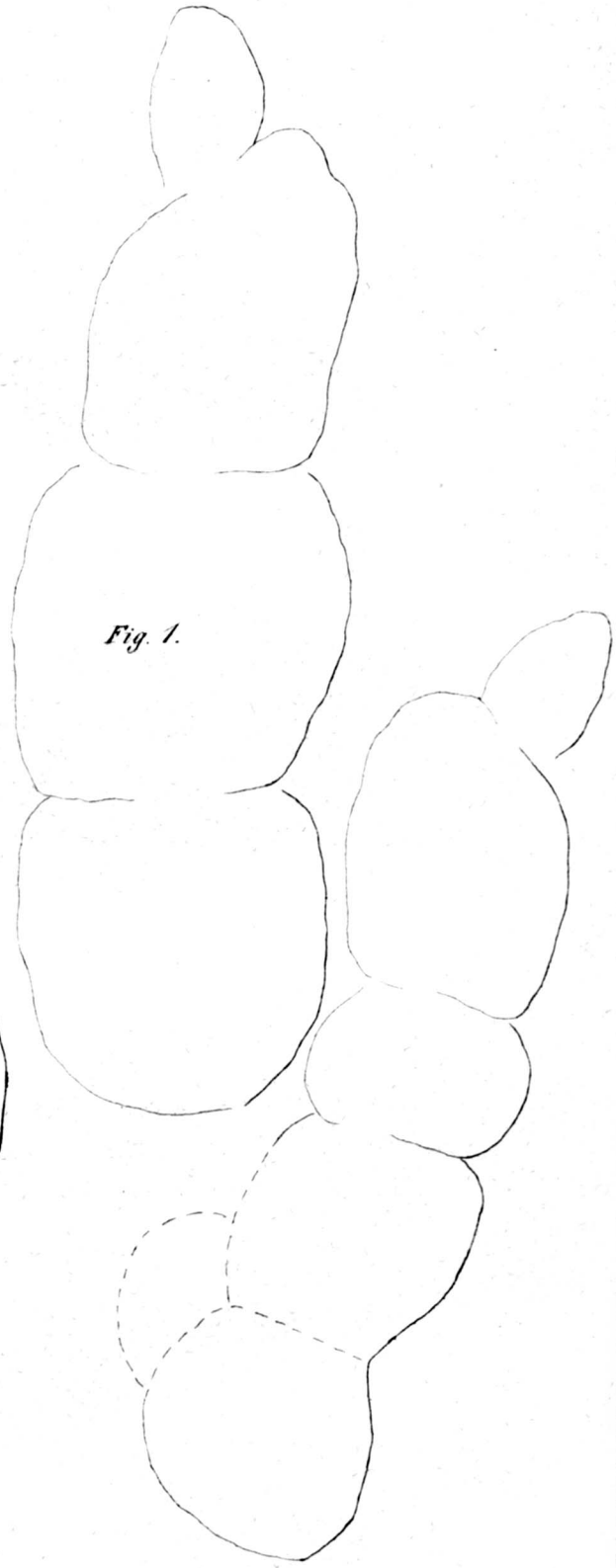


Fig. 1.

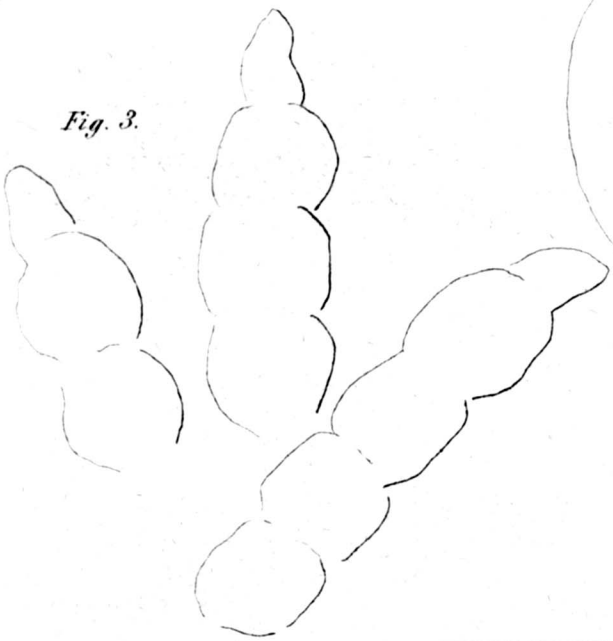


Fig. 3.

Lith. of G. & W. Endicott N. York.

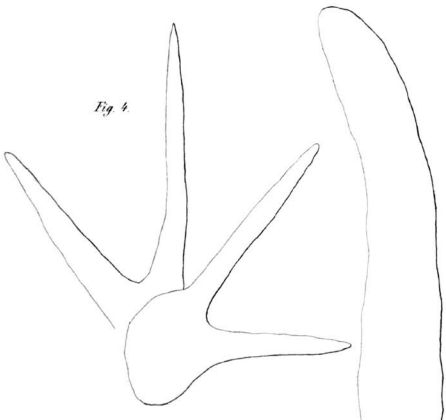


Fig. 4.

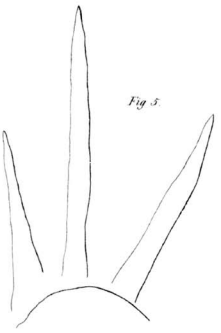


Fig. 5.

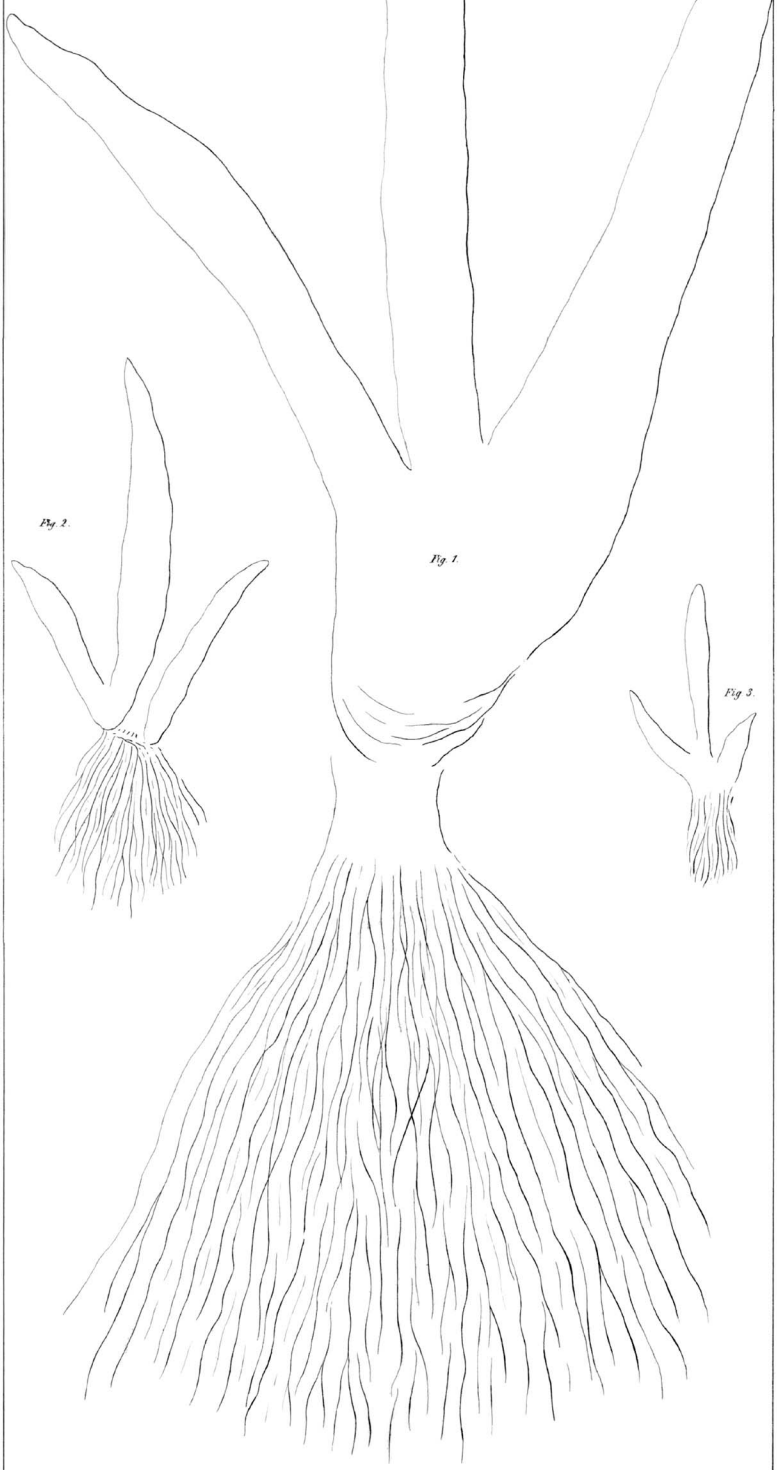


Fig. 1.

Fig. 2.

Fig. 3.

Lith. of C. & W. Endicott New York

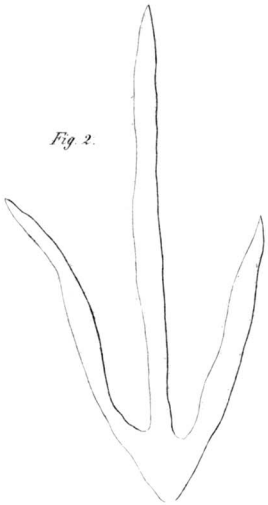


Fig. 2.

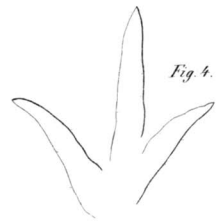
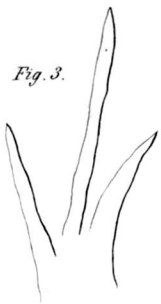


Fig. 4.

Fig. 1

Fig. 5.

Lith. G.W. Endicott New York.



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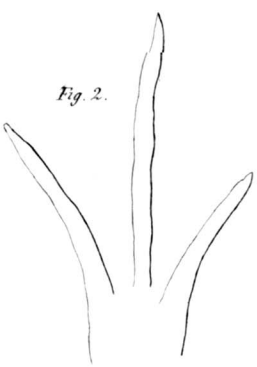

Fig. 2.

Fig. 5.

Fig. 4.

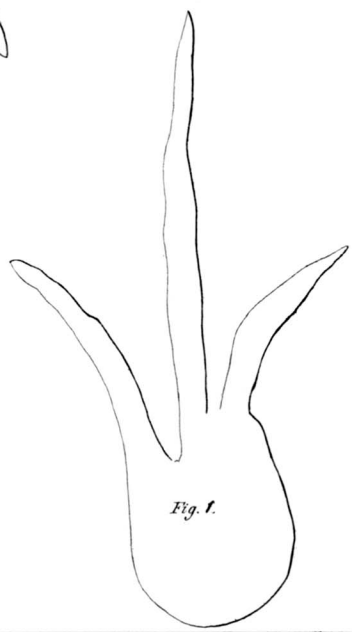

Fig. 1.

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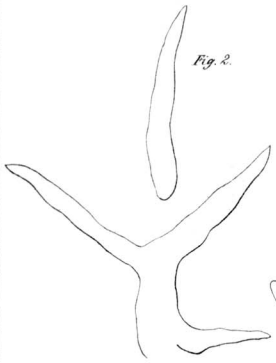
Lith. of J. & W. Endicott N York.



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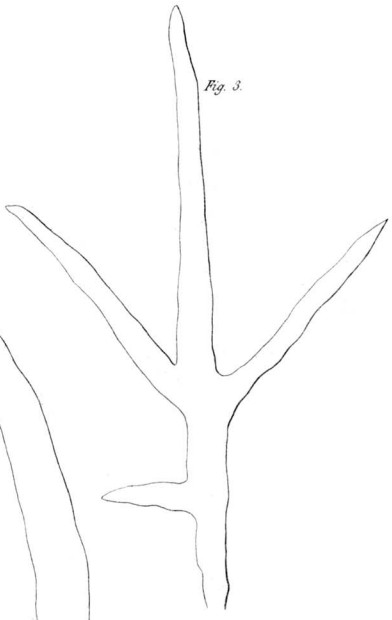


Fig. 3.

Fig 1.

Lith. of C. & W. Endicott New York.

Fig. 6.

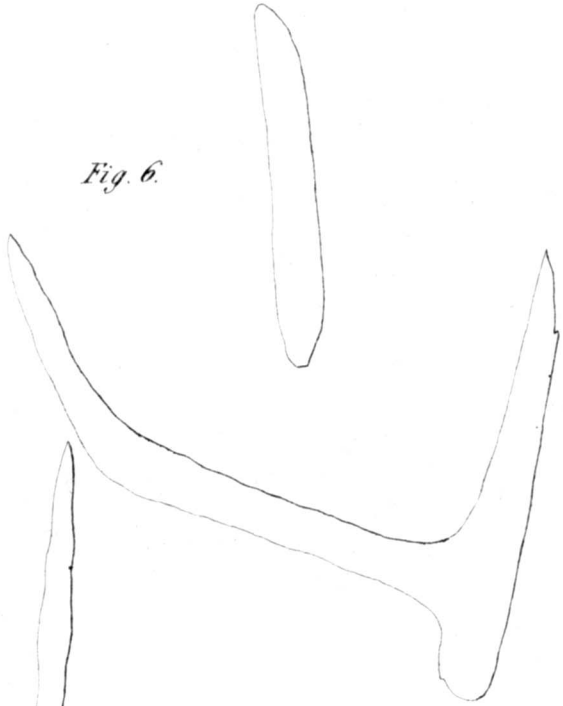


Fig. 5.

Fig. 4.

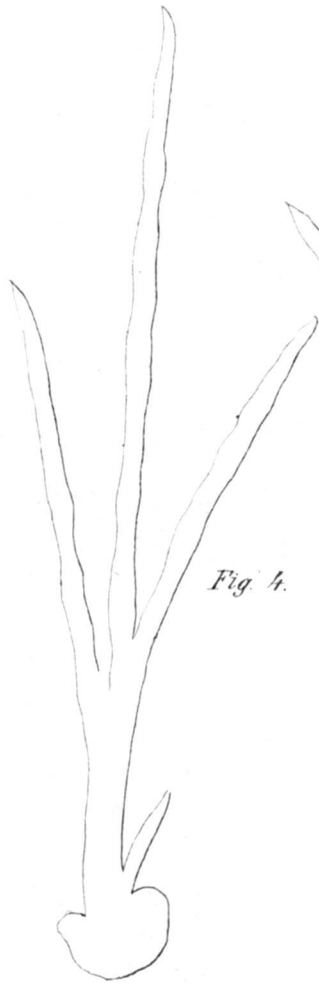
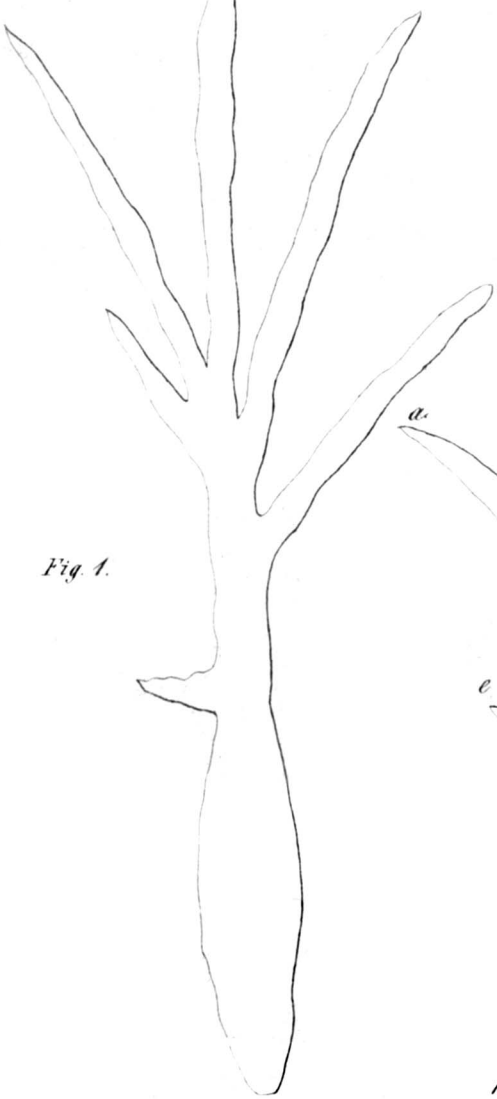


Fig. 1.



