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C. G. Abbot,
Secretary of the Smithsonian Institution.

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MORPHOLOGY AND MECHANISM OF THE INSECT THORAX

BY
R. E. SNODGRASS
Bureau of Entomology

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INTRODUCTION

Nowhere has nature more strikingly displayed her mechanical genius than in the thorax of a winged insect; nowhere else can we find a mechanism so compact, so efficient, so simple, and yet of such varied powers. Locomotion by the coördinated action of three pairs of legs, flight by the unified vibration of two pairs of wings—these are the common functions of the thorax; but, add to them the powers of leaping, grasping, climbing, digging, swimming and many others of which the legs of various insects are capable, and consider that the wings may carry the body forward or backward slowly or with great speed, or keep it hovering almost stationary in the air, while, rubbed upon each other, by some insects they can be made to produce sounds of great volume, and it becomes needless to repeat that the insect thorax is a marvelous bit of machinery.

If we had but to describe the thorax as it is, the task of the anatomist would not be a simple one, but it is always necessary to look beyond the facts that confront us and to discover the more fundamental structures upon which they are reared, an undertaking which requires redoubled effort, but without which there can be no true morphology. An artist may depict the form and color of a building in a manner pleasing to the eye, but, unless he has understood the framework and the principles of its construction, his picture cannot be convincing to the mind.

It is certain that insects did not start out to be either six-legged creatures or winged creatures, and that, during their evolution, the thorax has been continually refashioned to adapt it to the new modes of locomotion. The embryonic history of insects shows that the thorax was first differentiated as the locomotor region of the body by the specialization of its three pairs of segmental appendages as the principal organs of progression, this being accompanied by the reduction of the gnathal appendages to feeding organs, and by the suppression of most of the abdominal appendages (fig. 1). Walking or running on three pairs of limbs instead of on many, now, not only involved a perfection of these appendages themselves, and a considerable amount of reconstruction in the segments bearing them, in order to give the legs better support and their muscles more effective attachment, but it necessitated a remodeling of the general body structure and proportions to effect a proper balance about the newly localized center of gravity. When, at some later period, lateral expansions of the tergal plates began to serve, perhaps, as parachutes, and insects became gliders, it is but natural that the tergal lobes which eventually became wings should be those of that body region already fixed as the locomotor center. Flight, however, being an entirely new mode of progression, the development of the wings and the perfection of their mechanism meant a further and much greater alteration in the structure of the wing-bearing segments than that which was evolved to accommodate the legs. In a study of the thorax, therefore, we should proceed on the assumption that its elemental structure is to be found in insects that never possessed wings, and that the special

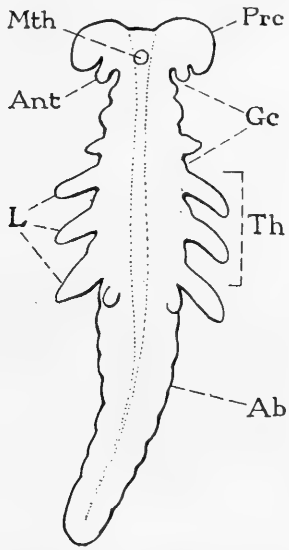

FIG. 1.—Young embryo of an insect, showing its four body regions and their appendages. (Embryo of *Naucoris*, Heymons, 1899.)

The primitive head, or procephalon (*Prc*), bearing eyes, mouth (*Mth*), and antennæ (*Ant*); the jaw region (*Gc*) of three segments, bearing mandibles, first maxillæ, and second maxillæ; thorax (*Th*) of three segments, bearing the legs; abdomen (*Ab*) of at most twelve segments, each but the last with a pair of rudimentary appendages in some insects.

thoracic structures of winged insects are characters that have been superposed on those primarily adapted to progression on three pairs of legs.

Facts and theories should run parallel; in entomology it seems they often diverge. Some theories, however, have served as useful stepping stones, though they themselves have later been swept away by the current; others are illusions of the imagination and land us in mid-stream. There have been many speculations concerning the number of segments in the insect thorax—some anatomists have claimed that there are five and even ten segments represented in its construction; embryologists say there are only three. Many entomologists, though they reject the multiple segment theory, have, nevertheless, thought it necessary to postulate four consecutive rings in each of the three segments, conceived to have arisen from four primitive transverse folds of a soft-bodied ancestral form, in which the sclerites of the segment were originally laid down as chitinizations of the integument. This theory at first appeared to have much in its favor, but the more the thoracic skeleton has been studied, especially in connection with the musculature, the more the four-ring theory loses support, and gradually entomologists have relinquished it in favor of the idea that the various sclerites are secondary divisions of primitively simple plates. The last review of the evidence against these theories of thoracic segmentation and annulation is given by Weber (1924), and the theories should now be laid away for the historian, and respected for the fact that they have been helpful.

Recently another theory has been proposed by Feuerborn (1922), which would make the insect thorax a rather complicated assortment of parts derived from four segments. It appears, however, that this conception has been based on a misinterpretation of the facts in the metamorphosis of certain Diptera. Feuerborn's theory has been opposed by Martini (1922) and by Weber (1925, '27); particularly by Weber has the evidence put forth in its favor been thoroughly and critically examined and found to be wanting in essential points.

I. FUNDAMENTAL STRUCTURE OF AN ARTHROPOD SEGMENT

The anatomical form of most parts of animals, being a patchwork of changes or modifications that have been adopted in different stages of the animal's evolution, according to its changing needs, consists of a series of characters overlapping or built one upon the other into a concrete whole. The work of the morphologist, therefore, is largely one of analyzing compound structures, of separating them into their component elements, and of determining the chronological order of the evolutionary processes that have combined them. This he must do both from a study of embryology, and by the use of his imagination, guided by a knowledge of comparative anatomy. As a consequence, morphology is largely theoretical, and morphological theories continually supplant one another as new facts throw new light on the subject of animal structure. In the present paper, some of the older views on the structure of the insect thorax are discarded; but a base is taken from a later theory, combined with selections from others, some new observations are added, and from the mixture the basic theory is redistilled in a new form. The product, it is hoped, when tested, will be found to be a closer approximation to the truth than any of the ingredients, but it will fail of its purpose if it does not act as a stimulus to the further study of the facts bearing on the evolution of the insect thorax.

PRIMARY SEGMENTATION

In the study of insect evolution, we go back to a soft-skinned, worm-like creature with the body divided into a series of cylindrical parts, or *segments,* each of which bears a pair of lateral or ventrolateral *appendages.* In an animal of this sort the intersegmental rings are the lines of attachment of the principal longitudinal muscles; in fact, the circular grooves separating the segments, and, therefore, the segments themselves are determined by the muscle attachments—in other words, the body segmentation corresponds with the muscle segmentation. If, at an earlier phylogenetic stage, the animal was unsegmented, it would seem that the body segments, or somites, must have resulted from the division of the muscle layer into muscle segments, or myotomes.

Starting with the insect's ancestor as a soft-skinned, segmented animal, resembling in its segmentation the soft-bodied larvæ of some modern insects, we must believe that its body segments then corresponded with its muscle divisions (fig. 2 A). This type of body division we may call *primary segmentation.* The muscles, extending between the intersegmental rings, are segmental in arrangment. Already, we assume, the creature possesses well-established dorsiventrality and cephalization; *i. e.,* one surface, the back or *dorsum,* is normally uppermost, and the opposite surface, the *venter,* is downward, while, in the usual progression, one end, the head end, is forward.

SECONDARY SEGMENTATION

The modern adult arthropods, unlike their hypothetical ancestors, are in general hard-shelled animals; they have developed an external skeleton formed of calcareous or chitinous matter or both deposited in the ectoderm, and the hardening of the body wall has had a far-reaching consequence on the structure of the segments and on the general mechanism of the animal. The skeletal deposits have taken the form of segmental plates (fig. 2 B), the principal plates in each segment being a dorsal one, or *tergum* (*T*) and a ventral one, or *sternum* (*S*). These two plates are separated on the sides of the segment by a membranous *pleural area.* The hardened parts of the body wall could not occupy the entire length of each segment, for if they did the creature would become a tube that might be compressed or expanded dorsoventrally but that could not move otherwise. A circumferential part of each segment must, therefore, remain flexible.

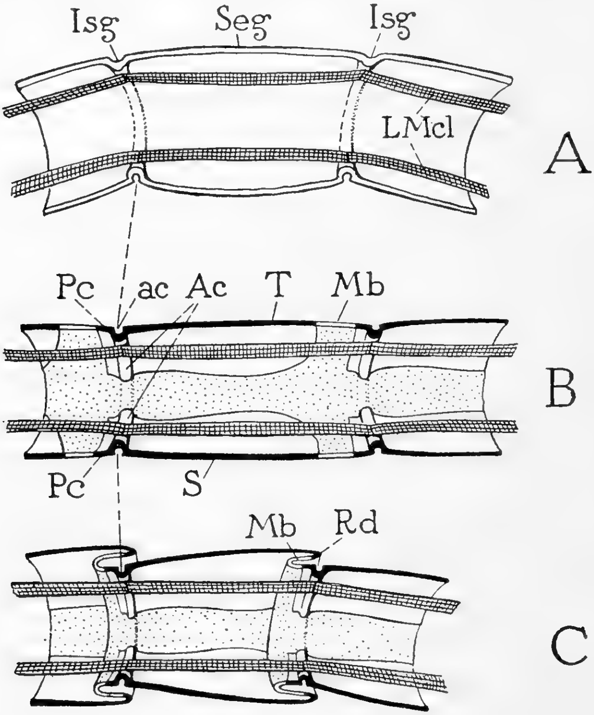

FIG. 2.—Diagrammatic lengthwise sections of a segmented animal, showing primary and secondary segmentation.

A, primary segmentation of soft-bodied animal, with segments (*Seg*) marked by intersegmental rings (*Isg*) to which longitudinal muscles (*LMcl*) are attached.

B, secondary segmentation of insect with hard plates in its body wall—each tergum or sternum (*T, S*) includes part of chitinized intersegmental groove before it, forming antecosta (*Ac*) internally and antecostal suture (*ac*) externally, with a narrow precosta (*Pc*) on anterior margin; posterior unchitinous part of segment becomes secondarily the "intersegmental" membrane (*Mb*).

C, secondary segmentation accompanied by telescoping of the segments, each segmental plate ending in a posterior fold, or reduplication (*Rd*).

The flexibility could not well be at the intersegmental lines, because the muscles are here attached and demand a firm support, for which reason the dorsal and ventral parts of the intersegmental grooves have been hardened and converted into internal ridges (fig. 2 B, *Ac*), each marked externally by a corresponding groove, or suture (*ac*). That each ridge should become continuous with the plate behind it rather than with the one before it, is decided by the fact that the animal already possesses cephalization. In order to retain the power of cephalic movement when the body wall becomes hardened, the segments must remain capable of being drawn forward by the contraction of their muscles, and this can be accomplished best if the flexible region of each segment is its posterior part. Hence, each intersegmental, muscle-bearing ridge has become continuous with the segmental plate behind it, and usually only a narrow lip extends forward of the ridge and its suture to connect with the preceding membranous area.