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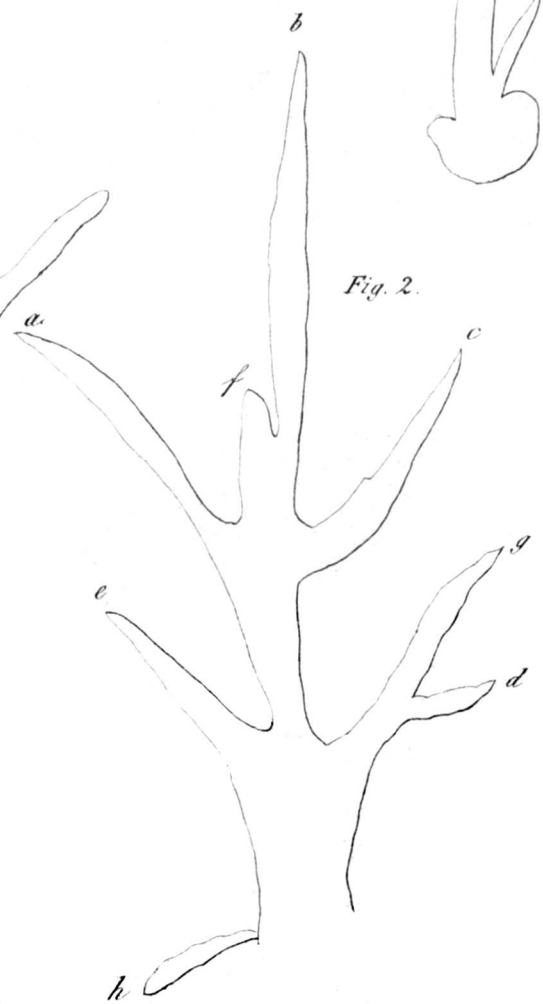

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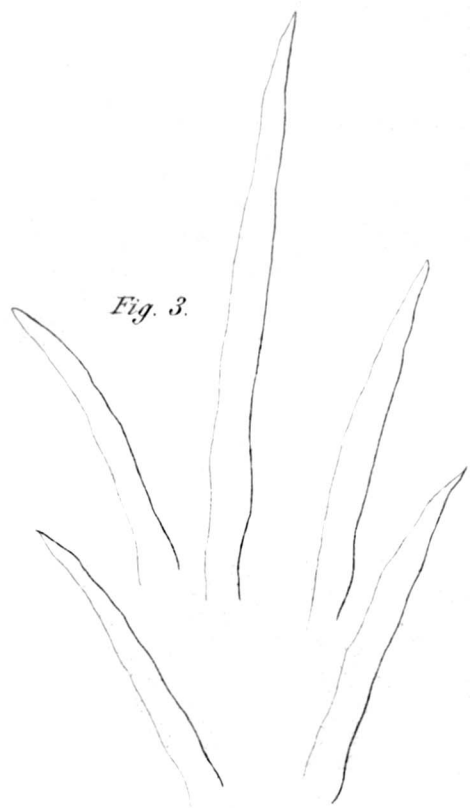


Lith of G. & W. Endicott N. York

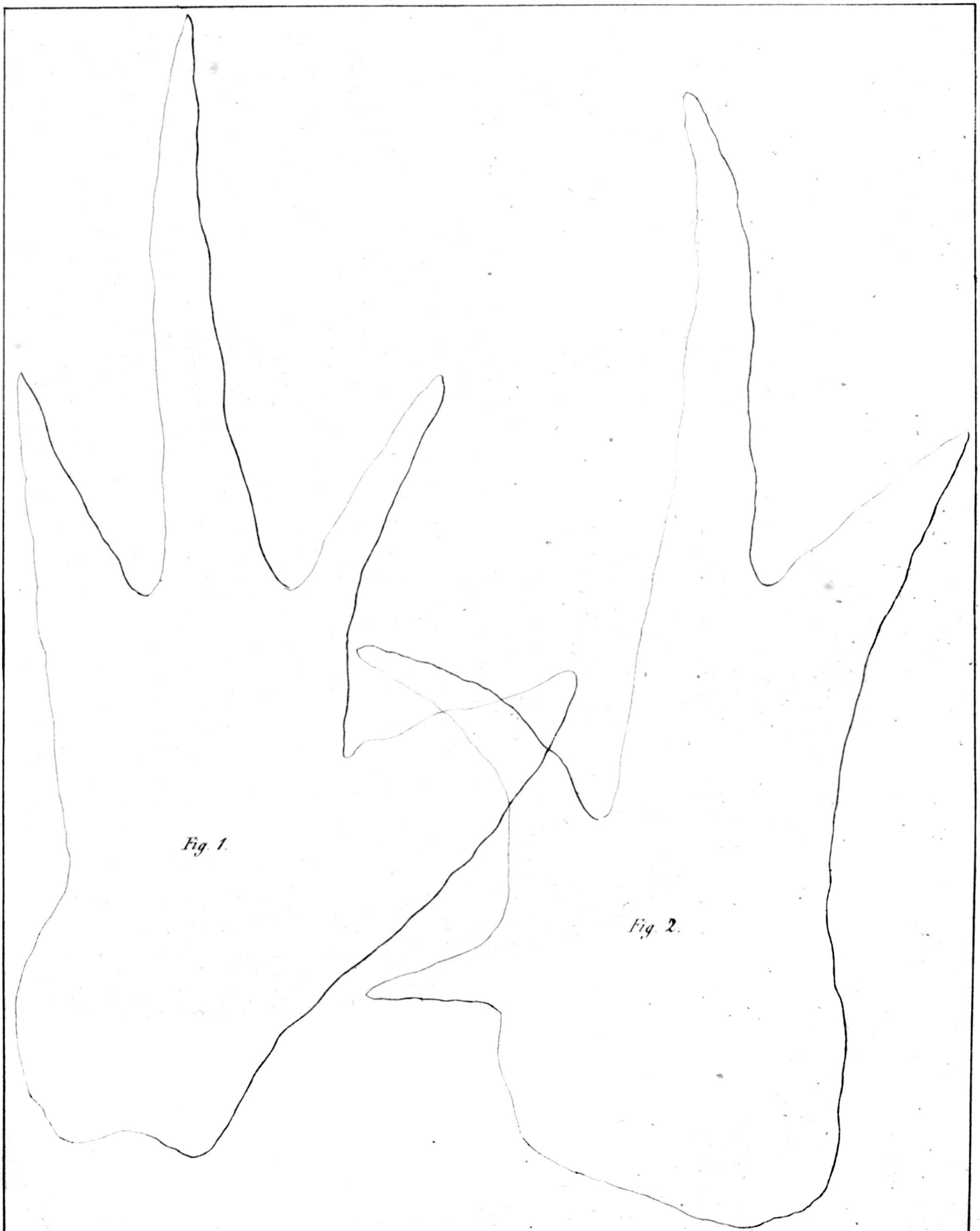


Fig. 1.

Fig. 2.

Luth. of G. & W. Endicott N. York.

Fig. 1

Fig. 2.

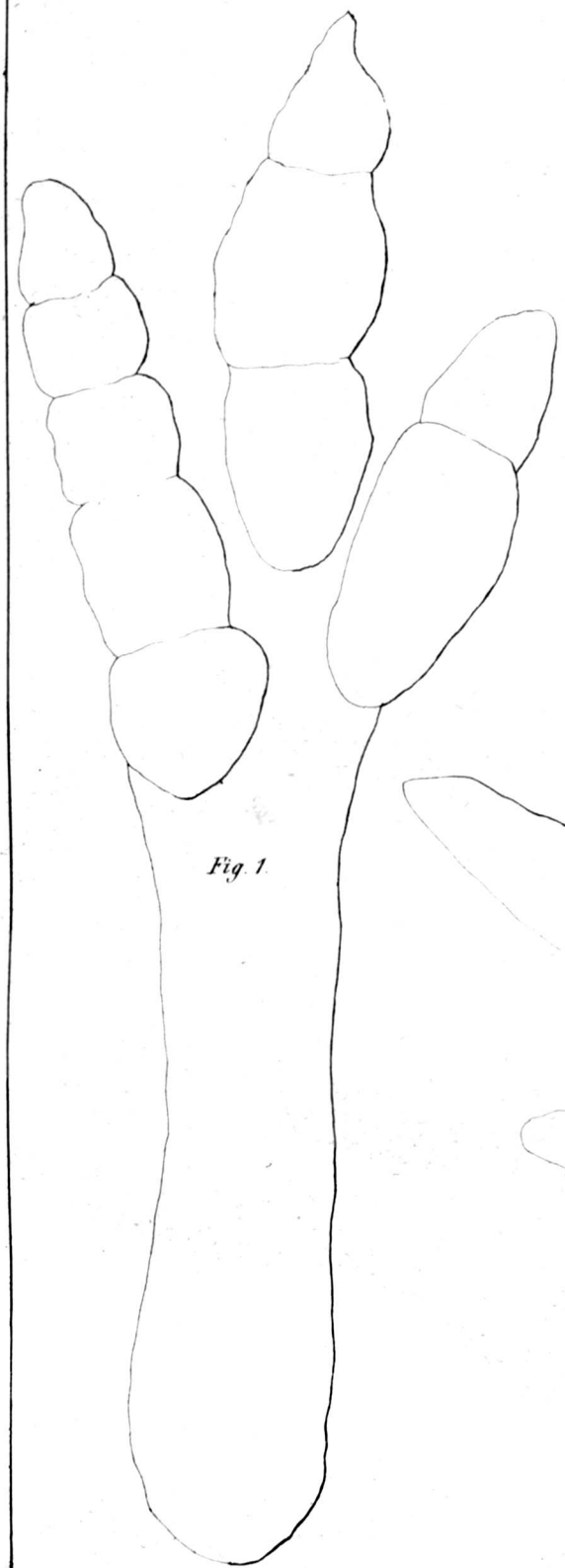
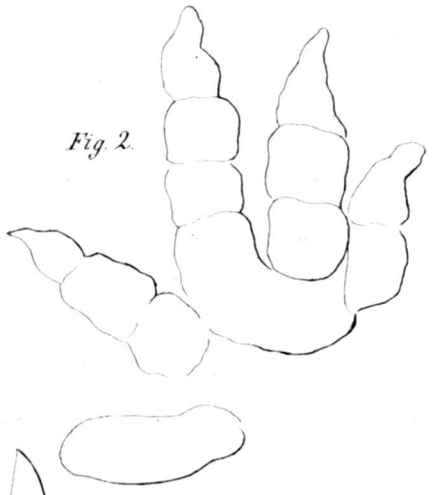


Fig. 1



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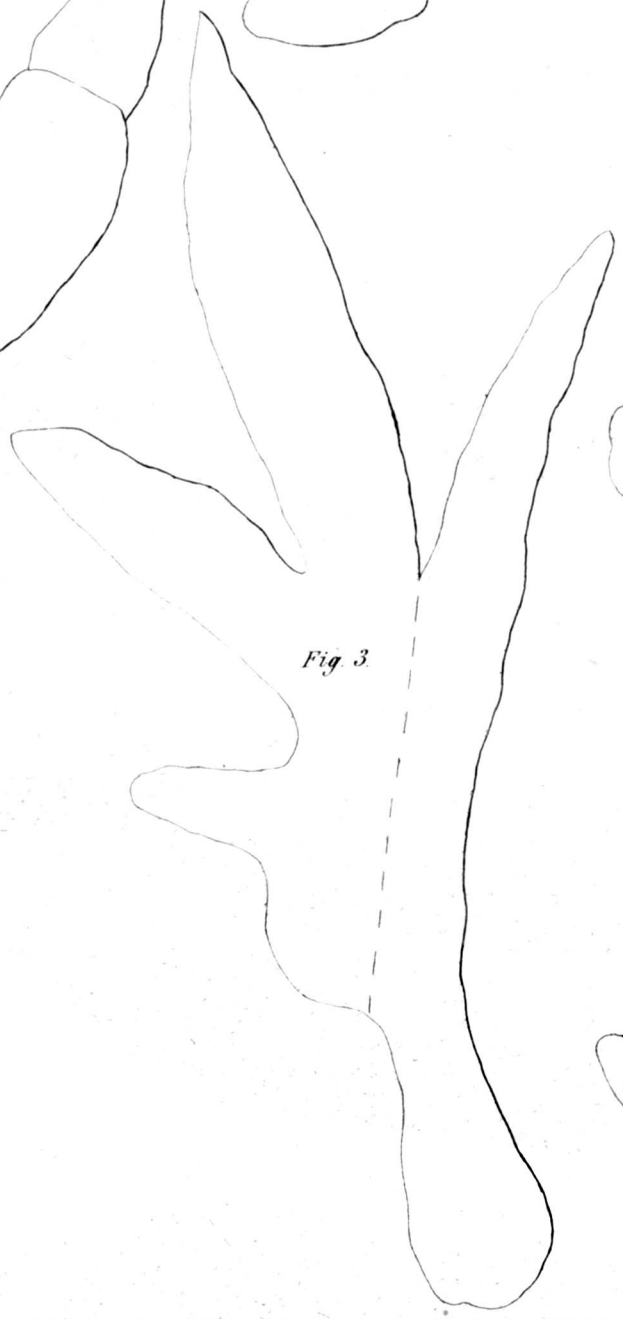


Fig. 3.

a

Fig. 5.

Fig. 6.

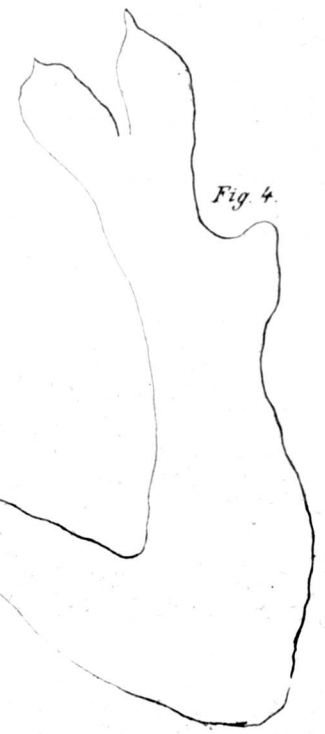


Fig. 4.

Lith. of G. & W. Endicott New York.

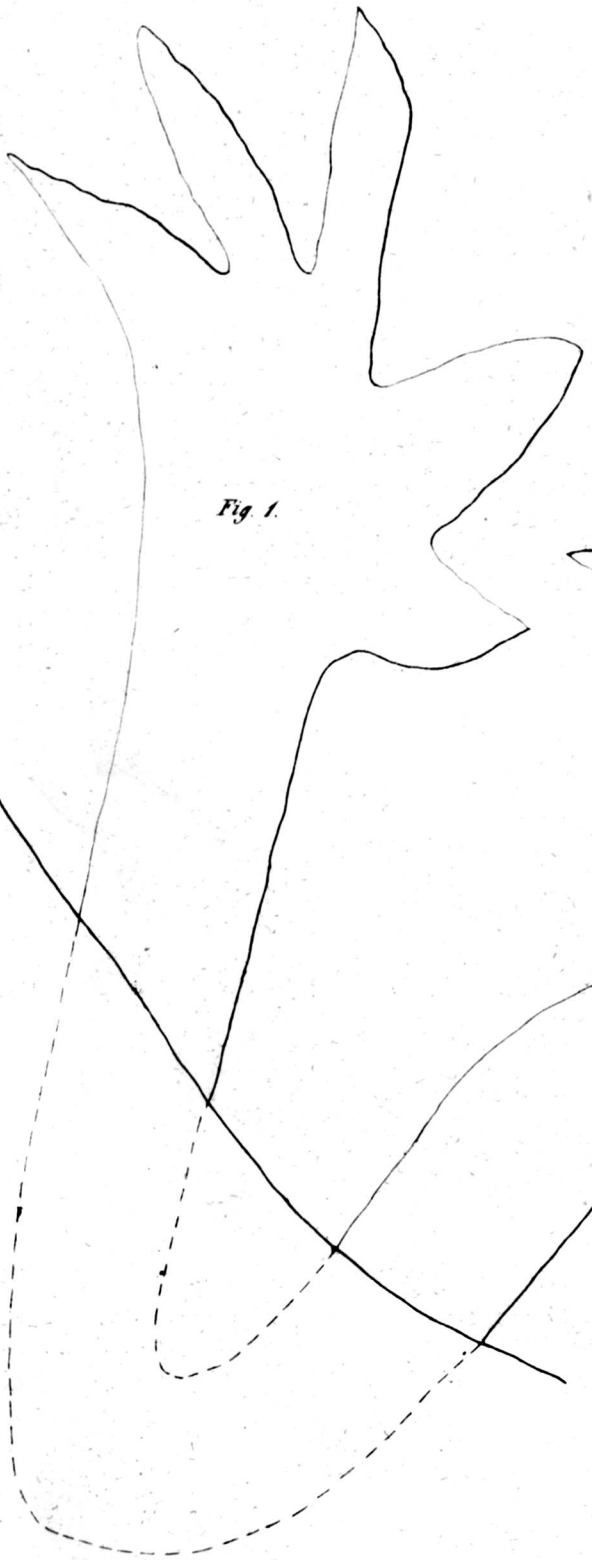


Fig. 1.

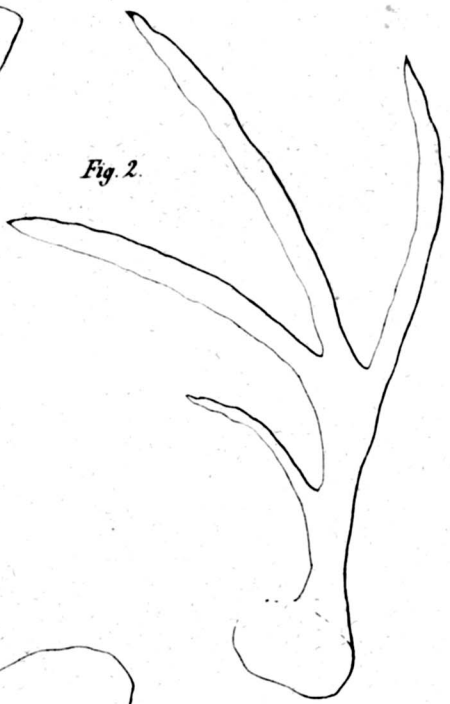
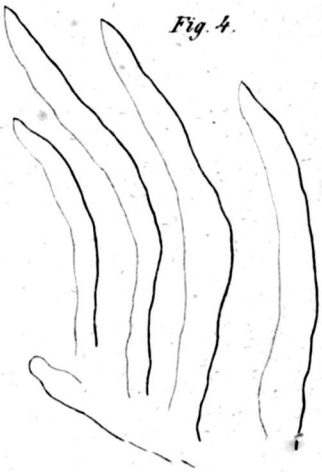


Fig. 2.

Fig. 5.



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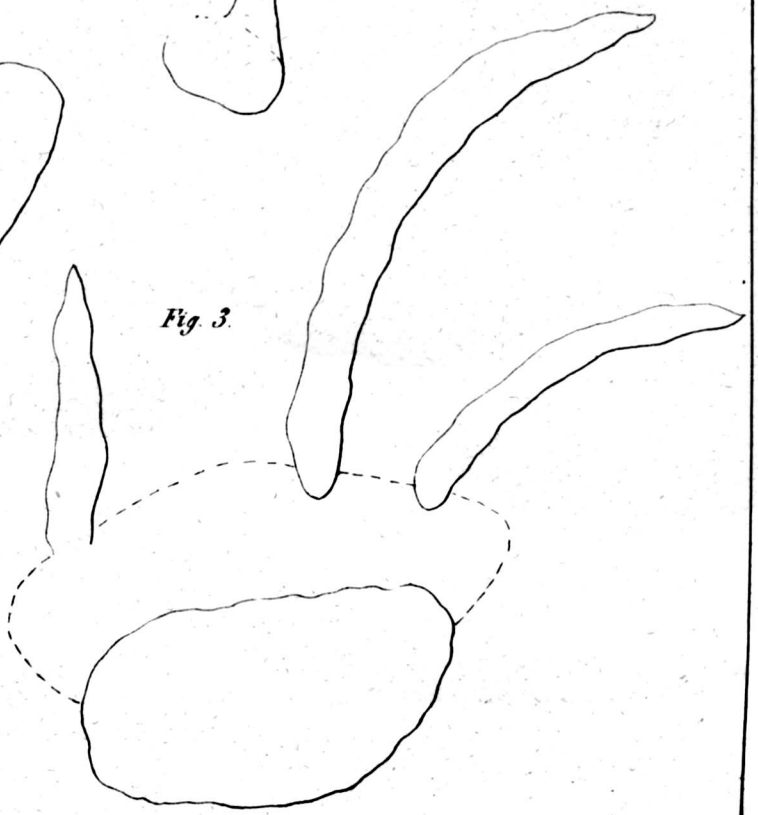

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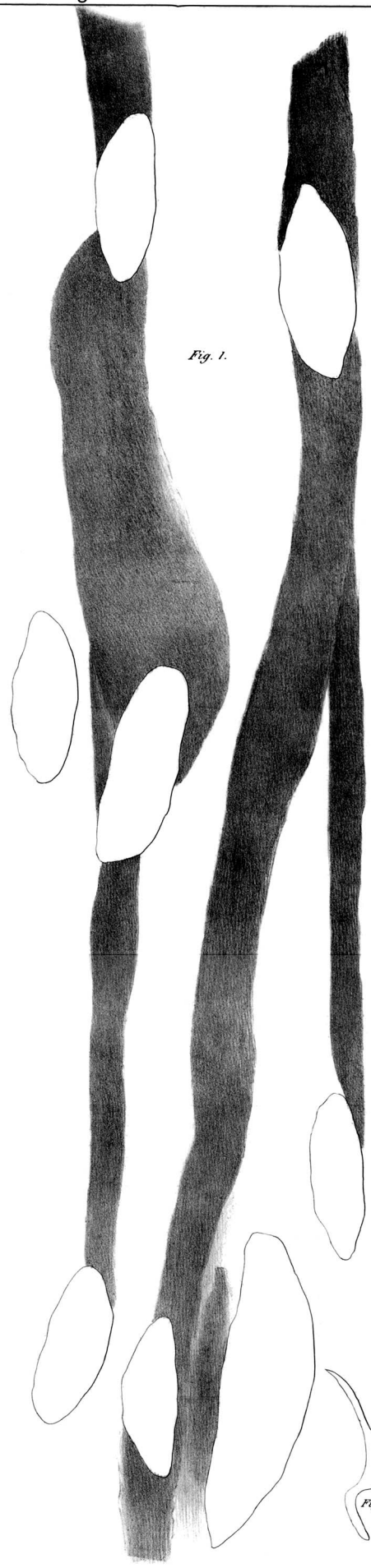
Lith. of G. & W. Endicott N. York.



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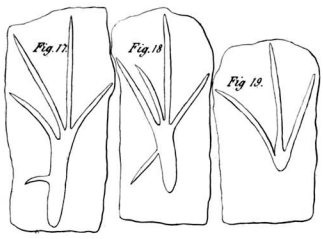


Fig. 17.

Fig. 18.

Fig 19.

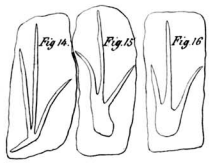


Fig 14.

Fig 15.

Fig 16

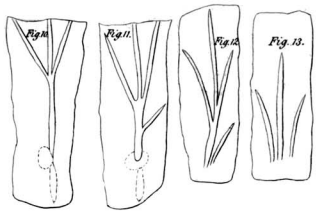


Fig 10.

Fig 11.

Fig 12.

Fig. 13.

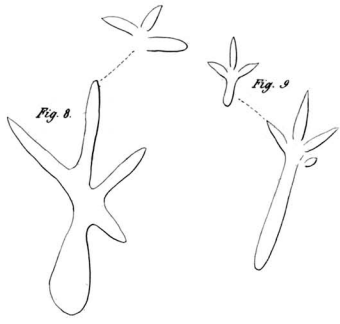


Fig. 8.

Fig. 9

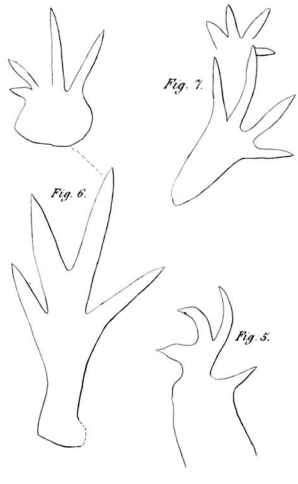


Fig. 7.

Fig. 6.

Fig. 5.

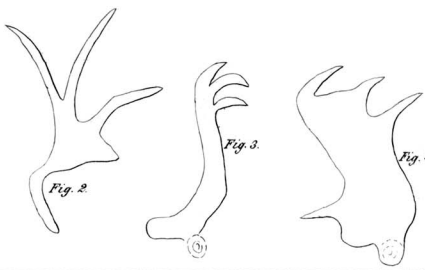


Fig. 2.

Fig. 3.

Fig. 4.

Lith. of G. R. Hall Eaglewood New York.

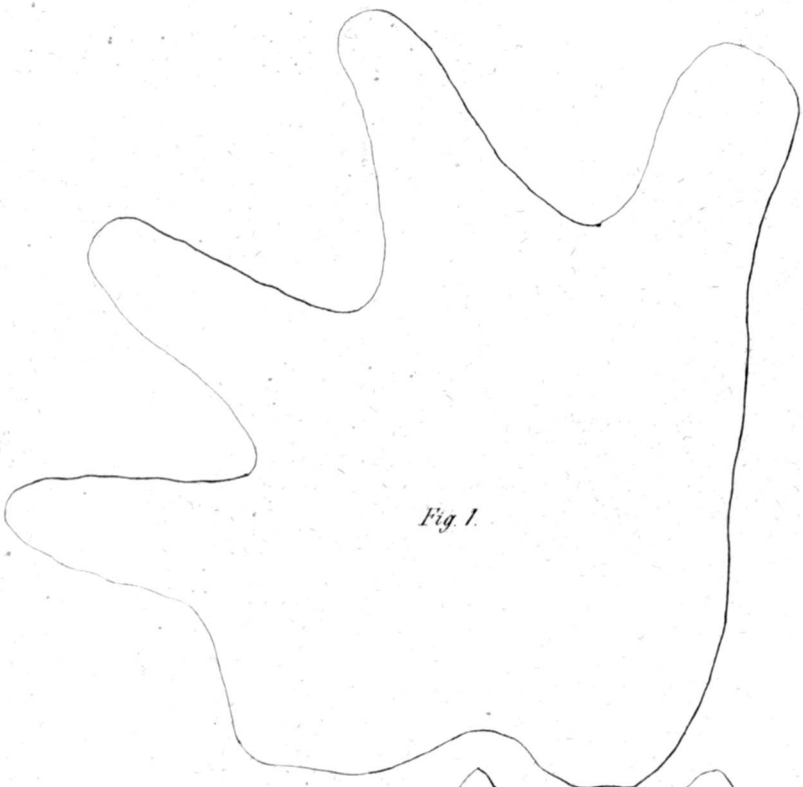
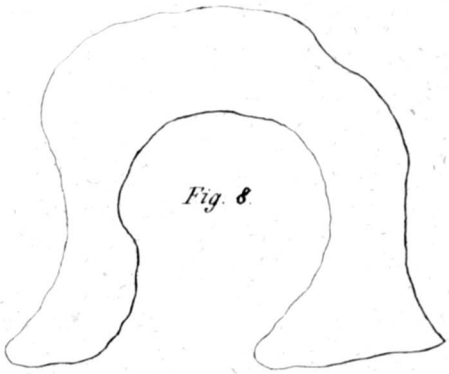


Fig. 1.



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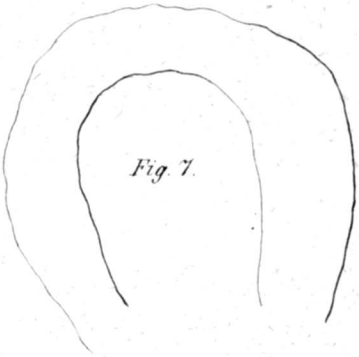


Fig. 7.

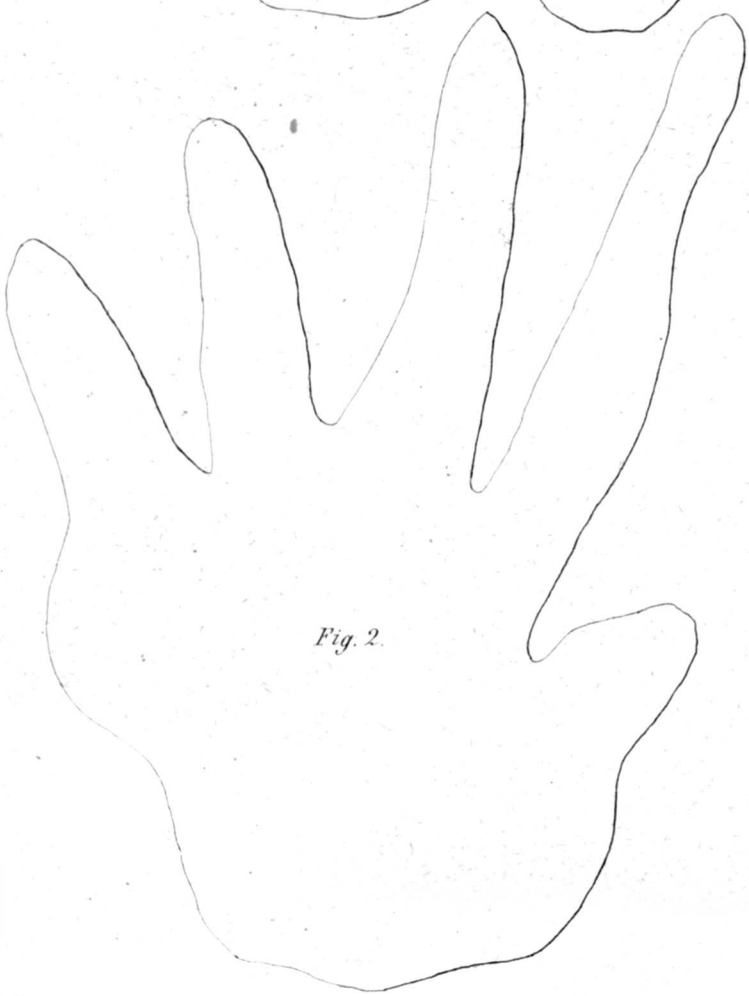


Fig. 2.

Fig. 6.

Fig. 5.

Fig. 3.

Fig. 4.

Lith. of G. & W. Endicott New-York.