Each dorsal or ventral plate of the body wall, *tergum* or *sternum*, now includes: (1) a segmental sclerite of varying extent, the primary tergum or sternum (fig. 2 B, *T*, *S*); (2) an anterior intersegmental part, consisting of an internal, transverse, sub-marginal ridge, the *antecosta* (*Ac*), marked externally by a corresponding *antecostal suture* (*ac*); and (3) a narrow anterior marginal lip, or *precosta* (*Pc*), belonging to the segment preceding. In the posterior part of each segment, behind the tergum and sternum, is a circular membranous area (*Mb*). In an animal thus constructed, the membranous rings of the body wall are its movable joints, and they are called the "intersegmental membranes"; the longitudinal muscles have become intersegmental in function, since they extend from the antecosta of one plate backward to the antecosta of the plate following. But, a body division of this kind is clearly a *secondary segmentation*. The antecostal ridges, still carrying the muscle attachments, mark the limits of the primitive segments. All adult insects with hard plates in their walls have a secondary segmentation; the soft-bodied larvæ of some insects, such as caterpillars, grubs, maggots, retain a primary segmentation. This difference in the segmental limits between larval and adult insects, and the fact that the membranous "intersegmental" rings of adult insects are the posterior parts of the true segments, has already been noted by Janet (1898), who says: "The name *intersegmental membrane* generally given to such a membrane, justified by its physiological function, is, however, inexact from a morphological standpoint."

Arthropods in general are characterized by another feature of their outer organization, and this is the telescoping of their segments, each segment being partially retracted into the one before it (fig. 2 C). This condition follows naturally from the relation of the muscle attachments to the segmental plates and to the flexible membranous areas. As a result, each tergum or sternum usually ends posteriorly in a fold, or *posterior reduplication* (*Rd*), which overlaps the anterior part of the segment following.

The segmental appendages, which in their origin are simple outgrowths of the body wall, have their bases in the pleural membranes, one on each side of the segment. In the Chilopoda and the Insecta, the pleural areas also contain skeletal plates, the pleurites, but most of these plates are probably derived from a basal part of the appendage. In pterygote insects the pleurites constitute a highly organized *pleuron*.

Entomologists have usually described the various small chitinizations that occur between the principal segmental plates of insects as "intersegmental" sclerites. The only true intersegmental elements, however, are the antecostæ or parts derived from them, such as the phragmata of the dorsum and the intersegmental muscle processes of the venter. Most other so-called "intersegmental" chitinizations belong either to the anterior or the posterior parts of the true segmental areas. Examples of sclerites of this sort probably are the neck plates, or cervical sclerites, though their exact morphological status has not yet been determined. Since the anterior ends of the principal dorsal and ventral muscles of the prothorax are attached anteriorly on the back of the head, it would appear, at first thought, that the neck-plates belong to the anterior part of the prothorax. But the post-occipital ridge of the head, and the tentorium, to which the prothoracic muscles are attached, are formed by invaginations between the maxillary and labial segments. It follows, then, that an intersegmental line has been lost somewhere between the anterior margin of the prothorax and the posterior margin of the labial segment; perhaps its position is indicated by the ends of certain muscles attached on the neck membrane in some insects. It is possible, therefore, that the cervical sclerites are derived from both segments. The two lateral plates constitute an important part of the mechanism for moving the head; their muscles extend to the back of the cranium, and to the tergum of the prothorax. The cervical sclerites of various insects have been described by Verhoeff (1903), Voss (1905), Martin (1916), and Crampton (1917, 1917a, 1926).

II. ELEMENTAL STRUCTURE OF A THORACIC SEGMENT

Though the form of the insect thorax most familiar to entomologists does not present to the eye the basic structure of its parts, it is that on which our nomenclature has been established, and, therefore, it will be necessary to consider first a typical thoracic segment in its definitive state in order to explain the terms in common use applied to its various parts. The morphologist is often tempted to throw off the nomenclatural shackles that bind him to the past, for new ideas could be much more freely stated if they did not have to be expressed in the terminology of former errors, or, at least, in the language of what we now regard as the misconceptions of a less enlightened earlier age. Yet, a discarding of old names might only set an example for a future generation, which, most likely, would proceed in turn to reject our terms along with our ideas, and adopt a new orismology expressive of its own ideas. After all, even a scientific term usually meets with the fate common to all names, and soon becomes accepted as a label for an object, without significance of derivation, and without respect to the original conception it implied.

GROUND-PLAN OF A THORACIC SEGMENT

We have already seen that a primitive limb-bearing segment presents a dorsum and a venter, in each of which is developed a chitinous plate, the tergum and the sternum, respectively, and a membranous pleural area between the two on each side, in which the limb is implanted, and in which also there are usually present a number of chitinizations, the pleurites, or collectively the pleuron.

The tergum, or notum as the dorsal segmental plate is frequently called, in its typical form is a simple sclerite covering the back of the segment (fig. 3 A, *T*) and in wingless segments often produced downward on the sides, sometimes overlapping the bases of the legs. The tergum of the mesothorax, and usually that of the metathorax is marked anteriorly by a submarginal antecostal suture (*ac*) and corresponding internal antecostal ridge (B, *Ac*), the two setting off a narrow precosta (*Pc*) from the anterior margin of the principal tergal plate. The tergum of the prothorax, however, always lacks a true antecosta and precosta, these parts apparently having been lost in the "neck." The dorsal muscles of the prothorax that arise posteriorly on the antecosta of the mesotergum thus come to be inserted anteriorly on the head, and to act as muscles for moving the head. The metatergum also sometimes lacks an antecosta and a precosta, but in such cases these parts are found to have been transferred to the mesothorax, and, in the same way, the corresponding elements of the first abdominal tergum may become a part of the metathorax. The antecostæ of the mesotergum, metatergum, and first abdominal tergum commonly develop plates, called *phragmata* (fig. 23 C, *1Ph, 2Ph, 3Ph*), that extend into the thoracic cavity to give increased surfaces for the attachment of the dorsal longitudinal muscles. The rear margin of any tergum usually forms a transverse fold, or posterior reduplication (fig. 3 B, *Rd*), that of the protergum sometimes widely overlapping the mesothorax.

The sterna of the thoracic segments of insects never have the structure typical of segmental plates, such as that of the more simple thoracic terga, or that of the abdominal sterna of insects, or the sterna of the leg-bearing segments of the Chilopoda. The thoracic sterna have been modified, apparently since an early stage in the evolution of insects, through an alteration in the segmental relations of

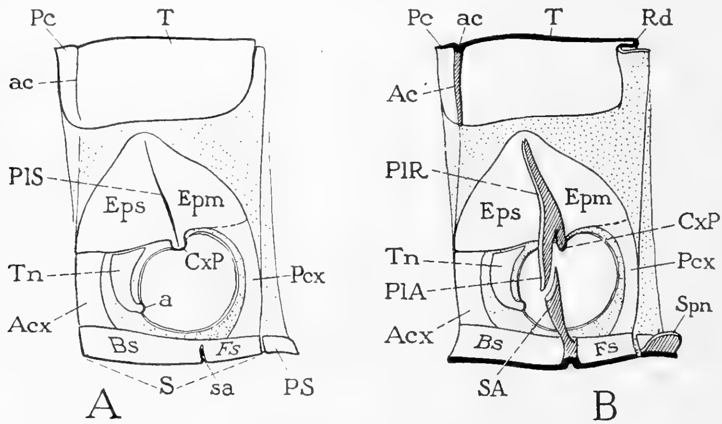

FIG. 3.—Ground-plan of a wingless thoracic segment, showing the usual or typical structure in pterygote insects.

A, external lateral view, left side; B, internal view of right side. *Ac,* antecosta; *ac,* antecostal suture; *Acx,* precoxal bridge; *a,* articulation of trochantin with coxa; *Bs,* basisternum; *CxP,* pleural coxal process; *Epm,* epimeron; *Eps,* episternum; *Fs,* furcisternum; *Pc,* precosta; *Pcx,* postcoxal bridge; *PlA,* pleural arm, or apophysis; *PlR,* pleural ridge; *PlS,* pleural suture; *PS,* poststernum *S,* sternum; *SA,* sternal arm, or apophysis; *sa,* external root of sternal apophysis; *Spn,* spina; *T,* tergum; *Tn,* trochantin.

the ventral muscles. In the thorax, these muscles are attached not to anterior ridges of the sternal plates, but to processes arising from the posterior parts of the sterna or from intersternal folds or chitinizations of the integument.

It is difficult to select, among the numerous variations in form of the ventral thoracic plates, a structure that may be regarded as "typical" of a thoracic sternum. The most constant sternal landmark consists of a pair of entosternal arms arising either independently from the region between the bases of the coxæ, where their roots are marked externally by two pits in the cuticula, or jointly from a common median base. Since the second condition is the more frequent in higher insects, the compound, forked apodeme has been named the *furca*, but the presence of two independent processes undoubtedly represents the more primitive condition. In some cases, the sternal arms, or apophyses (figs. 3 B, 4, *SA*), arise from a transverse ridge of the sternum, as in the prothorax of Acrididæ, and the external groove of the ridge then divides the sternum into two parts; but again, a division of the sternum may occur anterior to the bases of the furcal arms. The two parts of the sternum have been called somewhat loosely the sternum and sternellum, but since the first name should be reserved for the entire sternal plate (fig. 3 A, *S*), the terms *basisternum* and *furcisternum* (*Bs* and *Fs*) proposed by Crampton (1909) are to be preferred, though the first sternal sclerite is not "basal" and the furca is not necessarily a process of the second.

In addition to the sternal arms or furca, there is often present in the lower orders of winged insects a median sternal process known as the *spina* (fig. 3 B, *Spn*) situated behind the paired apodemes. Sometimes the spina appears to be carried by the posterior margin of the furcisternum, but typically it is borne on an independent sclerite, the *spinisternum* in Crampton's nomenclature. Another sclerite, the *postfurcisternum*, is found in rare cases between the furcisternum and the spinisternum, or extends as a fold laterally, where it may bear a pair of small processes known as the *furcillæ*. It is probable, however, that both furcisternum and spinisternum are parts of one poststernal region.

In general, then, we may say that the ventral chitinization of a thoracic segment consists of a principal plate, the true *sternum* (fig. 3 A, *S*), and of one or two poststernal sclerites constituting a *poststernum* (*PS*), the latter usually associated with, or incorporated into, the posterior part of the sternum proper. There is reason to believe, as will be shown later (page 21), that the poststernal parts are primary intersegmental elements that once constituted the precosta and antecosta of the sternum following. At any rate, this assumption explains the apparent reversal in the attachments of the ventral thoracic muscles, which, as the poststernal sclerites are lost, become transferred to the posterior parts of the preceding sterna and finally to the furcisternal apodemes.

The two divisions or regions of the sternum proper usually differ considerably in shape and size. The basisternum lies mostly before the bases of the legs (fig. 7 B, Bs_2, Bs_3,) and may become expanded laterally or fused with a precoxal part of the pleuron (fig. 3 A, *Acx*). Its anterior part is sometimes differentiated as a *presternum*, being separated from the rest by a suture, and an internal ridge simulating an antecosta, but the ventral muscles are never attached to this ridge. The furcisternum lies between the coxal bases; it is usually narrow, sometimes reduced to a mere base for the furca. When the coxal cavity is closed behind by a postcoxal bridge from the pleuron (fig. 3 A, *Pcx*), the bridge unites below with the furcisternum and is usually continuous with it. In some of the Apterygota and in some species of the higher pterygote orders the coxa of the mesothorax and of the metathorax is articulated ventrally to the sternum by a condyle on the lateral margin of the furcisternum.