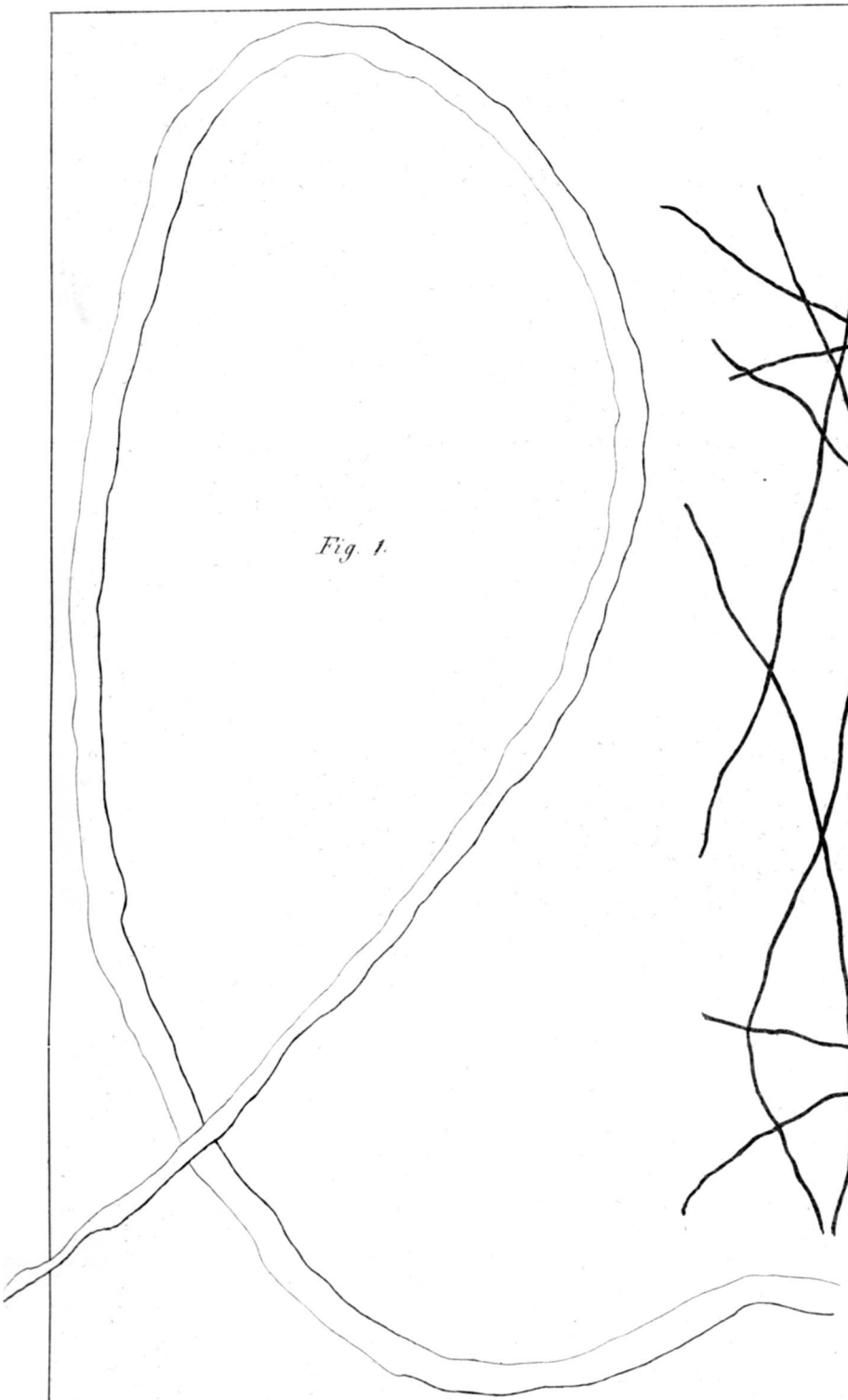
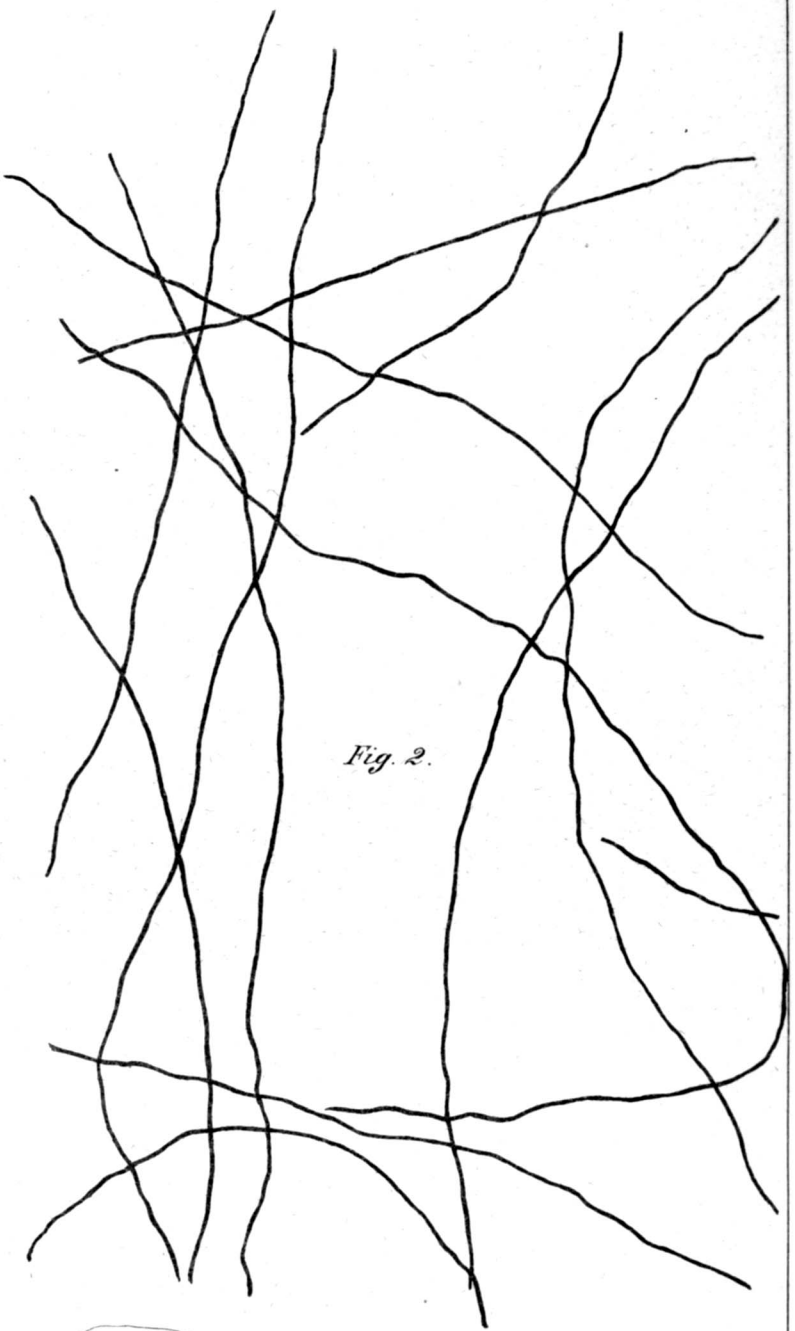


Fig. 1.



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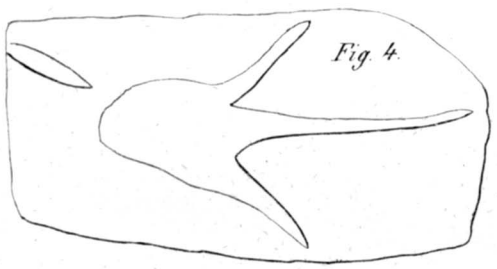


Fig. 4.

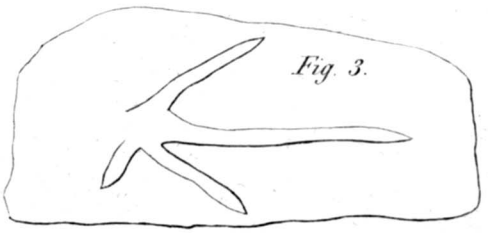


Fig. 3.

Lith. of G. & W. Endicott New York.

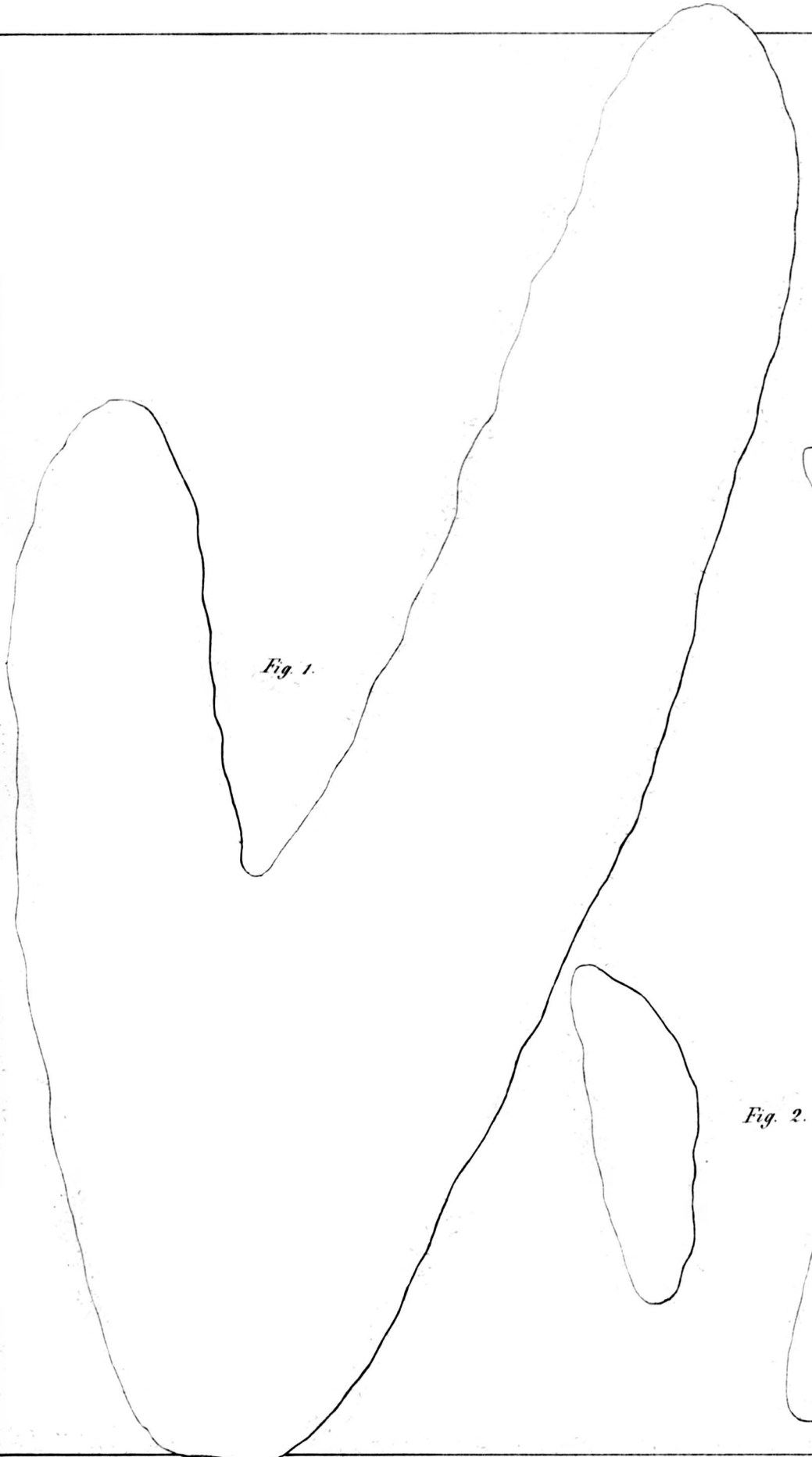
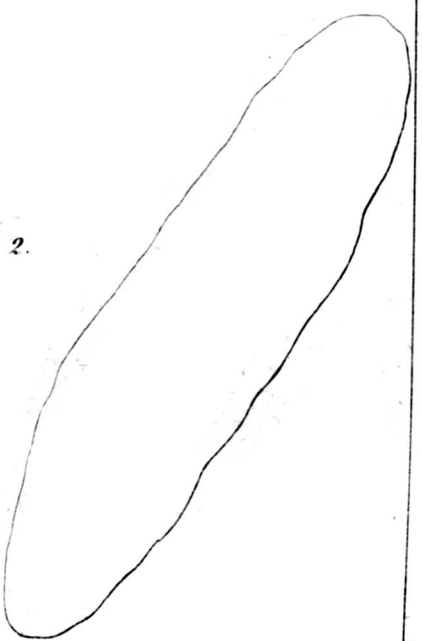


Fig. 1.

Fig. 3.

Fig. 2.



Lith. of G. & W. Endicott New York.

Fig. 1

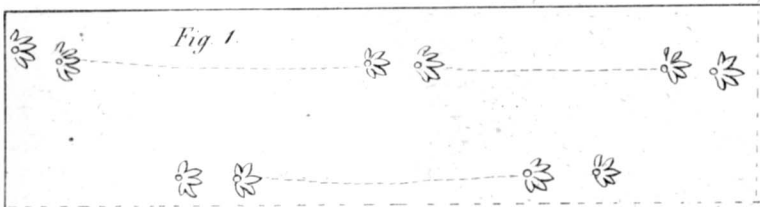
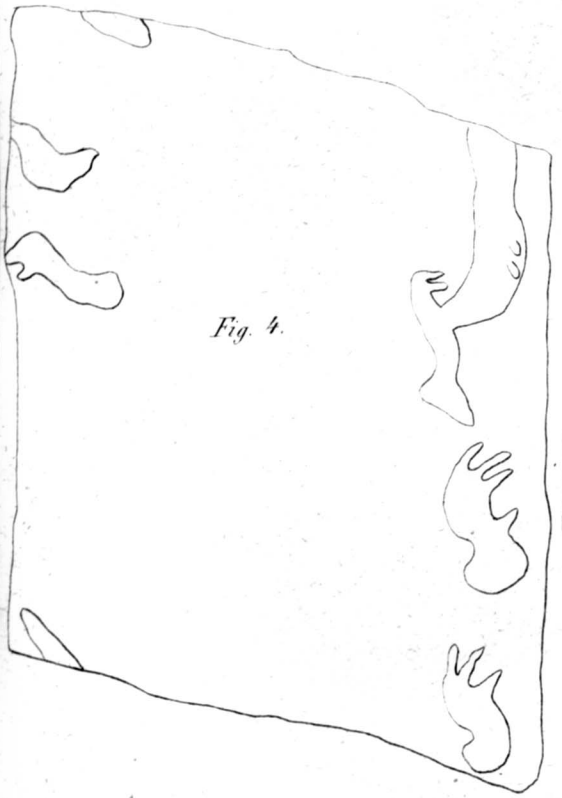


Fig. 2.

Fig. 3.

Fig. 4.



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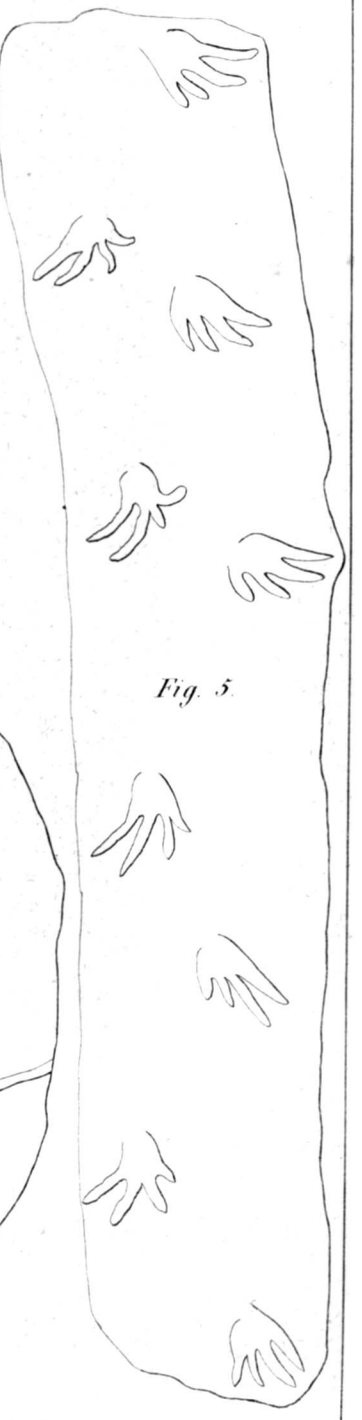
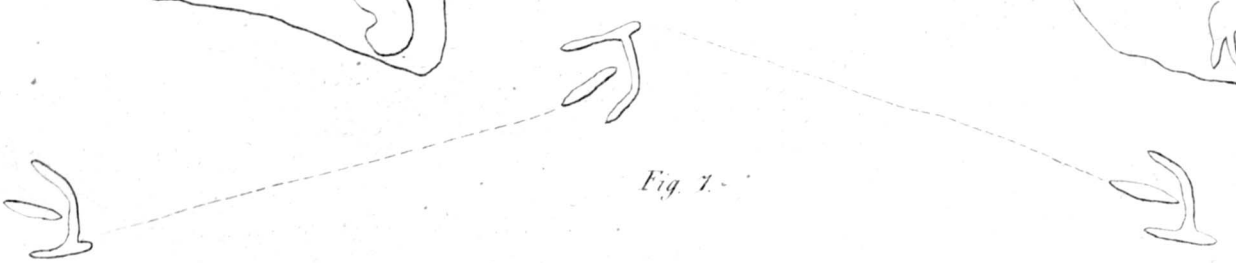


Fig. 6.

Fig. 7.



Lith. of G. & W. Endicott New York

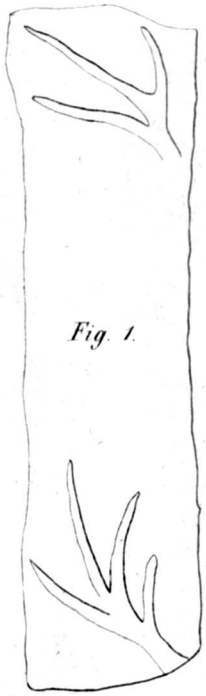


Fig. 1.