The sternal arms, whether they are independent apophyses of the sternum, or are united upon a common base, extend upward and out-

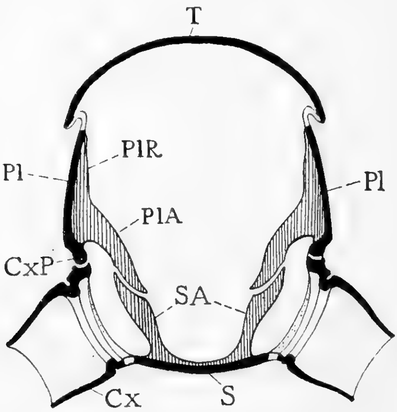

FIG. 4.—Diagrammatic cross-section of wingless thoracic segment of a pterygote insect.

Cx, coxa; *CxP,* pleural coxal process; *Pl, Pl,* pleura; *PlA,* pleural apophysis; *PlR,* pleural ridge; *S,* sternum; *SA,* sternal apophyses; *T,* tergum.

ward toward descending apodemes of the pleuron (figs. 3 B, 4, *PlA*), and the two sets of processes are almost always closely associated, in some cases fused, but more generally united by short muscle fibers (fig. 28, *G*). The sternal and pleural arms thus form bridges across the coxal cavities, and the similarity of their position and their complimental function suggest a correlation in origin. Neither pair is present in the Apterygota.

The pleuron, though subject to an endless number of minor variations, shows a general plan of structure in the Pterygota which may be simplified to the diagrammatic scheme shown in figure 3 A. In the Apterygota the pleuron is little developed, and does not indicate an evolution toward that of the winged insects, but it does suggest, as will be shown later (page 22), the nature of the structure from which has been developed the pleural sclerites in both the Apterygota and the Pterygota.

The key to the structure of the adult pterygote pleuron is the *pleural suture* (fig. 3 A, *PlS*), a groove extending upward from above the base of the coxa, and forming internally the *pleural ridge* (fig. 3 B, *PlR*). The pleural ridge is to be identified by the *pleural arm* (*PlA*), which extends inward and ventrally from its lower part, and by the condyle at its ventral end, the *pleural coxal process* (*CxP*), which forms the dorsal articulation of the coxa with the body. The part of the pleuron dorsal to the coxa is divided by the pleural suture and pleural apodeme into an anterior region, the *episternum* (fig. 3 A, B, *Eps*), and a posterior region, the *epimeron* (*Epm*). These two sclerites are thus secondary divisions of a primitive plate, there being no evidence of their origin from separate centers of chitinization. The relation of the pleural arm to the corresponding sternal arm (fig. 3 B, *PlA* and *SA*) has already been noted.

The anterior ventral angle of the episternum is usually extended toward the sternum to form a *precoxal bridge* (fig. 3, *Acx*) before the base of the leg, and often a similar extension from the epimeron forms a *postcoxal bridge* (*Pcx*) behind the leg, the first becoming continuous with the basisternum, the second with the furcisternum. The anterior bridge, however, in some of the lower insects is separated from the episternum and constitutes an independent sclerite, the *anterior laterale,* occasionally divided into an upper and a lower piece. Less frequently is the posterior bridge an independent *posterior laterale.* When all the regions of the pleuron thus far described—episternum, epimeron, precoxal bridge, postcoxal bridge—are well developed, they constitute an arch over the base of the coxa, braced upon the sternum below, from which the leg is suspended by the coxal process at the lower end of the pleural ridge.

In the generalized pterygote pleuron a sclerite known as the trochantin (fig. 3 A, *Tn*) lies before the base of the coxa, but behind the precoxal bridge (*Acx*). The trochantin is usually triangular in form, elongate dorsoventrally, with its upper end touching upon the episternum or fused with the lower part of the latter. Its lower end articulates by a *trochantinal coxal process* (*a*) with the anterior margin of the coxal base. The trochantin is a highly variable sclerite; it is best developed in the Apterygota and in the lower orders of the Pterygota, though it may differ much in closely related species; in the higher pterygote orders it is rudimentary or absent. In some of the Apterygota the trochantin forms an arch over the base of the coxa; only in rare cases does it extend dorsal to the coxa in pterygote insects as a free sclerite, being usually fused into the lower part of the episternum, or limited to the region between the episternum, precoxal bridge, and the coxa. It is clear that the trochantin is a sclerite of the pleuron that has played a more important rôle in primitive insects, and one now in a state of becoming obliterated in the higher insects. The evidence bearing on its past history will be discussed in the next section of this paper.

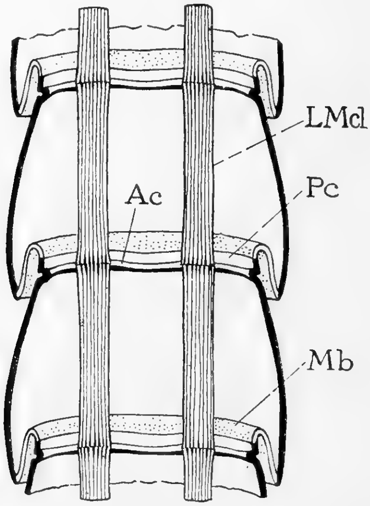

FIG. 5.—Inner surfaces of typical dorsal or ventral segmental plates of insect with secondary segmentation.

Ac, antecosta, or anterior submarginal ridge of segmental plate; *LMcl,* longitudinal muscles, attached to antecostæ; *Mb,* secondary "intersegmental" membrane; *Pc,* precosta, narrow anterior lip of plate, before the antecosta.

EVOLUTION OF THE THORACIC SCLERITES

It is one thing to formulate in a general way a working plan for the study of the thoracic sclerites as they occur in modern adult insects; it is quite another to understand how the structure represented by this plan has been evolved from a more primitive one, and to determine what the primitive structure itself may have been. In pursuing this line of investigation a study of the thorax of the Apterygota should be of assistance, though, as we shall find, the apterygote thorax gives little evidence of having evolved into the pterygote thorax. Yet, the thorax of apterygote insects has preserved certain characters, which, though degenerate in some respects, afford better evidence of the structure of the primitive insect thorax, and therefore of that of the extinct ancestors of the Pterygota, than is to be found in the thorax of modern winged insects, or in that of the earliest winged forms known from the paleontological records.

THE TERGUM

The dorsal plates of the thoracic segments, though highly specialized in the mesothorax and metathorax of the Pterygota, have been affected less in the adaptive reconstruction of the thorax than have either the sternal or the pleural parts. The reason for this is clearly to be found in the fact that the evolution of the terga is correlated with the development of the wings, organs of comparatively recent origin, while the evolution of the sternal and the pleural parts began with the differentiation of the thorax as the specialized locomotor center of the body. In general, the dorsal plates of the thoracic segments have preserved the structure characteristic of the terga of arthropods having a secondary segmentation, in which the dorsal muscles extend between antecostal ridges (fig. 5) derived from the primitive intersegmental folds (fig. 2). In the prothorax, however, the tergum always lacks a true antecosta and precosta, and the principal dorsal muscles are attached anteriorly on the back of the head, as are also the ventral muscles. By this anatomical arrangement the head becomes movable on the body by the action of the prothoracic muscles.

In the Apterygota the thoracic terga are comparatively simple plates. In *Japyx* (fig. 6 A) the mesotergum and metatergum have particularly large precostæ (Pc_2 Pc_3), each set off by a distinct antecostal suture (*ac*), and marked by a median pair of prominent setæ, as is also the precosta of the first abdominal segment (*IPc*). Verhoeff regarded the precostal sclerites of *Japyx* as representing terga of rudimentary intercalary thoracic segments; Enderlein (1907) claimed that they are but "apotomes" of the following terga; it is now clear that they are nothing more than unusually large precostæ, since the dorsal muscles are attached to ridges at their bases. Behind each principal tergal plate is a membranous area (fig. 10, *Mb*) continuous with the pleural area on each side of the segment. In the Protura the tergum of the mesothorax and of the metathorax (fig. 8, *T*) does not cover the entire back of the segment, there being a large membranous or weakly chitinous area behind it. This area Berlese (1910) regards as "intersegmental," but Prell (1913) distinguishes in it two regions, the first of which he calls the "nothotergite," while the second he suggests is the homologue of the postnotal plate of certain winged insects. The postnotum, however, as will be shown later, when present is a development of the precosta normally attached to the tergum following, and the post-tergal region in the proturan dorsum does not appear to be a part of the small precosta behind it in either the mesothorax or the metathorax.

In *Lepisma* the lateral margins of the thoracic terga are somewhat produced above the bases of the legs, in *Machilis* they form free lobes reaching down on the sides of the segments and overlapping the

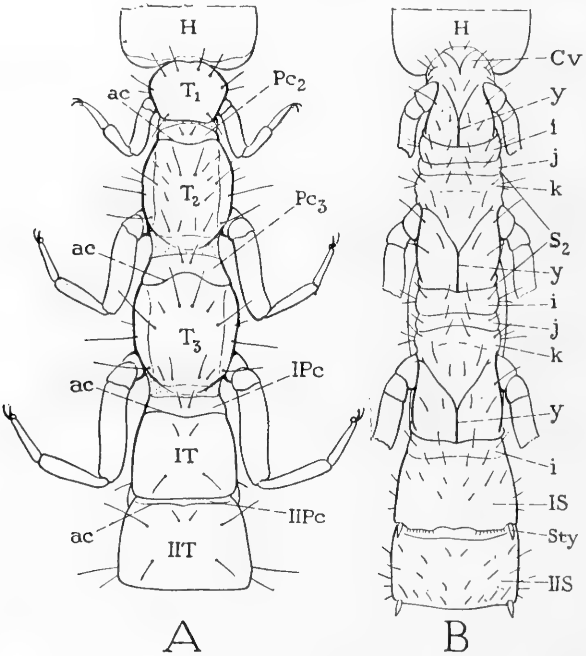

FIG. 6.—Thorax of *Japyx sp.*, with base of head and of abdomen.

A, dorsal view, showing larage precostæ (*Pc*) of mesotergum (T_2), metatergum (T_3), and first abdominal tergum (*IT*). B, ventral view, showing anterior apotomal folds (*i, j, k*) of sterna, and sutures (*y*) of Y-shaped ridges of thoracic sterna.

leg bases, but there is no reason for believing that these tergal extensions in the Thysanura have any phylogenetic relation with the tergal lobes from which the wings of pterygote insects are presumed to have evolved.

In the Pterygota, the terga of the thorax reach their highest degree of development in the second and third segments, where they present numerous specializations fitting them to their functions of supporting the wings and of giving efficient attachment to the principal muscles that move the wings. The features of the wing-bearing terga, however, will be described in the discussion of the structure of a wing-bearing segment (page 45). The pterygote protergum shows various modifications of form, but none of its characters is to be homologized with the special structures of the mesotergum or metatergum, a fact indicating that the rudimentary wing lobes of the prothorax of the Palæodictyoptera (fig. 19) were never developed into movable appendages in later insects.

THE STERNUM

The most important thing to be noted in a study of the sterna of the insect thorax is the fact that the ventral longitudinal muscles,

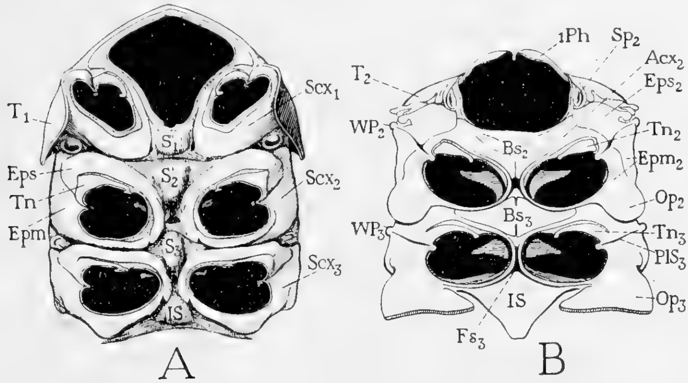

FIG. 7.—Pleuro-sternal parts of thorax of a cicada (*Tibicina septendecim*).

A, ventral view of thorax of mature nymph, legs removed, showing the pleural parts continuous around inner sides of coxal cavities, suggesting that each pleuron represents a basal, or subcoxal, segment (*Scx*) of a leg (see figs. 15 B, 16 D). B, ventral view of mesothorax and metathorax of adult, showing pleural folds on inner sides of coxal cavities persisting as chitinous ridges on edges of sterna.

except in the Protura, extend between posterior parts of the sternal sclerites, and are never attached as they are in the abdomen, or as are the dorsal muscles of both thorax and abdomen, to anterior ridges of the segmental plates. The ventral musculature is greatly reduced in the thorax of all adult pterygote insects, but in holometabolous larvæ (Coleoptera, Lepidoptera, Diptera) the sternal muscles of the thorax are developed in proportion to the rest of the body musculature, and include large latero-ventral bands of fibers continuous with the muscle bands of the abdomen. In the Protura, according to Berlese (1910), the longitudinal musculature is complicated in a manner characteristic of primitive forms, and presents features suggestive of the musculature of larvæ of holometabolous insects. The ventral muscles, for example, consist of two latero-ventral bands of fibers continuous through the abdomen and thorax. In the abdomen, except in the first segment, the fibers are attached to antecostal ridges of the sterna, and in the thorax to the anterior margins of the sternal plates, except in the prothorax where they are inserted anteriorly on the head. Here is unquestionably a uniformly primitive condition of the ventral musculature. It is probably of no phylogenetic significance that, anterior to the fifth abdominal segment, the fibers of these muscles are of the length of two segments and are attached to alternate sterna.

The sternal chitinization of each thoracic segment of the Protura, according to Berlese (1910) and Prell (1913), consists of two plates (fig. 8), one lying before the bases of the legs, the other between and behind them. In the mesothorax and metathorax the second sternal plate bears a median apodemal ridge, which in the Eosentomidæ is forked anteriorly and has the form of a **Y** with the arms extending toward the bases of the coxæ.

In *Japyx* the principal part of the sternal region in each thoracic segment consists of a large quadrate plate conspicuously marked externally by the lines of a **Y**-shaped ridge on the inner surface (fig. 6 B, *y*). The arms of the ridge extend outward and forward to the bases of the legs, where each becomes continuous with a basal ridge of the coxa and constitutes a sternal coxal articulation. The anterior part of each sternum consists of a semimembranous area (fig. 6 B, *k*) indistinctly separated from the rest, and bearing four prominent setæ in a transverse row. Before this area there are two well-marked sternal folds (*i, j*) that appear as replicas of it, each bearing likewise four setæ similarly placed. A single fold with four setæ occurs between the metasternum and the first abdominal sternum (*IS*). These sternal folds, the sternal "apotomes" of Enderlein (1907), the "intersternites" of Crampton (1926), are usually regarded as intersegmental, but that they belong to the sternum following is shown by the fact that the anterior margin of the first one of each thoracic set, as seen in side view (fig. 10, *i*), coincides with the line of the antecostal suture of the tergum (*ac*) of the same segment. A striking feature of the sternal structure in the thorax of *Japyx* is the reversed overlapping of the sternal plates, the posterior edge of each principal plate being covered externally by the anterior fold of the sternum following. The posterior ends of the median ridges of the sternal apodemes project as free processes into the body cavity.

There are no continuous bands of longitudinal muscle fibers in the thorax of *Japyx,* as there are in the Protura. Grassi (1886) says, in both *Japyx* and *Campodea* the longitudinal ventral muscles of the thorax are not recognizable with certainty. In this respect these forms resemble the adults of winged insects, though it would be difficult to homologize individual sternal muscles in the two groups. In each thoracic segment of *Japyx* a pair of divergent muscles goes forward from the arms of the sternal apodeme to the posterior edge of the sternal plate preceding. These muscles clearly act as retractors of the anterior sclerite, their action in this capacity being made possible by the reversed overlapping of the adjoining sternal parts, and the flexibility of the folds between the chitinous plates. The median ridge of the **Y**-apodeme gives origin to muscles that go obliquely outward to the coxæ, and other coxal muscles of the sternum are attached between the arms of the apodeme. The dorsal muscles of the coxæ arise on the tergum.

The sternal apodeme of the Protura and of the entognathous Thysanura is evidently a homologous structure in both groups. It consists of a median ridge in *Acerentomon* and *Campodea* (Grassi), but is forked anteriorly in *Eosentomon* and *Japyx*. This apodeme can scarcely be a prototype of the furca of the Pterygota, because the median base of the furca is clearly a secondary development in the higher winged insects, the arms, developed from lateral sternal invaginations, being the primitive elements of the furca.

The thoracic musculature of *Lepisma* and *Machilis* is complicated, especially so is that of *Machilis,* but, while a thorough study of it would make a valuable contribution to our knowledge of the Thysanura, it does not appear, from a superficial examination, that it would throw any light on the evolution of the sternal musculature in the Pterygota. The Thysanura do show, however, that the ventral longitudinal muscles of the thorax have become attached to the posterior margins of the sterna, which latter apparently have absorbed the antecostal ridges following, since antecostæ and precostæ are not present in the typical position on any of the thoracic sterna, or on the first abdominal sternum.

The larvæ of pterygote insects with complete metamorphosis have in most cases a primary segmentation of the body, in which the attachments of the longitudinal muscles are at the intersegmental grooves. Even where segmental plates are present in the body wall, as in the larvæ of some beetles (fig. 25), the areas of the muscle attachments may be non-chitinous, but wherever a costa is formed (*ac*) it is in the intersegmental fold and is attached to the segmental plate following it.

In the larva of *Dytiscus marginalis,* as described by Speyer (1924), a pair of furcal arms arises on each sternal region of the thorax between the legs, and each pair is supported on a transverse ridge, or infold of the sternal wall. An inflection of the integument between the prothorax and the mesothorax, and one between the mesothorax, and the metathorax form intersegmental folds between the thoracic sterna. The fold between the first and second segments bears laterally on each side a small process, the furcilla, and medially an unpaired process (the spina); the fold between the second and third segments has only a median process. The musculature of the *Dytiscus* larva, Speyer shows, is primitive in many ways; both abdomen and thorax, for example, are traversed by continuous latero-ventral bands of muscle fibers. In the abdomen the fibers of these muscles are attached to anterior folds of the sterna, except in the first segment where all but one pair are inserted anteriorly on posterior parts of the metasternum, either on the furcal arms and the supporting ridge, or on lateral points corresponding in position with the furcillæ of the first intersternal fold of the thorax. In the thoracic segments the ventral muscles are attached to the furcal arms, to the furcillæ, to the median process, and to a transverse ligament at the posterior edge of the segment, except in the prothorax where one set ends on the back of the head and another on the cervical sclerites. Without going farther into details of Speyer's account, it is clear that the sternal thoracic muscles in the larva of *Dytiscus* are attached either to posterior parts of the sterna, or to processes (furcillæ and spina) of intersegmental folds. The folds, Speyer says, appear to be derived from the anterior part (acrosternite) of the sternum following in each case.

In the adult of *Dytiscus* (Bauer, 1910), the principal ventral muscles of the thorax consist of paired bundles of longitudinal fibers extending between the sternal apophyses, and from the prosternal apophysis to the back of the head. This is the general condition of the longitudinal ventral musculature in the thorax of adult Pterygota, except that where median apophyses are present some of the muscles are attached to them.

A study of both the Apterygota and the Pterygota, therefore, appears to indicate that the first step in the evolution of the thoracic sterna consisted of a union or close association of the points of attachment of the ventral muscles with the sternal plates preceding. It may be questioned whether the folds bearing the muscle attachments in the thoracic region ever formed antecostæ of the sterna following, as they do in the abdomen, but it is reasonable to suppose that they did, considering that the sterna of the Chilopoda are of uniform structure in all the limb-bearing segments, and that the ventral thoracic muscles of the Protura are attached to the anterior margins of the sterna (Berlese). Chitinizations of the intersegmental folds bearing the ventral muscle attachments have thus come to form apparent *posterior* elements of the sterna, or have been incorporated into the posterior parts of the sterna, and in this respect, as pointed out by Weber (1924), the sternal structure in the thorax is comparable to the tergal structure in those segments where a postnotal plate and phragma, originally intersegmental or a part of the succeeding tergum, become a part of the preceding tergum. By analogy, the intersegmental or posterior part of the definitive sternum may be termed the *poststernum* (fig. 3 A, *PS*). That the poststernal part in each segment, which sometimes consists of two parts (postfurcisternite and spinisternite of Crampton) is a true intersegmental element has been effectively stated by Weber (1924), who says: "One may conclude with all appearance of truth that the postfurcasternite has arisen from the membranous region between the true sterna, perhaps as a result of the muscles attached to it, and that it is a structure in every way similar to the postnotum of winged insects, though doubtless of older origin." Where two postfurcal sclerites are present, the second, or spinisternum, Weber believes, is only a detached piece of the first comparable to the phragma of a postnotum. Again, reviewing the prothoracic structure of the Neuroptera, Trichoptera, and Lepidoptera, in his paper on the thoracic skeleton of the Lepidoptera, Weber (1924 a) says: "The fourth section of the sternum, the *postfurcasternite,* is usually clearly separated from the furcasternite and is obviously a secondary structure. In *Sialis* it is only suggested, in the Trichoptera it is a distinct posterior appendage of the sternum, in *Hepialus* it becomes extremely long, and here there begins the formation of a posteriormost and likewise secondary piece of the sternum, which may be identified with the spinisternite of Crampton. This sclerite borders so closely on the mesosternum that it becomes a question whether it should be reckoned as a part of this sclerite or of the prosternum."

The poststernal sclerites, however, are not generally persistent elements of the sterna, for in most insects they are either lost or become indistinguishably fused into the posterior edges of the true sternal plates. Some of the ventral muscles that remain in the adult stage are attached to the spina, if this process is present; the attachments of the others become transferred to the posterior part of the sternum, where, in the Pterygota, they are carried mostly by the furcal arms. The development of the furcal arms, or lateral sternal apophyses, has differentiated the primitive sternal plate into basisternum and furcisternum, but the presence of these processes is a character of the Pterygota, there being no trace of them or other homologous sternal apodeme in any of the Apterygota. While, therefore, the general structure of the thoracic sterna has been developed in connection with the specialization of the thorax as the locomotor center of the insect body, the special structure of the thoracic sterna of winged insects has evolved within the pterygote group, probably as an adaptation to an indirect function in connection with the wings. Though Crampton (1926) distinguishes a basisternum and a furcisternum in some of the Thysanura, the structures separating the sternal regions so named, such as the **Y**-shaped ridges of *Japyx* (fig. 6 B, *y*) are not to be homologized with the sternal apophyses of the Pterygota.