Fig. 2.

Fig. 3.

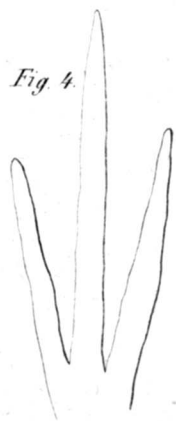


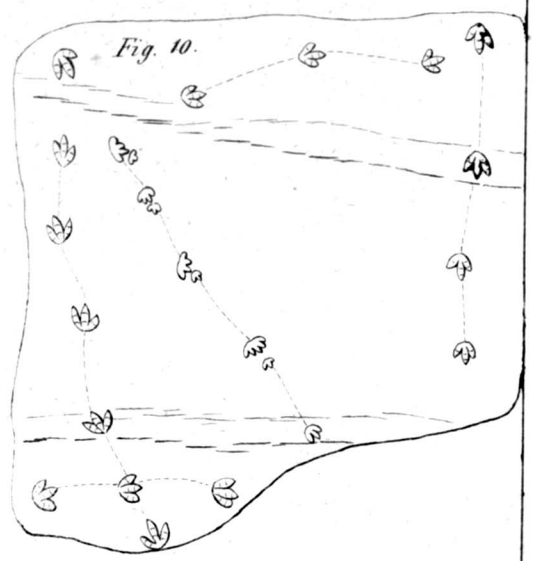
Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.



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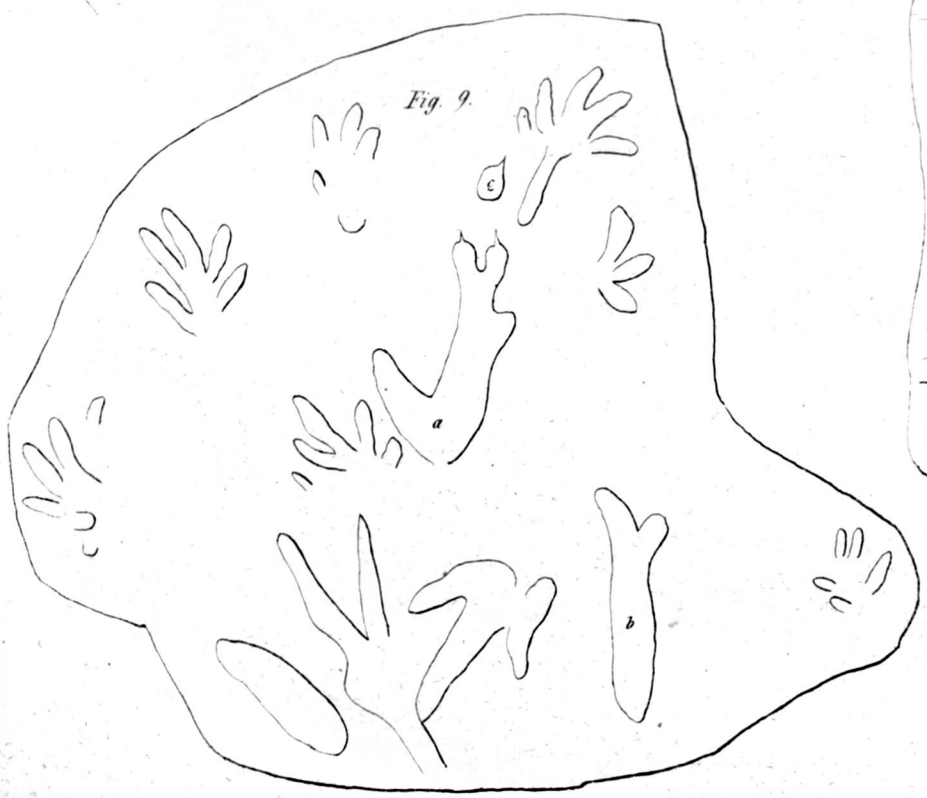
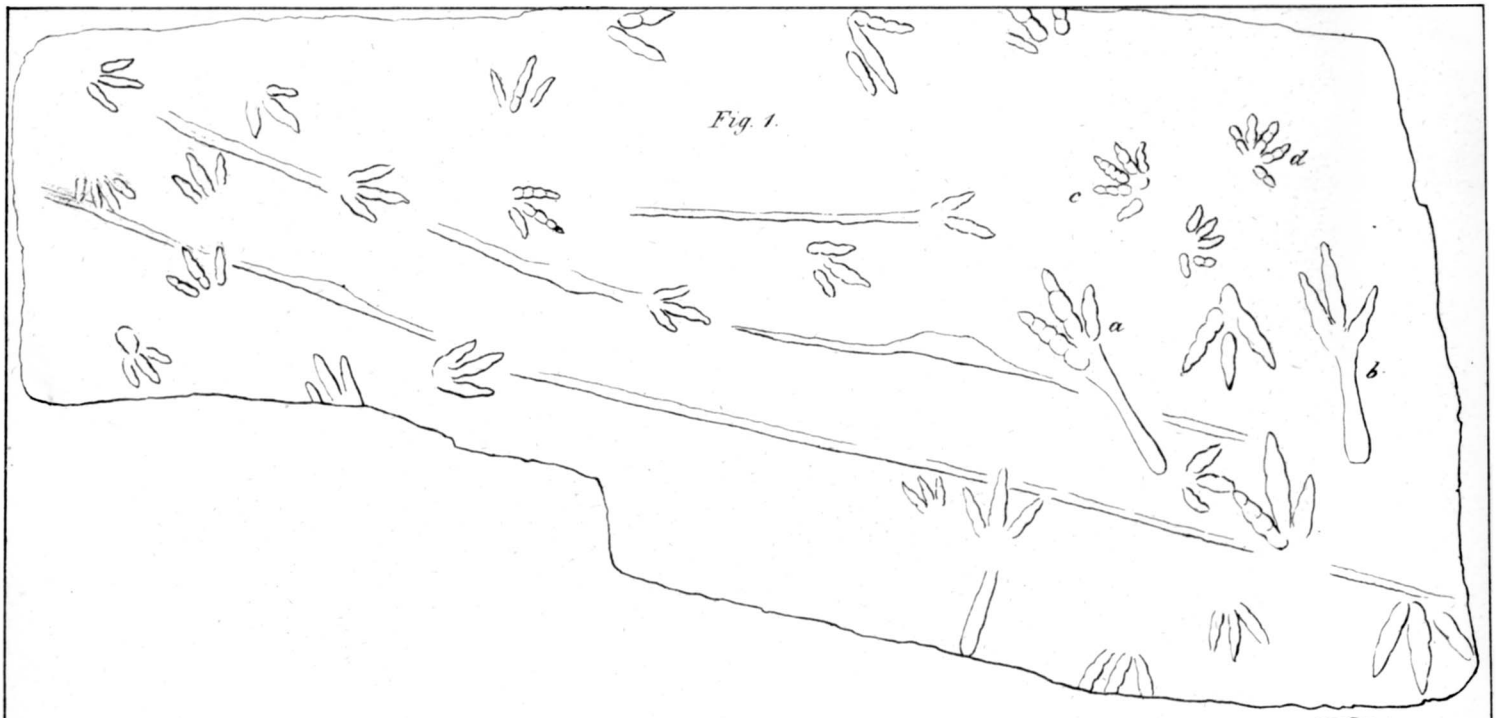


Fig. 9.

Lith. of G. & W. Endicott New York.



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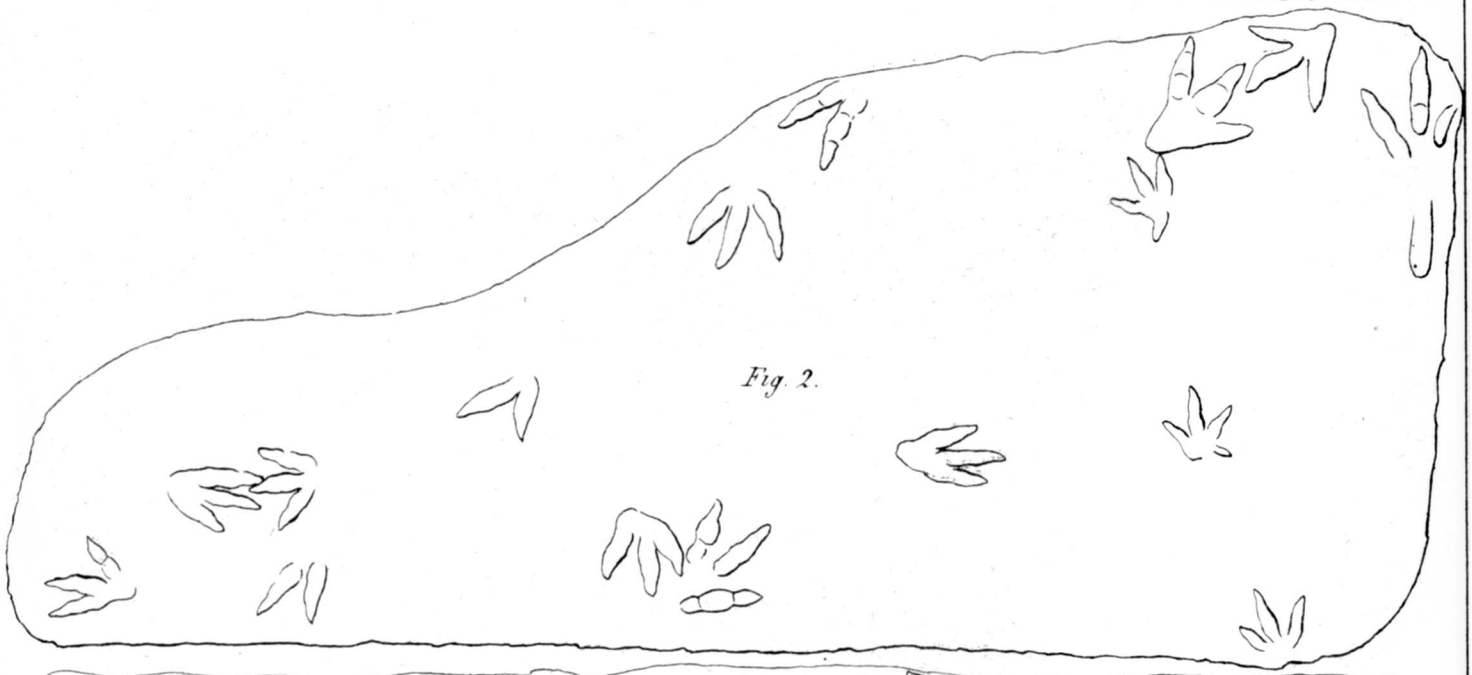

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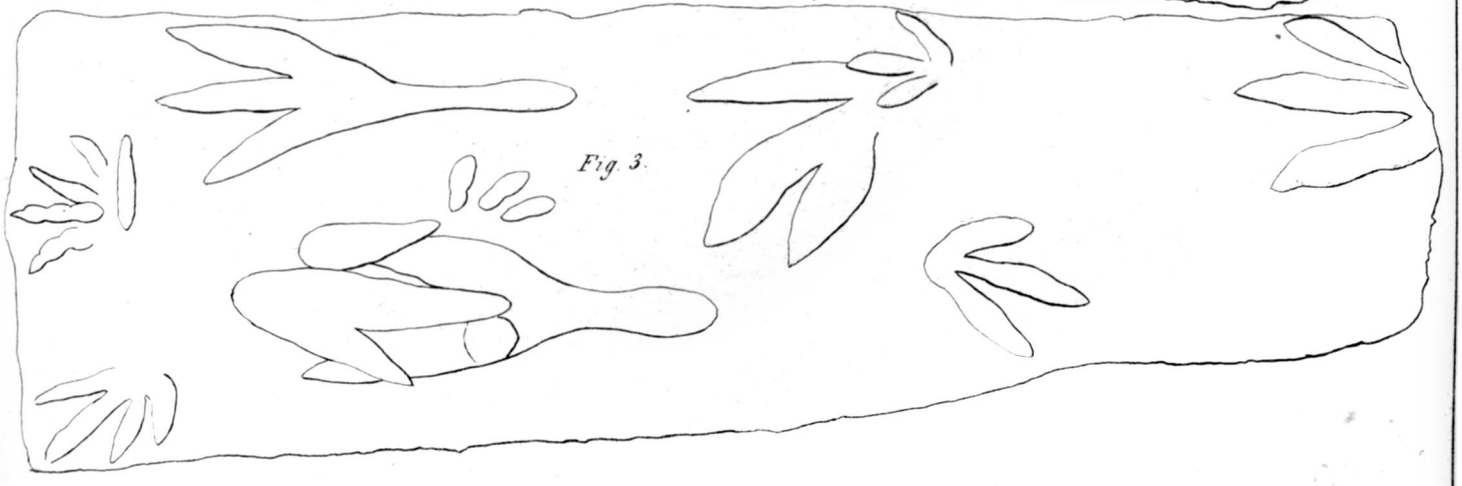


Fig. 3.

Lith of G. & W. Endicott New York

Lith. of G. & W. Endicott New York.

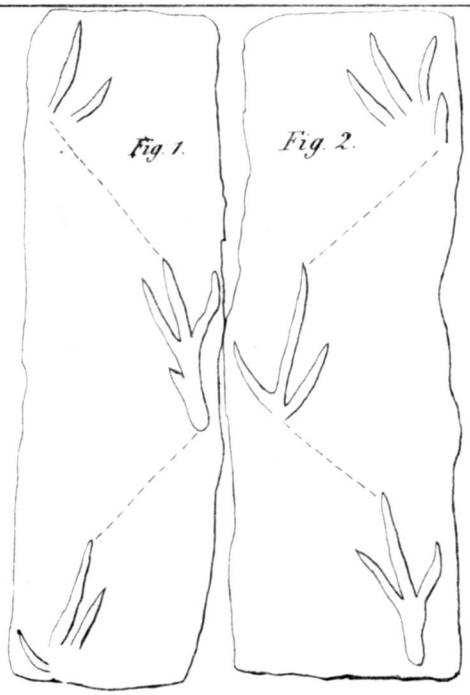
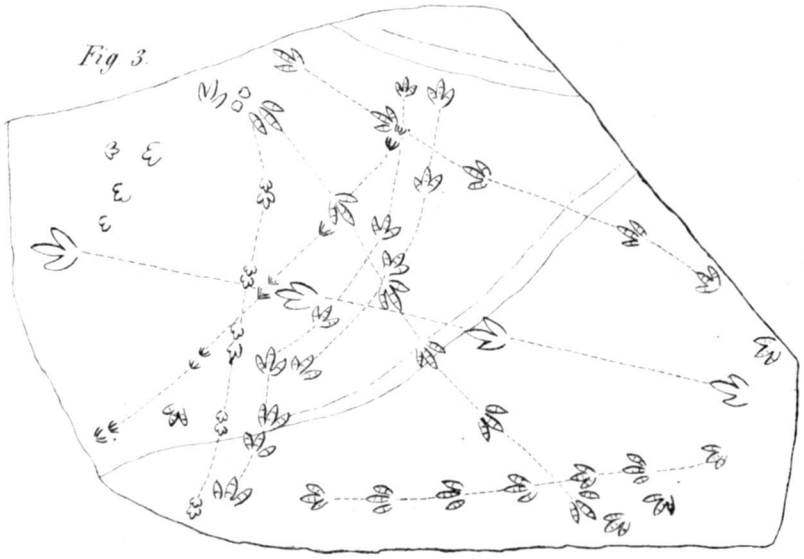


Fig. 1.

Fig. 2.