THE PLEURON

The pleuron of a thoracic segment offers a more difficult problem in morphology than does either the tergum or the sternum, and the question of the origin of its sclerites has been the subject of much speculation and discussion. Our prevalent ideas concerning the structure of the pleuron have been derived largely from a study of the pterygote thorax, but, since the pleurites as they occur in a winged insect are certainly not primary elements in the wall of any primitive segment, we see, undoubtedly, in the thoracic pleuron of winged insects a highly specialized structure. A study of the apterygote thorax, therefore, might give more valuable suggestions concerning the basic structure of the pterygote pleuron than are to be had from a knowledge of the pterygote pleuron itself, since the pleural structure of the Apterygota should be less removed from the common ancestral structure than is that of the Pterygota.

The largest number of pleural sclerites is found in the Protura. In the mesothorax and metathorax of *Eosentomon,* as described by Prell (1913), there are nine principal plates on each side of the segment between the tergum and the sternum (fig. 8). Four of these (*a, b, c, d*) are more dorsal than the others and constitute a series of *tergopleurites,* according to Prell's interpretation. Four others (*e, f, g, h*) form a ventral series believed by Prell to represent the true pleural plates of other insects. Since Crampton (1914) has named the corresponding area in Pterygota the *eupleuron,* the series of plates having an analogous position in *Eosentomon* and other Apterygota may conveniently be termed the eupleural sclerites. The ninth plate in the general pleural area of *Eosentomon* (*Tn*) is a semicircular chitinization over the dorsal half of the coxa (*Cx*), and this sclerite Prell calls the *trochantin,* since its anterior part is clearly the homologue of the usual trochantinal sclerite of pterygote insects. It is important to note that the eupleural and trochantinal sclerites of *Eosentomon* form a group of small plates arched over the coxal base, and that in this way they correspond with the pleurites in a pterygote pleuron. It may be questioned whether the plates of the eupleural series in *Eosentomon* are to be identified individually with specific pleural sclerites of winged insects, as Prell suggests, but it is true, at least, that they occur in homologous parts of the pleural area. There can be little doubt, however, that the trochantin is the same sclerite in both insect groups. In *Eosentomon* its anterior part tapers downward and ends in a recurved point articulating with the anterior

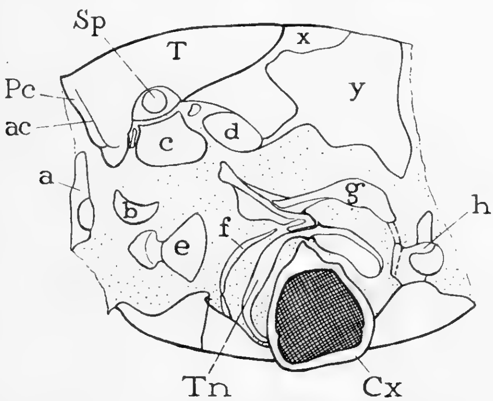

Fig. 8.—Mesothorax of a proturan, *Eosentomon germanicum.* (Figure from Prell, 1913, but differently interpreted, and re-lettered.)

The dorsum contains a tergum (*T*) with narrow precosta (*Pc*) separated by antecostal suture (*ac*), and two posterior weakly chitinized regions (*x, y*). The pleural area contains a dorsal series of tergo-pleurites (*a, b, c, d*), a ventral group of true pleurites (*e, f, g, h*) about the base of the coxa (*Cx*), and a trochantin (*Tn*) arched over the coxa.

ventral rim of the coxal base, while its dorsal part, Prell says, articulates both with the dorsal edge of the coxa and with the median pleural plate (*g*) above it.

In the Chilopoda, the pleural regions of the leg-bearing segments contain a number of small sclerites. The more dorsal plates in each segment are probably tergopleurites, but those immediately above and before the base of the leg would appear to represent the eupleural and trochantinal sclerites of the Protura. In *Lithobius forficatus,* as figured by Verhoeff (1903), there are two sclerites lying dorsal to the base of the coxa (fig. 9), of which Verhoeff calls the upper one (*o*) the "anopleure," and the lower (*Tn*) the "katopleure." A third (*p*), lying before the coxa, Verhoeff regards as the "trochantin";

and a fourth (q), apparently forming the dorsal part of the coxa (Cx), he calls the "coxopleure." When compared with *Eosentomon* (fig. 8), it appears more likely that the plate over the coxa in *Lithobius* should be the trochantin, of which the more ventral sclerite (p) may

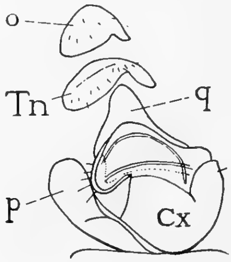

FIG. 9.—Coxa and pleurites of one segment of a centipede, *Lithobius forficatus*. (Verhoeff, 1903.)

Cx, coxa; *o*, eupleural sclerite (anopleure of Verhoeff); *p*, precoxal sclerite; *q*, coxal sclerite (coxopleure of Verhoeff); *Tn*, trochantin (katopleure of Verhoeff).

be a part, though the latter might correspond with the precoxal sclerite (f) in *Eosentomon*. In *Lithobius sp?* (fig. 32 B) there is only one plate dorsal to the coxa. Though the Chilopoda and the Protura cannot be regarded as related except indirectly through some remote common

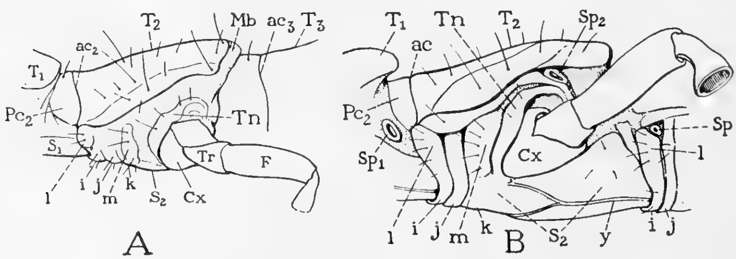

FIG. 10.—Lateral view of mesothorax of Japygidæ.

A, *Japyx sp.*, pleural region occupied by trochantin (Tn) curving over base of coxa (Cx), and by two lateral extensions (l, m) from apotomal folds (i, k) of sternum. (Spiracles not seen in this species.)

B, *Heterojapyx sp.* (large species from Australia), showing spiracles. Sp_1, prothoracic spiracle; Sp_2, mesothoracic spiracle; a metathoracic spiracle in corresponding position; Sp, first metathoracic spiracle, at upper end of pleural apotomal folds. Other lettering as on figure 6.

ancestor, yet it does not appear impossible that their pleural sclerites may have been derived from the same basic structure.

In the Japygidæ, the pleural structure appears, at first sight, to have little in common with that of the Protura. In some forms (fig. 10 B) there is a tergopleural fold in the mesothorax and metathorax immediately below the edge of the tergum, above and behind which is the segmental spiracle (Sp_2). Arching over the base of the coxa is a chitinized fold which should represent the trochantin (*Tn*), though it is continuous basally with the sternum before the articulation of the latter with the coxa (*Cx*). Anterior to the trochantin are two or three chitinized pleural areas (A, B, *l*, *m*) continued from the apotomal folds of the sternum (*i*, *j*, *k*). The apotomal folds constitute a specialization in the Japygidæ, but the true pleural parts apparently are reduced to the trochantinal fold over the coxa.

In *Lepisma* the thoracic pleural regions have well-defined chitinous plates. In the mesothorax and metathorax, two sclerites (fig. 11, *r*, *Tn*) arch concentrically over the base of the coxa, while a third

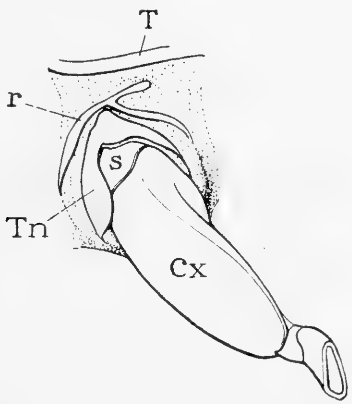

FIG. 11.—Mesothoracic pleuron, edge of tergum, and base of leg of *Lepisma*. *Cx*, coxa; *r*, eupleural sclerite; *s*, sclerite on base of coxa; *Tn*, trochantin; *T*, tergum.

smaller one (*s*) is attached to the rim of the coxa itself. The first is evidently a sclerite of the eupleural series. It is a narrow chitinous band, with a short dorsal arm projecting upward and posteriorly, to the end of which is attached a muscle. The second sclerite (*Tn*) has the position of the trochantin in *Eosentomon* (fig. 8), though it fits closely over the upper end of the coxa, and has no special articular points with the latter. It is larger than the dorsal sclerite, triangular over the coxa, and expanded again where it overlaps the anterior angle of the coxal base. The third sclerite (*s*) is a small triangular piece closely attached to the base of the coxa, and is probably a detached piece of the latter. It suggests Verhoeff's "coxopleure" in *Lithobius* (fig. 9, *q*), but is apparently not the sclerite so designated by Verhoeff in *Lepisma*. In the prothorax, the same pleural sclerites are present, though they are here less distinct and not easily separated.

The pleural pattern of *Lepisma* is surprisingly similar to that of *Lithobius* (fig. 9), and is one also that conforms with the pleural pattern in *Eosentomon* (fig. 8), except that the eupleural series of plates is represented by a single sclerite in *Lepisma* (fig. 11, *r*). It is not implied, however, that *Lithobius* and *Lepisma* have any immediate relationship, or that either is descended from *Eosentomon,* but that through the disintegration of a primitive chitinization in the pleural region of a common ancestor, there have resulted the pleural patterns of *Eosentomon, Lithobius* and *Lepisma.*

The pleuron of *Machilis* has little resemblance to that of the other Apterygota. It consists of a single, small, triangular plate (fig. 12, *t*)

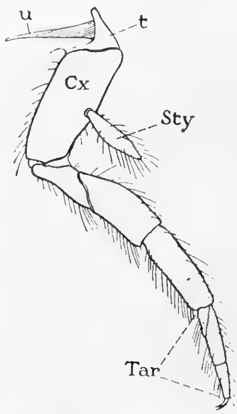

Fig. 12.—Left mesothoracic leg and pleural sclerite of *Machilis,* anterior view. *Cx,* coxa; *Sty,* stylus; *t,* pleural sclerite, *Tar,* tarsus; *u,* apodeme of pleural sclerite.

closely attached to the base of the coxa, but extending dorsally to the base of the lateral fold of the tergum. Many writers, probably following Hansen (1893), designate this sclerite the trochantin (or subcoxa), and its close connection with the coxa would suggest its trochantinal nature. Its basal angles are continued into a fold that surrounds the base of the coxa; its triangular lateral surface is marked by a vertical groove in which a deep invagination forms a long, slender, internal arm (*u*) to which is attached a muscle from the tergum. Crampton (1926) assumes that the plate belongs to the eupleural series, and that its areas before and behind its external suture are equivalent to the episternum and epimeron of pterygote insects. It is suggested by Prell that the median plate in the eupleural series of *Eosentomon* is likewise the common fundament of the pterygote episternum and epimeron. It may be questioned, however, whether these are cases of actual homology or of resemblances in structures arising independently in response to similar demands. There is no evidence of lineal or connected relationship between the Protura, *Machilis,* and the Pterygota.