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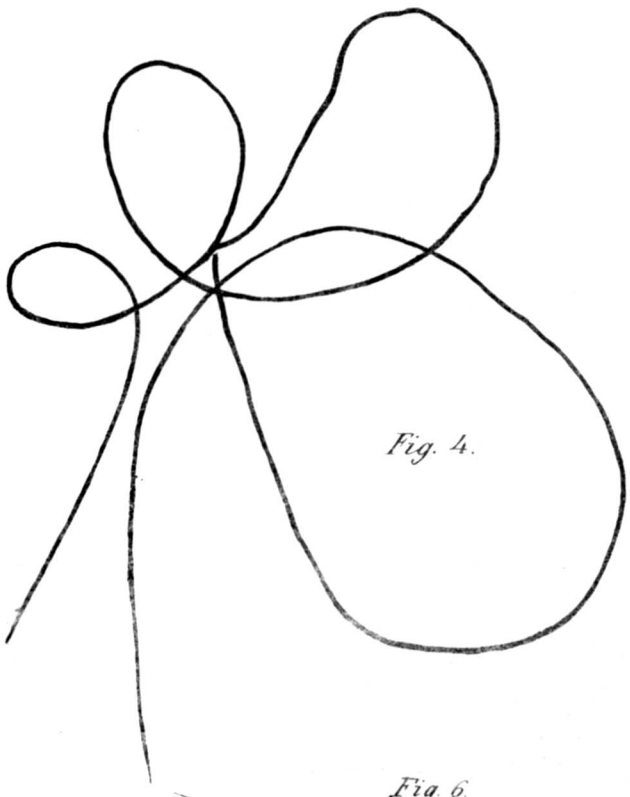

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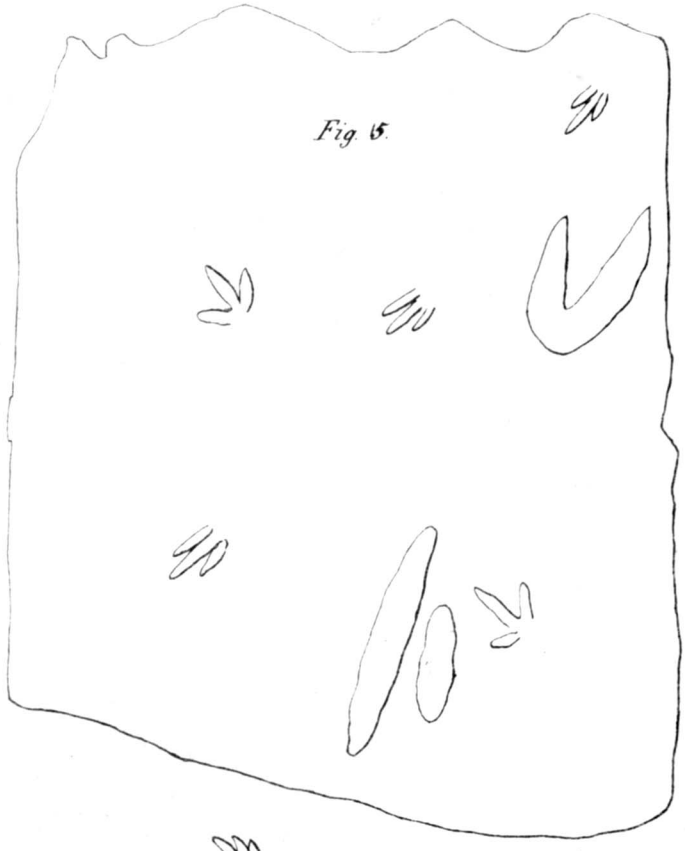

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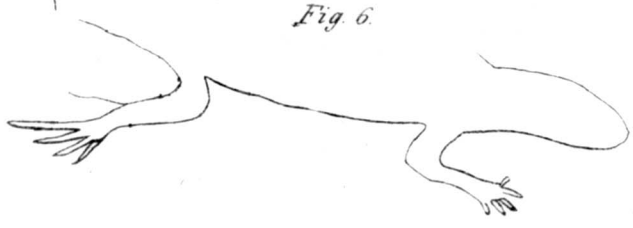

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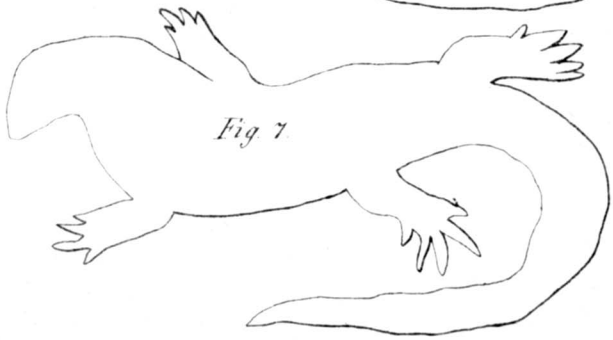
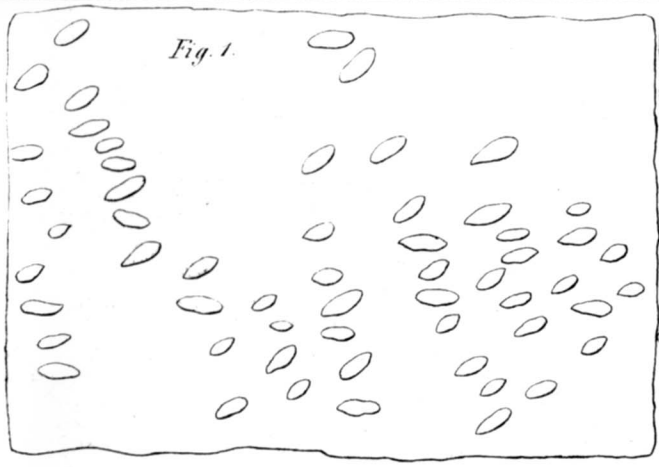


Fig. 7.

Lith. of G. & W. Endicott New York.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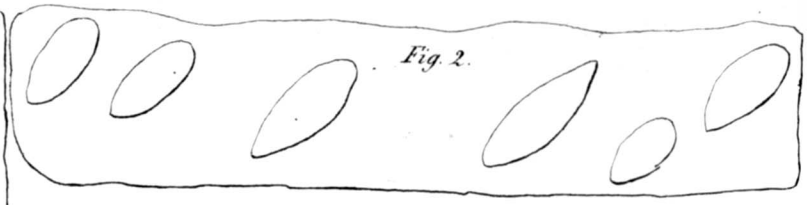
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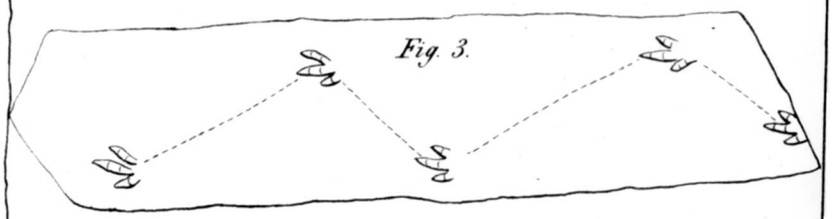
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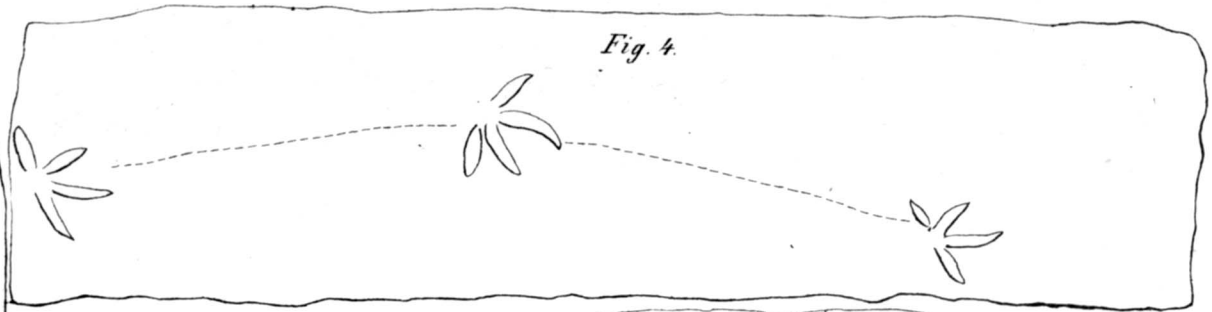
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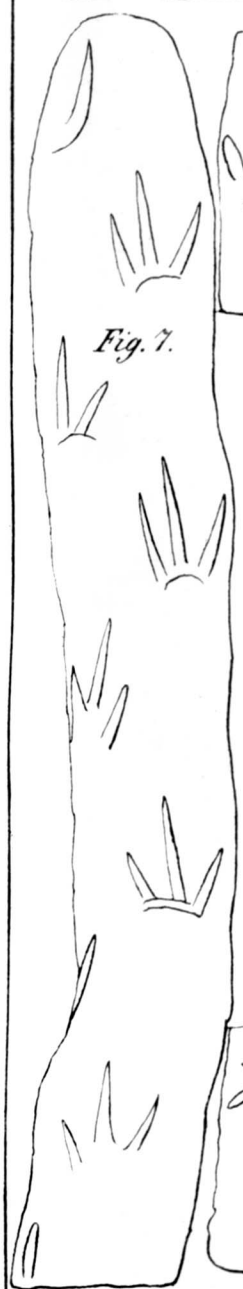


Fig. 7.


Fig. 5.

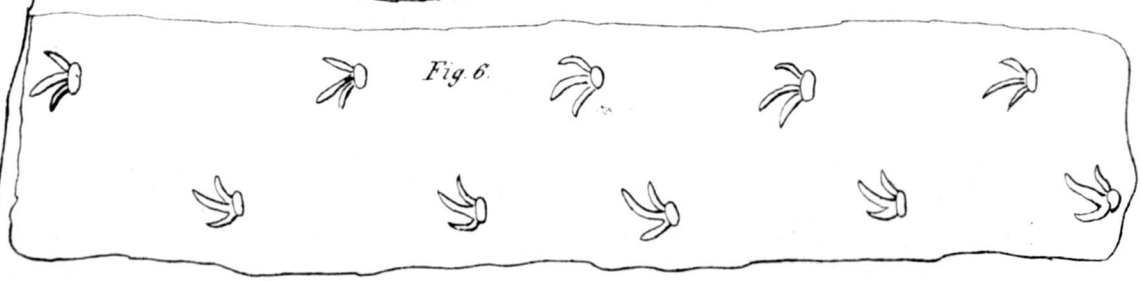


Fig. 6.

Lith. of G. & W. Endicott New York.

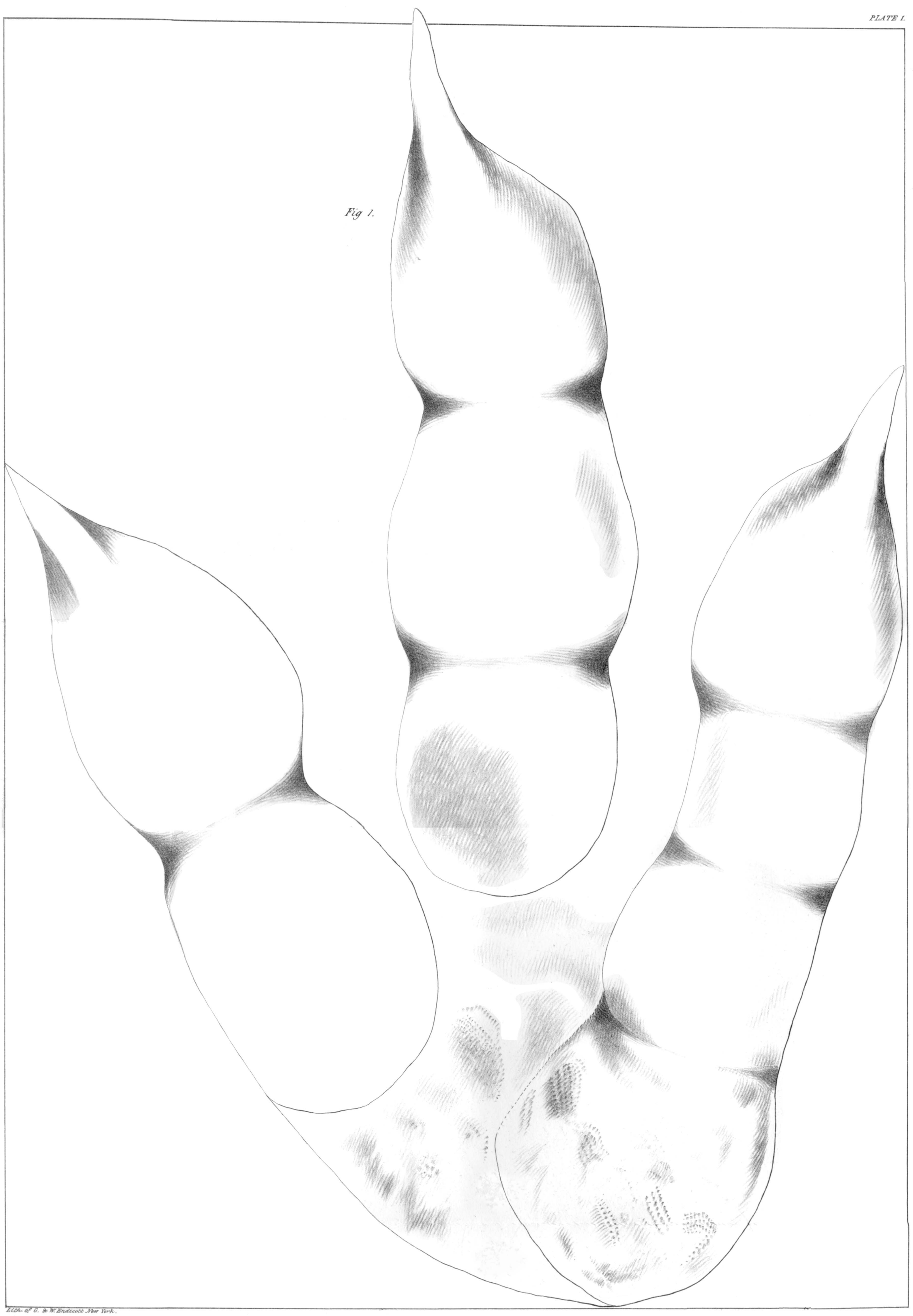
A TABULAR VIEW

OF THE CHARACTERS OF THE TRACK-DISCOVERED ANIMALS OF THE UNITED STATES.