A study of the pleura of *Eosentomon, Japyx,* and *Lepisma* leads to the generalization that the pleurites of the Apterygota comprise a eupleural series of chitinizations arched over the base of the coxa, and a trochantinal sclerite in immediate contact with the coxa, while with them there may be associated a sclerite derived from the coxal base. A suggestion of the same pattern is to be found in the pleura of the Chilopoda. In *Machilis* the pleurites are reduced to a single plate, the identity of which is obscure—it might be the trochantin, or it might be a sclerite of the eupleural series. In the Collembola the thoracic pleurites are but poorly developed. Crampton (1926) finds a trochantin closely associated with the coxa, and a pleural sclerite lying above the coxa, but of the collembolan sclerites in general, he says, they "are too weakly developed, and too unsatisfactory in nature to afford much evidence of relationships to other forms." The line of descent of the Collembola, Crampton believes, "leads off in a direction having no especial bearing on the evolution of the higher forms." The present writer would add that the same may as truly be said of any of the apterygote groups. There is no suggestion, for example, in the Apterygota of the probable steps in the evolution of the pterygote pleuron; rather, each pleural pattern in the Apterygota appears to have resulted independently from the disintegration of a more concrete earlier structure. Reasons will later be given for believing that the structure of the pterygote pleuron is correlated with the wings, and that it has been developed in the extinct and unknown line of descent that led to the winged insects.

The typical structure of the pterygote pleuron has already been described and shown diagrammatically in figure 3. A more generalized condition, however, is to be found in the prothorax of the Plecoptera (fig. 13). Here there is a dorsal eupleural sclerite, or *anapleurite* (*Apl*), and a trochantinal sclerite (*Tn*) intervening between the anapleurite and the coxa, and articulating both anteriorly and dorsally with the coxa (C, *a, b*). The anapleurite is divided by an external suture and an internal ridge into an anterior episternal region and a posterior epimeral region.

The more usual pleural structure in the Pterygota includes a precoxal bridge from the episternal part of the anapleurite to the basisternum, and often also a postcoxal bridge from the epimeral region to the furcisternum. This chitinous arch constitutes the *eupleuron* (Crampton, 1914), and it is clear that it corresponds closely with the eupleural series of sclerites in *Eosentomon* (fig. 8), though not necessarily in identity of individual plates. The "typical" trochantin of the pterygote pleuron (fig. 3, *Tn*) is excluded from the dorsal, or pleural, articulation of the coxa (*CxP*), but there are many insects in which it extends posteriorly to the articulation and takes part in the formation of the articular condyle (figs. 7, 14, 15 B, *Tn*), and, as we have seen, in the plecopteran prothorax (fig. 13), it intervenes entirely between both episternum and epimeron, and the coxa, and carries the dorsal condyle of the coxal articulation as well as the anterior one.

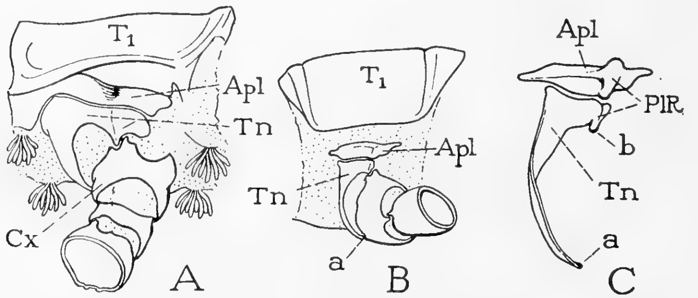

FIG. 13.—Prothorax of Plecoptera. (Proc. U. S. Nat. Mus., 1909.)

A, left side of prothorax and base of leg of nymph of *Pteronarcys;* pleuron composed of a dorsal anapleurite (*Apl*) of eupleural arch, and of a trochantin (eutrochantin of Crampton) carrying both anterior and dorsal articulations of coxa (C, *a, b*).

B, same parts of nymph of *Perla*.

C, inner view of right prothoracic pleural plates of nymph of *Perla; a,* anterior articulation of coxa; *Apl,* anapleurite; *b,* dorsal articulation of coxa; *PlR,* pleural ridge; *Tn,* trochantin.

We may conclude, therefore, that the basic structure of the pterygote pleuron, as shown at A of figure 15, is identical in plan with that of the apterygote pleuron, as exhibited in *Eosentomon* (fig. 8), and that the pleuron in each group consists of a eupleural series of sclerites, and of a trochantinal sclerite arching concentrically over the base of the coxa.

Though we may see, then, a fundamental identity of structure in the pleuron throughout the entire hexapod group, the evolution of the pleural sclerites has been quite different in the Apterygota and Pterygota. In the former, the sclerites show a tendency to reduction in different ways in different families, and the reduction, usually ending in obliteration of some of the sclerites, has produced the various and apparently unrelated pleural patterns characteristic of the Apterygota. In the Pterygota, on the other hand, the pleuron has evolved along a definite, constructive line. In the lower orders of winged insects it may consist, as in the Apterygota, of a number of separate sclerites, but in the higher orders it becomes a continuous plate, resting below upon the sternum, giving a solid point of suspension for the leg, and, in the wing-bearing segments, a support for the wing, and for the tergum also, since the latter must be braced against the downward pull of the tergo-sternal muscles in order that these muscles may function as elevators of the wings.

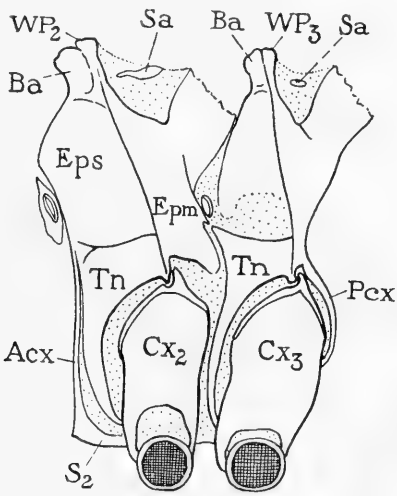

Fig. 14.—Mesopleuron and metapleuron of *Psocus venosus*.

The dorsal part of trochantin (*Tn*) of mesothorax here united with episternal part (*Eps*) of anapleurite (fig. 13, *Apl*); postarticular part of trochantin (fig. 13, *Tn*) either absent or fused with epimeron (*Epm*); basalares (*Ba, Ba*) not separated from episterna.

The evolution of the pterygote pleuron has included principally a development of the eupleural arch, and particularly of its anapleural region. With the latter has been united the dorsal part of the trochantin, as shown by Crampton (1914) and by Weber (1924). The resulting plate, bearing the dorsal articulation of the coxa, has been strengthened by an internal ridge extending upward from the coxal condyle, the external suture of which separates the definitive episternum and epimeron. There is perhaps no evidence as to whether the part of the trochantin posterior to the coxal articulation (fig. 13, A, B, C) has been absorbed by the epimeron, or has been independently lost, but there is abundant evidence of the fate of its pre-articular part. The part dorsal to the coxa unites partially or completely with the eupleural region above it, in the second case becoming a part of the definitive episternum, while the part before the coxa may separate from the supracoxal part to become a free plate (fig. 7 B, Tn_2), the sclerite ordinarily known as the trochantin (fig. 3, *Tn*). In the higher orders of the Pterygota, the trochantin becomes rudimentary or disappears entirely, and it is subject to much variation even in those orders where it is best developed. It is clear that the trochantin is a sclerite that has played a much more important part in the pleural mechanism of the earlier insects, and that it is now in process of degeneration.

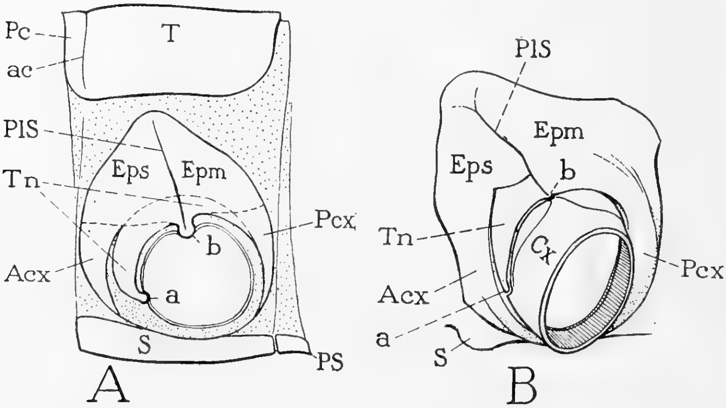

Fig. 15.—Theoretical composition of the pleuron, suggesting its origin from a subcoxal segment of the leg.

A, diagrammatic lateral view of a wingless segment, showing pleuron consisting of a eupleural arch (*Acx, Eps, Epm, Pcx*), and of a trochantinal arch (*Tn*), the latter fused dorsally with anapleurite (fig. 13, *Apl*) to form the definitive episternum and epimeron (*Eps, Epm*).

B, mesothoracic pleuron and base of coxa of mature nymph of cicada (*Tibicina septendecim*), showing parallelism in structure with A, and suggesting the origin of the pleuron from a subcoxal leg segment.

The foregoing review shows that there is a basic unity of structure in the pleural parts in both the Apterygota and the Pterygota, since in each group the pleurites fall into a eupleural and a trochantinal arch concentric over the base of the coxa. For practical purposes it is perhaps enough that we can trace the approximate evolution of the pleurites in their various modifications, but a deeper understanding of the thorax demands an explanation of the origin and nature of the pleurites themselves.

The pleural sclerites have been regarded as intrinsic elements of the lateral walls of the segments, but their variability and their general weak development in the Apterygota, would indicate that the plates are of little use in wingless insects, and that they are in a state of degeneration in the Apterygota. It is, therefore, reasonable to suspect that the pleurites are derivatives of some earlier structure, which has become degenerate in the Apterygota, but which, in the wing-bearing segments of the Pterygota, has undergone a new development by which it has become remodeled into an essential part of the wing mechanism.

From a comparative study of the appendages of the Arthropoda, Hansen (1893) concluded that the coxa is the second segment of the primitive arthropod limb, and that, in insects, the rudiment of the true basal segment is the trochantin. It was later claimed by Heymons (1899), however, that the trochantin is only a small part of the original basal segment, the major part of which has formed the other pleural sclerites. This assertion Heymons based on a study of the development of the thorax in the Hemiptera. In the embryo, he says, the basal part of the leg divides into a proximal and a distal part, the second becoming the coxa, while the first flattens out and forms those parts of the thorax with which the leg articulates. The basal piece of the limb, or hypothetical basal leg segment, Heymons designated the *subcoxa*.

The idea that the arthropod limb in general includes a subcoxal basal segment has been particularly elaborated by Börner. According to Börner's most recently expressed view (1921), the subcoxa is retained as a free basal segment of the limb only in the Pentapoda (Pycnogonida); in other arthropods it is either incorporated into the body wall, forming the pleuron in Insecta and in some Crustacea, and in other Crustacea a part of the sternum, or it has entirely disappeared, as in the Arachnida.

Crampton and Hasey (1915) have opposed the theory of the subcoxal origin of the pleural plates in insects, pointing out that Heymons misinterpreted some of the elements in the pleuron of *Nepa,* and that according to his statement the epimeron is not included in the subcoxa of the Hemiptera, though Heymons says that the subcoxal region includes both the episternum and the epimeron in Blattidæ. The hemipteran species that Heymons studied are, indeed, not good forms on which to base a study of the pleuron, for in *Naucoris,* one of his examples, the epimeron of the metathorax is rudimentary, and the episternum of the mesothorax is united with the sternum. In each segment, therefore, only a single pleural plate is evident in both nymph and adult, and a failure to recognize these conditions might give the impression that a single pleural plate in *Naucoris* is the equivalent of the episternum and epimeron in generalized insects. Heymon's general conclusion is that the pleural parts of adult insects may not correspond exactly in their entire extent with the subcoxal leg segment of the embryo, but that they are either in part or principally derived from it. The subject needs further support from embryology; but the subcoxal theory is now generally accepted in one form or another by most European students of insect morphology, though some follow Hansen in regarding the trochantin alone as representing the subcoxa.

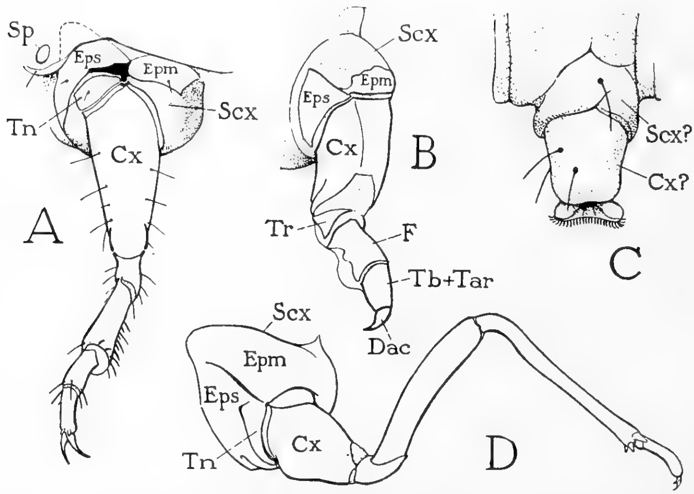

FIG. 16.—Legs and pleural parts of immature insects, suggesting that the pleural sclerites belong to a basal, subcoxal segment of the leg (*Scx*).

A, middle leg and pleural sclerites of larva of *Scarites* (Carabidæ).
B, middle leg and pleural sclerites of larva of *Pteronidea ribesi* (Tenthredinidae).
C, abdominal leg of a caterpillar (Lepidoptera).
D, hind leg and pleuron of mature nymph of *Tibicina septendecim* (Homoptera).

Students of other groups of Arthropoda also recognize a subcoxal segment, or *pleuropodite,* as the true base of the primitive limb (fig. 42 A). Some of the Acarina furnish particularly suggestive examples of structures that appear to be subcoxal leg segments. In the ticks (Ixoidea) each leg is articulated to a large basal piece (fig. 17, *Scx*) expanded on the ventral surface of the body, but continued over the base of the coxa as a narrow arch in the pleural surface. These leg bases are provided with tergal muscles *(Dermacentor, Amblyomma)*, and those of the first pair at least are capable of a slight rotary motion on their transverse axes. Each, moreover.

bears the basal attachments of the abductor and adductor muscles of the coxa *(Cx)*. In short, either the facts are most deceptive, or the ticks have retained subcoxæ in the form of functional leg bases.

A recent writer, Becker (1923, 1924), would, in a manner, reverse the relations between the pleuron and the base of the leg, since he claims that in the Chilopoda and the Insecta the coxa and trochanter are derived from the pleuron, the latter being a primary part of the thoracic wall. Becker's claim, however, may be simply another way of stating that the pleuron and the base of the leg are parts of the same structure.

Though it must be admitted that direct evidence for the derivation of the insect pleuron from the base of the limb is still insufficient,

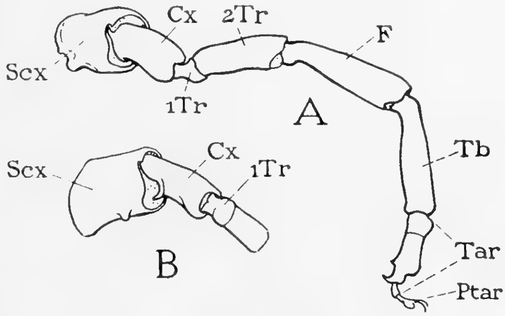

Fig. 17.—Legs of Acarina.

A, hind leg of *Amblyomma tuberculatum*, ventral view; B, base of hind leg of *Dermacentor variolatus*. *Cx*, coxa; *F*, femur; *Ptar*, pretarsus; *Scx*, subcoxa, or ventral plate of body wall bearing free part of limb; *Tar*, tarsus; *Tb*, tibia; *1Tr*, first trochanter; *2Tr*, second trochanter.

there are many facts that may be adduced as circumstantial evidence. In a cicada nymph, for example, each leg is attached to a large, oval, subcoxal, latero-ventral area of the body wall between the tergum and the sternum of its segment (fig. 7, A, *Scx*). The lateral part of each area is occupied by the pleural sclerites (figs. 7 A, 15 B, 16 D), and the precoxal and postcoxal parts (fig. 15 B, *Acx, Pcx*) are continuous in a semi-membranous fold around the mesal side of the base of the coxa (fig. 7 A). Even in the adult, the mesal subcoxal fold is quite distinct from the true sternum (fig. 7 B), though it is here chitinized and appears as an elevated marginal rim of the sternum. This structure recalls Heymons' statement that the adult sternum in the Hemiptera includes the ventral part of the subcoxa. The pleurites of a young cricket (fig. 26 A) and of other Orthoptera in the first instar likewise give the impression of belonging to a basal leg segment flattened out in the lateral wall of the body segment. In some holometabolous larvæ, as in the larva of a carabid beetle (figs. 16 A, 25), or in a sawfly larva (fig. 16 B), the thoracic legs are carried on subcoxal mounds *(Scx)* of the body wall, which have the appearance of being the true bases of the legs, and in which are situated laterally the pleural sclerites.

To trace the evidence of subcoxal elements in the abdominal segments of adult and larval insects (fig. 16 C) would take us beyond the limits of a paper on the thorax, but the contention by Börner (1909) that the gills of mayfly nymphs are homologues of the thoracic legs, and that their basal supports are subcoxæ is too interesting to pass over. Dürken (1909), it is true, has shown that the musculature of the gill does not fit with Börner's interpretation; but if Börner had compared the gill muscles, not with the tergal promotors and remotors of the coxæ, but with the coxal abductors and adductors, which should arise within the subcoxæ, there might be less objection to his homology of the skeletal parts. The general subject of the musculature of the leg base, however, will be given special attention in a following section (page 83), wherein it will be shown that the coxa appears to possess muscles that should belong to two leg segments.

Börner rightly says that an arthropod limb, in order to be an effective instrument of locomotion, must be able to turn forward and backward on its base. If a subcoxal segment was the primitive base of the limb, it, therefore, moved upon a vertical axis in the pleural membrane between tergum and sternum. Börner assumes also that the coxa moved in the same manner as the subcoxa; but this would give a double-jointed movement of the limb base in one plane. More reasonable does it seem that the primitive coxa moved in a vertical plane on a horizontal axis between anterior and posterior articular points on the subcoxa, thus duplicating the movement of the following coxo-trochantinal joint, rather than that of the limb with the body. When the subcoxa then became a fixed part of the body wall, its function as the leg base necessarily devolved upon the coxa, and the latter, taking over the promotor and remotor muscles of the subcoxa, shifted its axis from the horizontal to an oblique position and finally to a vertical one.

The subcoxal theory, then, as proposed in this paper, assumes that the coxa originally articulated with the hypothetical basal segment of the limb (fig. 18 A, *Scx*) by an anterior articulation *(a)* and a posterior articulation *(b)*, and that, in insects, the lateral walls of the subcoxa have furnished the pleural sclerites of the thorax, while the

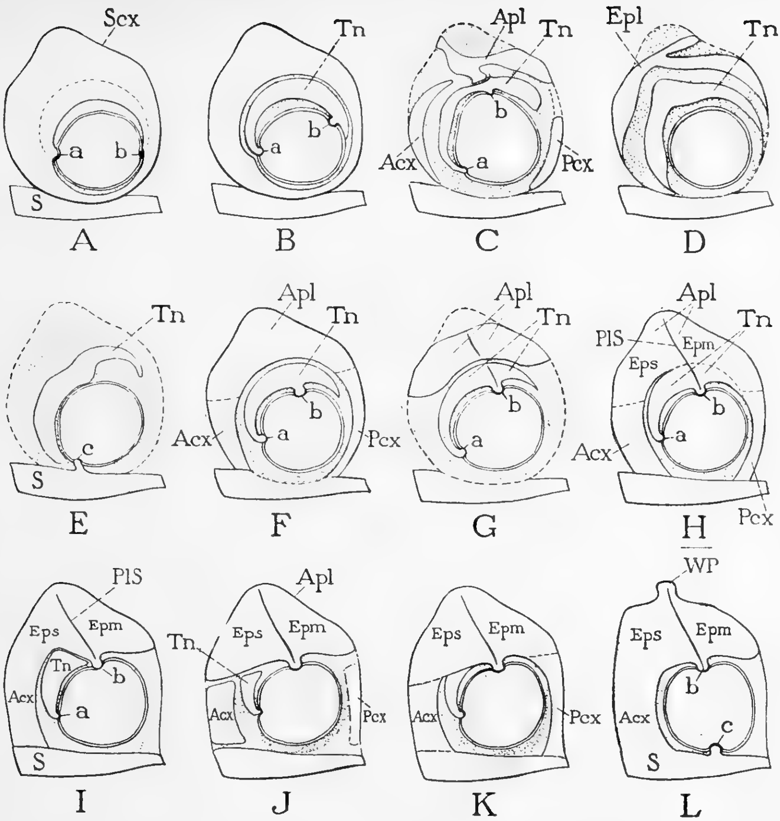

Fig. 18.—Diagrams outlining the possible origin and evolution of the thoracic pleurites from a subcoxal segment of the leg.

A, the theoretical subcoxa (*Scx*) as a primitive basal leg segment, with anterior and posterior coxal articulations (*a, b*) on a horizontal axis. *S*, sternum.

B, theoretical separation from subcoxa of a supra-coxal, trochantinal sclerite (*Tn*) bearing the coxal articulations (*a, b*).

C, subcoxa flattened into pleural wall of segment; its basal chitinization broken up into a series of eupleural sclerites (*Acx, Apl, Pcx*) forming an arch over coxa concentric with the trochantin (*Tn*); posterior articulation of coxa (*b*) dorsal in position. (*Eosentomon*, fig. 8.)

D, pleuron consisting of a eupleural sclerite (*Epl*) and a trochantinal sclerite (*Tn*), concentric over coxa. (*Lepisma*, fig. 11.)

E, subcoxal part of pleuron with a single sclerite, the trochantin (*Tn*); coxa articulated to sternum. (*Japyx*, fig. 10.)

F, theoretical primitive pterygote pleuron, consisting of a eupleural subcoxal arch (*Acx, Apl, Pcx*) based on sternum, and of a trochantin (*Tn*) carrying anterior and dorsal articulations of coxa (*a, b*).

G, prothoracic pleuron of Plecoptera (fig. 13), consisting of anapleurite (*Apl*) of eupleural arch, and of trochantin (*Tn*).

H, usual structure of pterygote pleuron: trochantin (*Tn*) fused dorsally with eupleural arch, and united areas divided by pleural suture (*PlS*) into episternum and epimeron (*Eps, Epm*).