	Number of toes.	Divarication: Of the outer front toes.	Divarication: Of the inner and second front toes.	Divarication: Of the second and third front toes.	Divarication: Of the third and fourth front toes.	Divarication: Of the fourth and fifth front toes.	Divarication: Of the hind toe and middle front toe.	Length: Of the inner toe.	Length: Of the second toe.	Length: Of the third toe.	Length: Of the phalangeal impressions of the inner toe.	Length: Of the phalangeal impressions of the middle toe.	Length: Of the phalangeal impressions of the outer toe.	Length: Of the claw of the middle toe.	Length: Of the fourth front toe.	Length: Of the fifth front toe.	Length: Of the hind toe.	Length: Of the foot.	Length: Of the step.	Length: Of the heel.	Length: Of the middle front toe beyond the rest.	Distance: Between the tips of the outer toes in front.	Distance: Between the tips of the inner and second front toes.	Distance: Between the tips of the second and third toes.	Distance: Do. the middle front and hind toe and the fourth front toe.	Distance: Between the tracks of the hind and fore feet.	Distance: Of the heel from the line of direction = ½ the distance of the rows of tracks.	Versed Sine: Of the inner toe.	Versed Sine: Of the middle toe.	Versed Sine: Of the outer toe.	Versed Sine: Of the fourth toe.	Width: Of the toes.	Width: Of the heel.	Width: Of do. at the roots of the toes.	Angle between the axis of the foot and the line of direction.	Number of phalangeal impressions made by the toes, reckoning outwards.
Brontozoum.																																					
1. giganteum,	3	40°	22°	15				10	12.5	12.5	3.8–4.4	3.4–3–2.6	3.3–3.5–2.1–2.4	1.75				16	56.		5.5	12.	7.45	7.5			2.5				2.5				2–3–4
2. Sillimanium,	3	35	25	15				4.4	6.	5.5	1.4–1.1	1.2–1.3–1.2	0.8–0.7–0.9–1.1	1.				8.	19.		3.	5.	4.	3.5							1.4				2–3–4
3. loxonyx,	3	28	17	10				4.4	6.	5.5	1.6–1.6	1.6–1.7–1.4	1–1.3–1.2–1.5	1.				8.	30.		3.	5.75	4.	4.							1.4			35°	2–3–4
4. expansum,	3	60	25	30				3.2	4.6	4.9	1.3–1.2	1.4–1.3–1.3	1.6–1.2–0.9–1.3	1.1				6.5	25		2.4	6.	4.2	3.4							1.3				2–3–4
5. gracillimum,	3	50	25	25				1.7	2.2	2.	0.5–0.4	0.5–0.4–0.4	0.45–0.4–0.45–0.6	0.4				2.5	7.5		0.9	1.9	1.2	1.35			0.8				0.4			5	2–3–4
6. parallelum,	3	17	55	12				1.8	2.5	2.	0.8–0.9	0.8–0.8–0.8	0.55–0.4–0.4–0.55	0.4				3.2	18.		1.4	1.5	1.7	1.6							0.5			0	2–3–4
Æthyopus.																																					
1. Lyellianus,	3	35	15	20				4.2	6.4	5.2	1.6–1.8	1.8–1.8–1.7	1.2–1.2–1–1.5	1.				8.			3.3	4.8	4.1	3.9							1.5				2–3–4
2. minor,	3	60	25	35				2.5	3.2	2.9	1.2–0.8	1–0.8–0.7	0.8–0.7–0.6–0.5	0.7				3.8	9.		1.5	3.3	2.	2.5			1.25				0.8			8	2–3–4
Steropezoum.																																					
1. ingens,	3	60	35	20				9.75	13.	10.25								24.	56.	10.	4.5	9.5	6.7	6.3				0.5	0.7				8.	1.5		
2. elegans,	3	62	35	30				2.3	4.4	2.8								6.5	16.	2.2	2.4	3.	3.	2.6				0.15	0.35	0.2			2.	1.		
3. elegantius,	3	70	30	40				1.1	2.	1.3								2.5	7.	1.	1.2	1.5	1.4	1.4									2.5	0.4		
Argozoum.																																					
1. Redfieldianum,	3	75	30	45				8.	12.	9.5				2.				12.5	30.		6.	12.	7.8	9.				0.7						0.4		
2. dispari-digitatum,	3	47	24	23				2.8	5.3	3.2								5.5	15.		1.8	2.6	2.4	2.7			0.5							0	
3. pari-digitatum,	3	85	40	45				1.2	1.7	1.2								1.7	11.		0.8	1.8	1.1	1.4										20	
4. minimum,	3	90	50	40				0.6	0.85	0.7								0.9	3.2		0.35	1.1	0.7	0.6										10	
Platypterna.																																					
1. Deaniana,	3	70	45	25				1.5	3.	1.8								4.3	10.	1.2	1.8	2.3	2.1	2.2				0.17	0.12	0.22			1.2	1.		
2. tenuis,	3	53	25	28				1.	2.	1.3								2.4	7.(?)	0.6	1.	1.4	1.2	1.3									0.6			
3. delicatula,	3	40	22	18				0.6	1.1	0.75								1.5	3.	0.4	0.5	0.6	0.6	0.55									0.35	0.25		
Ornithopus.																																					
1. Adamsanus,	4	100	40	60			140	4.2	6.5	5.2							3.			6.(?)	4.3	7.	4.5	6.5	11.								3.5	2.2		
2. gallinaceus,	4	70	35	45			140	1.5	2.75	1.8							1.3	2.8	7.		1.5	2.37	1.9	1.8	4.2											
3. gracilior,	4	83	40	43			120	1.1	1.5	1.1							0.8	1.5		0.7	0.7	1.7	1.5	1.3	2.											
4. loripes,	4	100	50	50			120	3.75	5.	4.							2.75	6.8	19.	2.	2.5	5.7	3.9	3.9	6.8		3.	0.4	0.6	0.2	0.2			3.	10	
Polemarchus.																																					
1. gigas,	4	45	20	25			80	8.5	11.2	8.3							2.5	15.	48.	3.8	3.2	7.6	4.3	6.5	13.			0.5	0.9	0.3		3.9	2.5		
Plectropus.																																					
1. minitans,	4	90	40	50			100	2.2	3.1	2.1							0.9	4.7	16.	1.5	1.8	3.2	2.1	2.7	4.			0.15		0.1		0.45	0.4		
2. longipes,	4	72	32	40			95	1.7	2.8	2.1							0.8	7.5	15.	4.2	1.3	2.4	1.7	1.9	4.							0.3	0.4		
Trianopus.																																					
1. Baileyanus,	4	37	18	18			35	1.9	2.9	2.2							0.8	4.5	7.(?)	1.7	1.5	1.4	1.3	1.5	3.5							0.2	0.4		
2. Emmonsianus,	4	50	25	25			115	1.8	2.7	1.9							0.8	3.2		0.4		1.8	1.3	1.7	3.4			0.15	0.12	0.05		0.2	0.4		
Harpedactylus.																																					
1. gracilis,	4	70	33	35			55	1.9	2.2	1.8							0.9	3.7	8.	1.6	0.8	2.2	1.2	1.5	2.			0.17	0.13	0.2	0.12	0.2			
2. concameratus,	3	60	25	35				2.	3.2	1.6									1.2		2.2	3.5	1.7	3.4				0.3	0.6			2.	2.2		
Typopus.																																					
1. abnormis,	3	35	20	15				1.3	2.8	1.8								4.	18.	2.7	1.4	2.8	1.8	2.		.							0.25	2.2		
Otozoum.																																					
1. Moodii,	4	35	15	5	12			8.5	10.25	8.	3–2–3.4(?)	Second toe. 2.4–2.5–2.9–2.6(?)	Third toe. 2–2–3.8 (?) Outer toe. 1.6–1.6–5.4(?)		8.5			20.	36.			13.	6.5	3.4	2.7		2.5					2.7			15	3–4–3–3
Palamopus.																																					
1. Dananus,	4	67	25	30	15			2.	2.5	4.7					2.3		2.	8.5	21.	3.7	2.7	4.7	2.4	3.4	3.								2.	3.		
Thenaropus.																																					
1. heterodactylus, Hind ft.,	5	75	15	20	10	28		1.6	1.8	2.4					3.1	0.9		5.5	12.5			4.	1.2	1.5	2.	1.	3.5						2.2		30	
Fore ft.,	4	90	20	30	40			1.2	1.4	1.5					1.1			4.2				4.5	1.5	1.8	1.2						0.7	2.7	2.7	35	
Anomœpus. Hind ft.,	4(?)	47	25	20				2.4	3.2	3.3	0.7–0.7–0.8	1.1–1–0.7	0.8–0.8–0.6–0.6–0.6					7.	9.	4.2	1.2	2.7	1.9	1.8			2.5								20	3–3–5
1. scambus, Fore ft.,	5	87	27	17	40		95	1.	1.3	1.5	0.4–0.3	0.3–0.3–0.3	0.4–0.3–0.3–0.3		1.2	1.2	1.									2.								35	2–3–4–3–2
2. Barrattii, Hind ft.,	5	120	30	45	35	15		1.5	1.7	2.2					2.	1.6		7.5	12.	4.5?								0.4		0.15					
Fore ft.,	5																																			
Anisopus.																																					
1. Deweyanus, Hind ft.,	4	45	20	10	10			0.5	0.7	0.8					0.5			1.7	7.	0.9		1.4	0.6	0.45	0.4		1.5				0.25		1.2	30	
Fore ft.,	4	45	20	10	10			0.2	0.5	0.6					0.35			0.6				0.7	0.25	0.25	0.3						0.15			30	
2. gracilis, Hind ft.,	4	40	15	10	15			0.4	0.6	0.9					0.7			0.9	5.7			0.75	0.3	0.3	0.25						0.1		0.5	20	
Fore ft.,	5(?)	40	15	10	15			0.2?	0.4	0.55					0.4			0.55				0.4	0.2	0.15	0.25						0.08			20	
Hoplichnus.																																					
1. quadrupedans,																											3.						1.9			
Macropterna.																																					
1. rhynchosauroidea, Hind ft.,	4	80	30	50				0.45	0.7	0.5					0.25			1.8	4.6	1.2		0.75	0.5	0.55	0.4	1.	1.					0.15		30	
Fore ft.,	3	80	30	50				0.3	0.4	0.25								0.6		0.25		0.5	0.3	0.3								0.15		30	
2. recta, Hind ft.,	4	77	10	32	35			0.9	1.25	1.6					1.1			3.	7.7	1.4		1.7	0.7	0.9		1.						0.4			
Fore ft.,	4	100	30	35	35			0.25	4.	0.9					0.7					0.5		1.2	0.3	0.7								0.8			
3. divaricans, Hind ft.,	4	95	25	35	32			0.45	0.6	0.7					0.6			1.9	3.3	1.2		1.3	0.55	0.6	0.5		0.6					0.4		40	
Fore ft.,	5	125	50	50	25			0.25	0.45	0.4					0.3	0.1										0.5									
Xiphopeza. Hind ft.,	4	90	40	50			130	0.8	1.5	1.1							0.5	2.6	3.	1.2	0.6	1.5	1.	1.1			1.4					0.45	0.2		
1. triplex, Fore ft.,	4(?)																																			
Ancyrcpus. Hind ft.,	4							0.4	0.6	0.5							0.5	3.	5.	1.5		0.9	0.45	0.45	1.8		3.4	0.4	0.5	0.6		0.7		0	
1. heteroclitus, Fore ft.,	4(?)							0.3	0.4	0.35										1.8		0.5	0.3	0.25				0.4	0.5	0.6		0.8			
Harpagopus.																																					
1. giganteus,	2	15 to 25						5 to 7	10 to 13																						1.4 to 1.7			180	
2. Hudsonius,	2	40						2	3.5																		3.						1.9	90	
3. dubius,																																					

The angular measures in the above table are given in degrees; the linear measures, in English inches and decimals of the same.

Fig 1.



Lith. of C. & W. Endicott New York.

Luth. of G. & W. Endicott New York

Fig. 4.

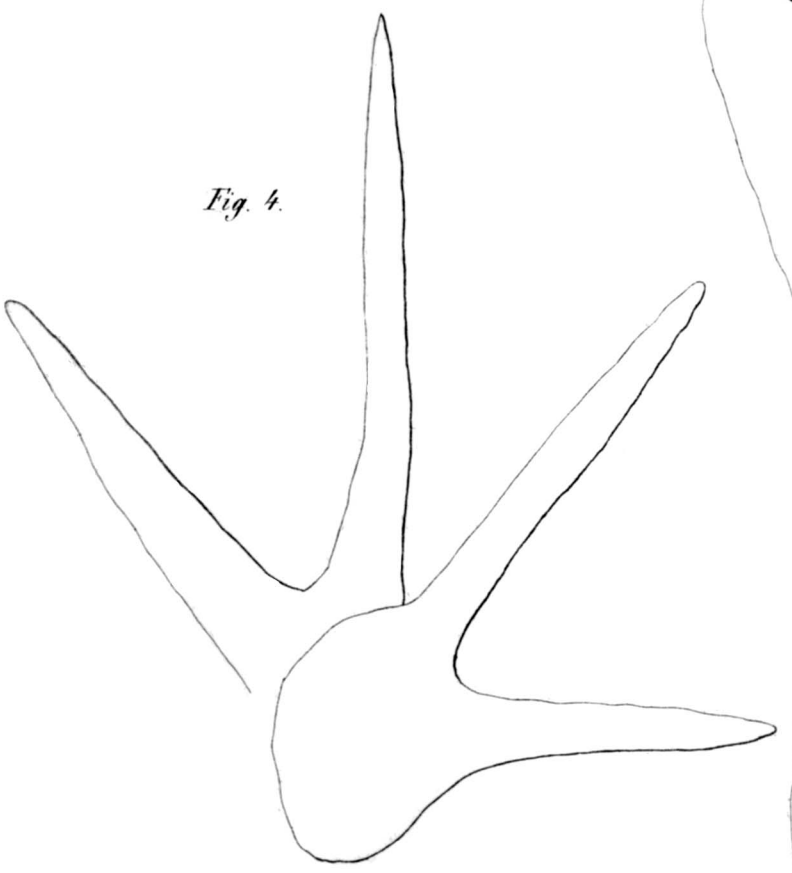
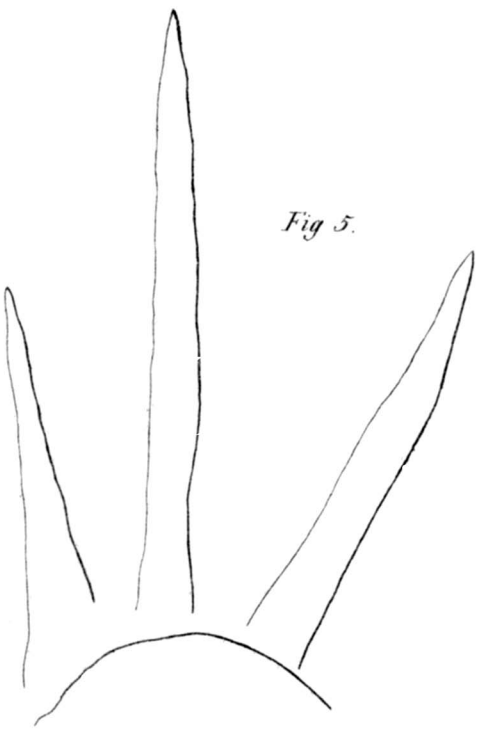


Fig 5.



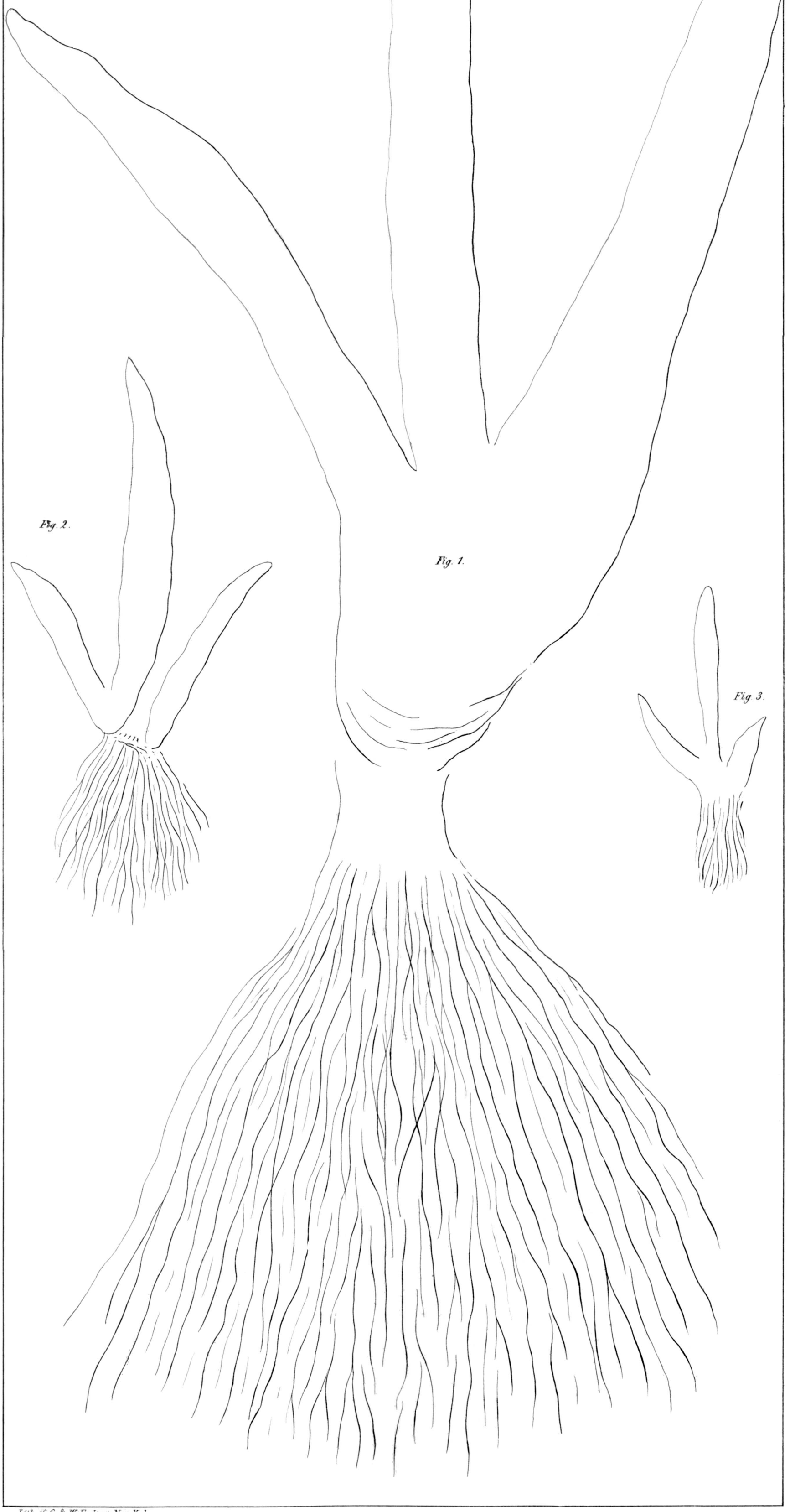


Fig. 2.

Fig. 1.

Fig. 3.

Lith. of G. & W. Endicott New York.

Fig. 2.

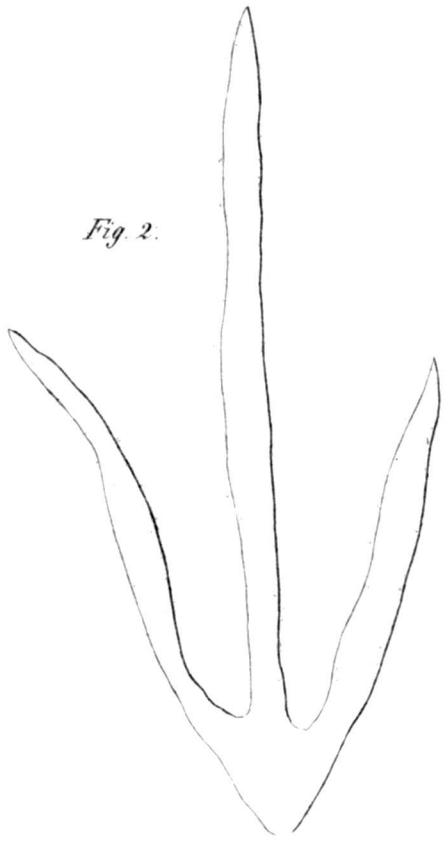
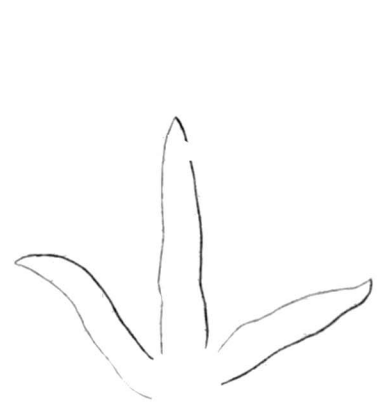


Fig. 4.



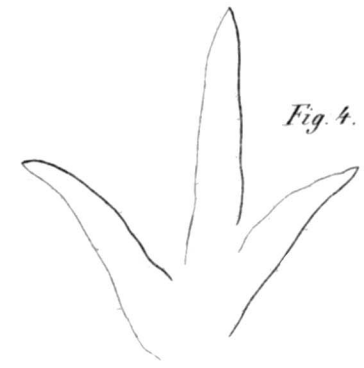


Fig. 1

Fig. 5.

Lith. G. & W. Endicott New York.

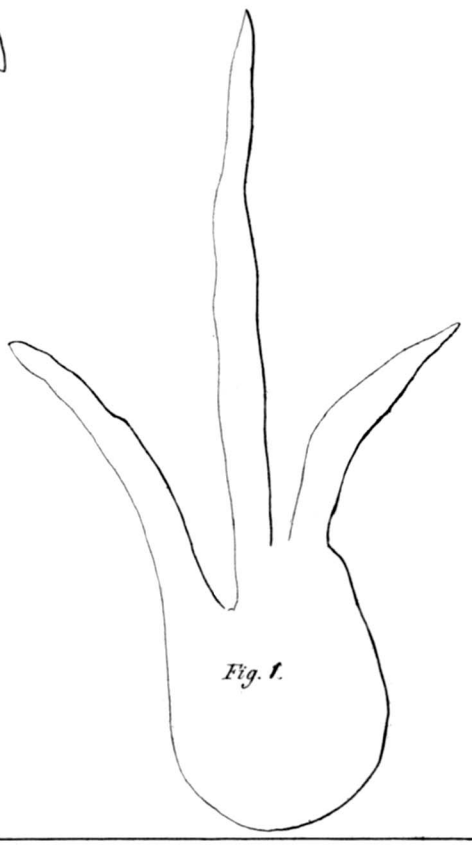
Fig. 3.

Fig. 2.

Fig. 5.

Fig. 4.

Fig. 1.



Lith. of G. & W. Endicott New York.

Fig. 2.

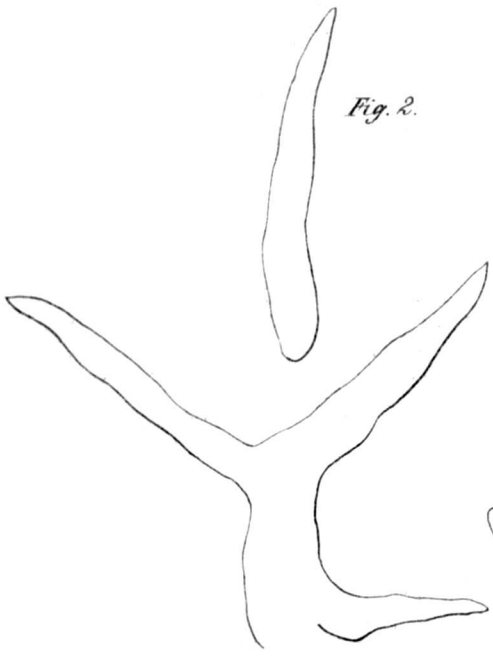


Fig. 3.

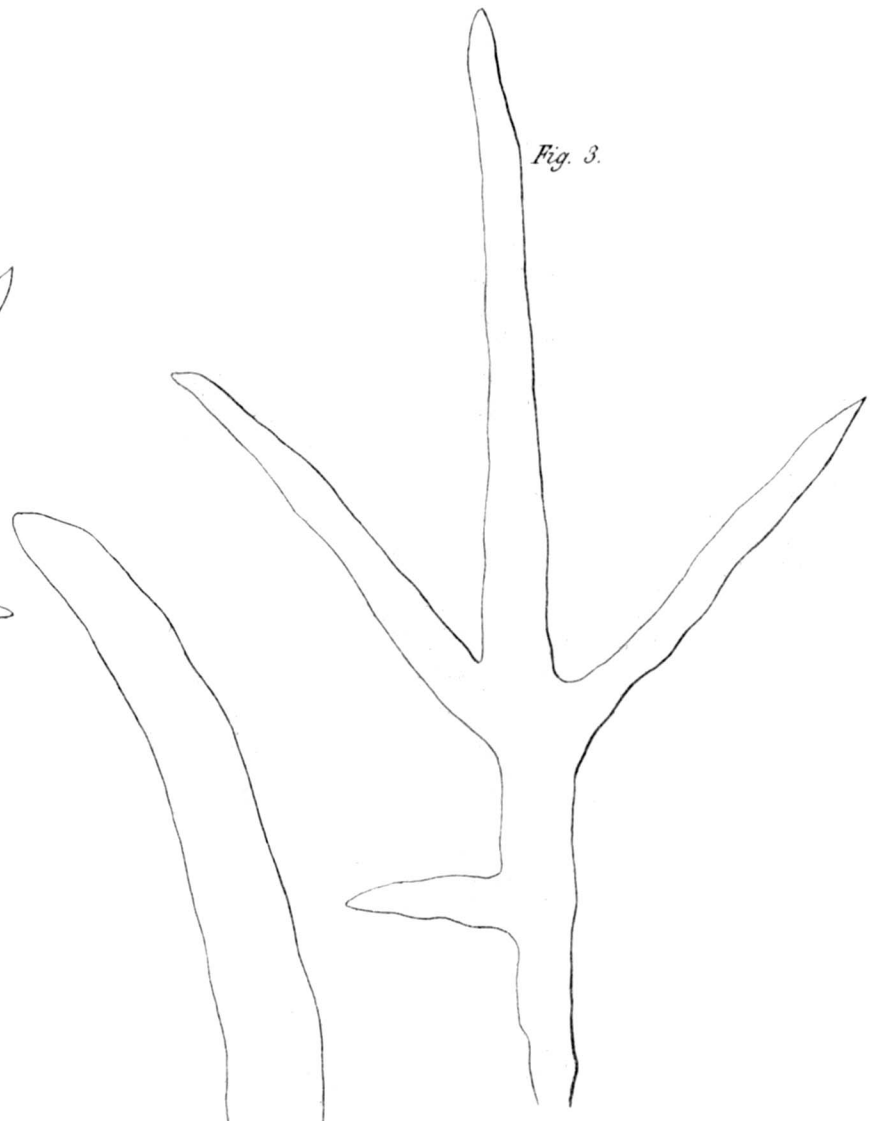


Fig 1.

Lith. of G. & W. Endicott New York.

a

a

a

b

b

Fig. 1

Fig. 2.

a

b

a

a

b

a

b

Lith. of A. & N. Rosenstein, New York.

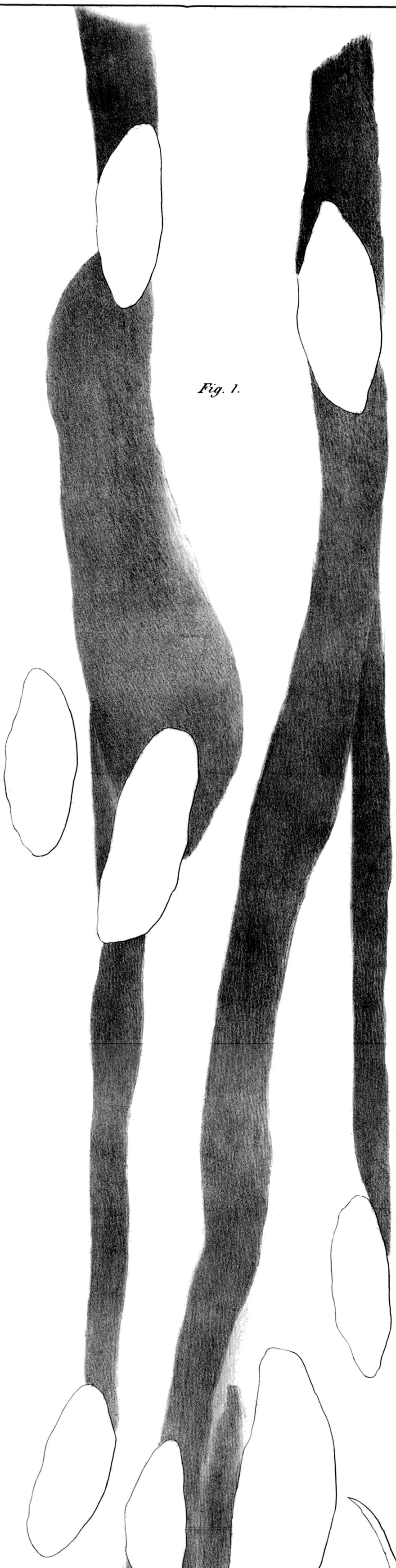
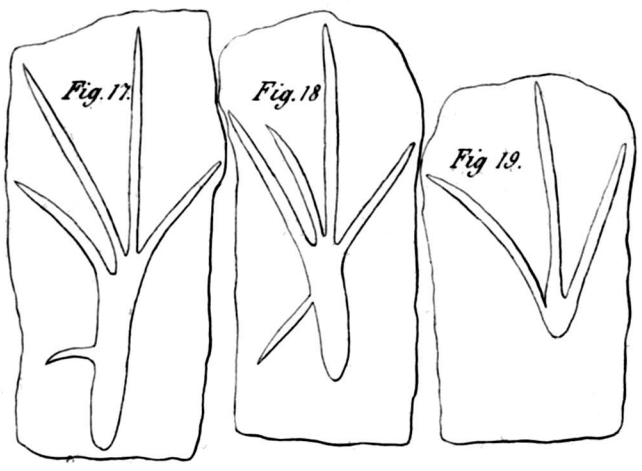
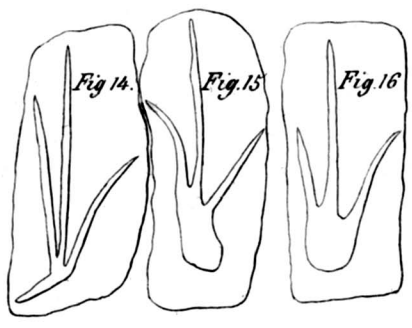
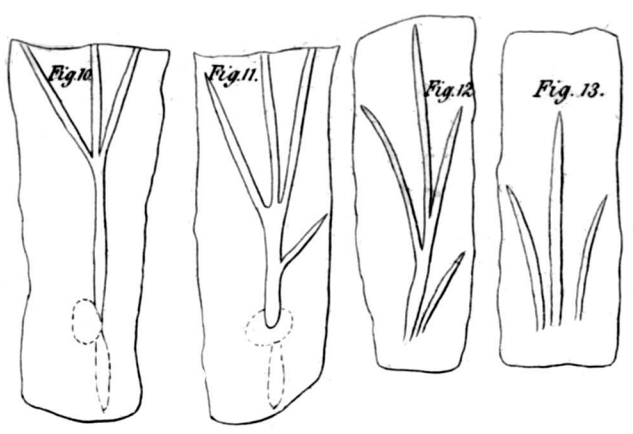
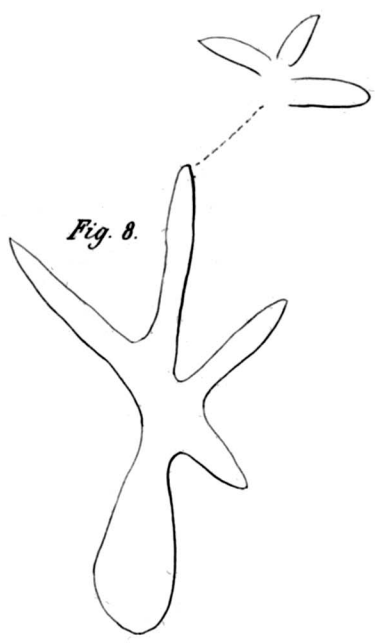


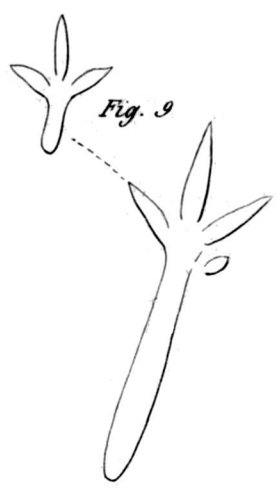
Fig. 1.

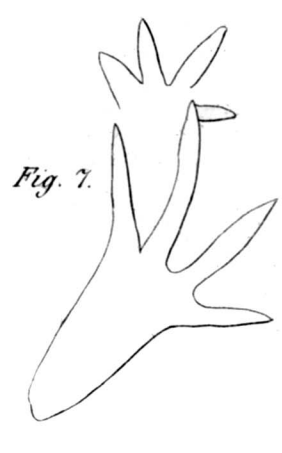


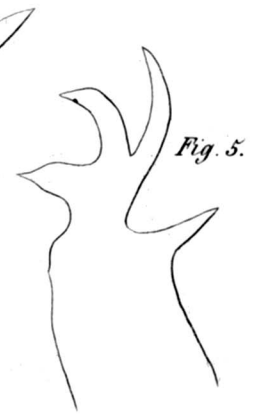


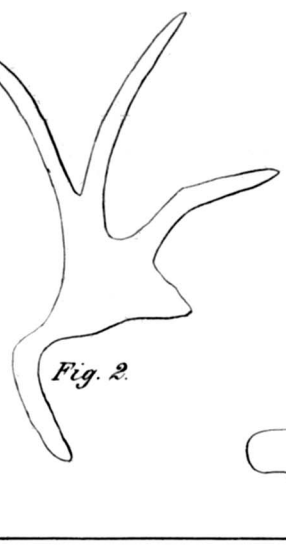


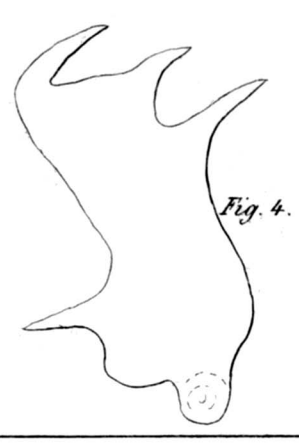












Lith. of C. & W. Endicott New York.

Lith. of G. & W. Endicott New York.