I, ventral part of trochantin (*Tn*) a free sclerite by separation from part rëunited with eupleuron; postcoxal part of eupleural arch lacking. (Blattidæ.)

J, precoxal and postcoxal parts of eupleural arch forming independent plates (*Acx, Pcx*).

K, eupleural arch complete, united below with sternum.

L, episternal, precoxal, and basisternal regions continuous; postcoxal part of eupleural arch lacking; sternum with secondary articulation with coxa (*c*).

median ventral rim has either become membranous, or has united with the edge of the sternum. In the Acarina, the ventral part of the subcoxa has formed the large plate in the ventral wall of the body to which the leg is attached, while the lateral part has been reduced to a narrow arch over the coxal base.

The assumed change in the coxal axis from a horizontal to an oblique position, when the coxa became the functional base of the limb, suggests a reason for the detachment of a supra-coxal piece, the trochantin (fig. 18 B, *Tn*), from the body of the subcoxa, for it is clear that the displacement of the axis would be facilitated if the part of the subcoxa bearing the articular condyles became a free sclerite. Börner's view that the ventral articulation of the coxa was originally with the sternum, and that the trochantin is derived from the sternum is contradicted by the fact that in Protura (fig. 8) and in the prothorax of Plecoptera (fig. 13) the trochantin is a free sclerite bearing both the anterior (ventral) and the dorsal articulations of the coxa. In scattered cases, in both the Apterygota and the Pterygota, the coxa is articulated ventrally to the sternum, but in most such instances this is clearly a secondary condition. That the primitive axis of the coxa was horizontal is attested, furthermore, by evidence, to be presented later, that the primitive musculature of the coxa consisted of abductor and adductor muscles. In the head, the mandible retains this form of articulation, and a simple abductor-adductor musculature.

It is not difficult to imagine the probable evolution of the basal part of the subcoxa into the eupleural sclerites. In the Apterygota and in the Chilopoda, this part of the subcoxa has broken up into small plates forming various patterns in different families. In *Eosentomon*, probably three at least of the ventral series of pleurites (fig. 8, *f, g, h*) belong to the leg base, and may be supposed to be remnants of the eupleural part of the subcoxa (fig. 18 C). These sclerites, as Prell (1913) has pointed out, correspond in position with the divisions of the pterygote pleuron (fig. 18 J), one being supracoxal in position *(Apl)*, and the other two *(Acx, Pcx)* precoxal and postcoxal. In the Chilopoda (figs. 9, 32 B), the pleural pattern is variable, and perhaps has little relation to that in any insect, but apparently there are to be distinguished in it both eupleural and trochantinal sclerites. In the Thysanura there is little uniformity in the pleural structure: *Lepisma* (figs. 11, 18 D) has a single eupleural plate; in *Japyx* (figs. 10, 18 E) the only true pleural chitinization appears to be the trochantin; in *Machilis* (fig. 12) one plate is present over the coxa, but its relation to the pleurites of other Apterygota is not clear.

In the Pterygota, the eupleural arch of the subcoxa is commonly differentiated into three regions, one forming a supracoxal plate, or *anapleurite* (fig. 18 F, *Apl*), lying above the coxa, and the others a *precoxal plate (Acx)* and a *postcoxal plate (Pcx)* lying before and behind the coxa, respectively. The anapleurite is the primitive basis of the episternum and epimeron, and is seldom undeveloped; the other two are variable, and one or both may be lacking. In the prothorax of Plecoptera (figs. 13, 18 G), the anapleurite *(Apl)* of the eupleuron, and the trochantin (*Tn*) are present and entirely separate from each other, the latter carrying both the anterior and the dorsal (posterior) articulations of the coxa *(a, b)*. In other pterygote forms, however, the dorsal part of the trochantin, with the dorsal articular condyle of the coxa *(b)*, is united with the anapleural region of the eupleuron (fig. 18 H). The free anterior part of trochantin may remain continuous with its dorsal part (H), but usually it separates from the latter, which becomes an integral part of the episternum, and constitutes a free sclerite lying before the coxa (I, J, K, *Tn*). The anterior trochantinal piece, however, becomes rudimentary or is lost entirely in most of the higher insects. The coxa then often acquires a secondary ventral articulation with the furcisternum (L, *c*). In a few insects the ventral rim of the subcoxa persists as a fold around the mesal side of the coxal base (fig. 7), but generally it is not distinguishable, and the precoxal and postcoxal parts of the subcoxa (fig. 18 H, *Acx, Pcx*) appear as ventral extensions from the episternum and epimeron to the sternum, which, if chitinized, form plates or bridges (J, K). The precoxal bridge is usually best developed (I), the posterior one being frequently lacking. Both may become confluent with the pleural plates above and with the sternal plates below, uniting all these parts into a continuous chitinization surrounding the coxal cavity *(K)*, but the postcoxal bridge may be absent, leaving the coxal cavity "open" behind (L). The numerous other variations of the pterygote pleuron familiar to students of the thorax need not be detailed here, for it will be clear that all are but modifications of the basic structure given above.

THE SPIRACLES

It seems most reasonable to suppose that the spiracles of primitive insects were situated in the pleural regions of the segments, between the edges of the terga and the bases of the limbs. From this neutral position, then, the tracheal branches from each spiracle went to the dorsal and ventral parts of the segment, and the dorsal and ventral muscles of the spiracular closing apparatus were attached to the tergum and the sternum of the same segment.

Embryologists give us little information concerning the exact position of the spiracles in the embryo with relation to the segmental plates. Lehmann (1925) states that the tracheal invaginations of a phasmid, *Carausius morosus,* appear laterally on the bases of the appendages close to the anterior margins of the segments. Heymons (1895), describing the development of *Forficula* and *Gryllus,* says the spiracles arise as pits on the anterior lateral parts of the spiracle-bearing segments, soon after the appearance of the segmental appendages. Wheeler (1889) says the tracheal invagination on the thorax of *Leptinotarsa decemlineata* are situated at the bases of the legs near the anterior edges of the somites to which they belong; those of the abdomen, however, are placed near the middle of the lateral half of each segment.

In modern adult insects the location of the spiracles is too variable to serve as an index of what the primitive position of the spiracles may have been, for the adult spiracles may lie in the terga, in the pleural membranes, or in the sterna, and these variations occur within the orders, and often on different segments of the same species. It can be stated as a general rule that the abdominal spiracles lie in a line along each side of the body; especially is this true of the spiracles of embryos and larvæ of most holometabolous insects (Lepidoptera, Hymenoptera, Diptera). In many cases, therefore, where the abdominal spiracles of the adult are located in lateral or ventro-lateral areas of the terga, or in lateral parts of the sterna, it would appear that the segmental chitinizations have simply extended from one direction or the other over the spiracular areas to include the spiracles in the definitive segmental plates. In other cases, again, it is possible that there may have been a dorsal or ventral migration of the spiracles, for often the first abdominal spiracle is considerably out of line with those following. In adult Coleoptera, the abdominal spiracles are commonly situated on the dorsal plane of the body, where they may be contained in lateral parts of the terga, in the pleural membranes, or in upturned lateral parts of the ventral plates. In the Scarabæidæ often the spiracles of the first three or four segments are in the pleural membranes, while those following are in the lateral sternal plates. In adephagous larvæ the spiracles (fig. 25, *Sp*) lie in lateral parts of the dorsum, the ventral limits of which are marked on each side by a lateral fold (*a, a*) extending through abdomen and thorax. In adults of this group the abdominal spiracles are inclosed in marginal plates of the terga. In lampyrid larvæ the spiracles are on ventro-lateral plates of the abdomen, beneath the projecting edges of the terga, which in the adults are fused with the lateral edges of the sterna and reflected dorsally. Since the homology of the so-called "pleural" sclerites in the abdomen of the Coleoptera is not known, the morphological position of the spiracles in this order cannot be exactly stated, but the nature of the variations in the location of the spiracles suggests that there has occurred, in some cases, dorsal and ventral migrations of the spiracles themselves from a primitive site in the pleural membranes.

The spiracles of the thorax in adult insects usually occur at varying levels on the sides, *between* the chitinous pleura. They appear, therefore, to be intersegmental in position. In embryonic and larval stages, however, the thoracic spiracles are usually well within the limits of the segments. In the typical Chilopoda (Pleurostigma) the spiracles are in the pleural membranes and generally in the posterior parts of the segments. In the Protura they lie in small plates in the lateral margins of the mesothoracic and metathoracic terga (fig. 8, *Sp.*). The tracheal branches from each abdominal spiracle in insects are distributed mostly within the segment of the spiracle, and the muscles of the closing apparatus of an abdominal spiracle arise from the tergum and the sternum of the same segment. There can be little doubt, therefore, that all spiracles are segmental organs, as claimed by Lehman (1925) in his recent review of the insect tracheal system, in which also he gives reasons for believing that the primitive tracheal invaginations of insects may represent the ectodermal parts of the ducts of the nephridial organs (nephromixia) of *Peripatus*. The apparent intersegmental positions of the thoracic spiracles are evidently the result of secondary displacements, which in many cases can be traced during development, though some writers (Comstock, 1924, Keilin, 1924, de Gryse, 1926) have argued that all spiracles are intersegmental in origin, and that their segmental positions are owing to secondary migrations. A spiracle could not be truly intersegmental in a soft-bodied insect without interference with its function, and the idea of any organ or set of organs other than folds for muscle attachments being intersegmental is at variance with our conception of the nature of metamerism.

The typical number of spiracles in insects is ten pairs, two pairs being thoracic and eight abdominal. There is much reason from developmental studies for regarding the usual first pair of spiracles as belonging to the mesothorax, and the second to the mesothorax, and for believing that their intersegmental positions, or the occasional prothoracic position of the first are due to forward migrations. Yet, it is disconcerting to observe that the dorsal muscle from the closing lever of the first spiracle of a caterpillar is attached dorsally to the lateral margin of the protergal shield, and still more so to find that there is a spiracle in the prothorax of *Japyx* and related genera in addition to one in the mesothorax.

The usual absence of prothoracic spiracles in adult insects has never been satisfactorily explained. Though Wheeler (1889) says the tracheal invaginations of the first thoracic segment in the embryo of the potato beetle (*Leptinotarsa decemlineata*) are small, and soon close over and disappear, and though Cholodkowsky (1891) mentions the presence of a pair of such invaginations in each segment of the embryo of *Blatta*, students of insect embryology in general have not been able to find traces of spiracles or tracheal pits in the prothorax at any stage of development (Lehmann, 1925). In *Smynthurus*, one of the Collembola, the single pair of spiracles present is located in the neck. Perhaps these are the prothoracic spiracles. In *Campodea* and *Japyx*, and related genera, there is a pair of spiracles on each of the thoracic segments; in *Japyx* there is an additional pair on the metathorax. In *Heterojapyx* the first spiracle (fig. 10 B, Sp_1) is on the side of the prothorax posterior to the base of the leg, the mesothoracic spiracle (Sp_2) lies between a dorsal (tergopleural) scelerite of the pleuron and the edge of the tergum, the corresponding spiracle of the metathorax has a similar position, while the fourth spiracle (Sp) lies latero-ventrally before the base of the hind leg, between the lateral ends of the first and second apotomal folds of the pleuron. The significance of the number and position of the thoracic spiracles of *Campodea* and *Japyx* is by no means clear. The dorsal spiracles that occur on the prothorax and at the posterior end of the abdomen in the larvæ of Diptera are probably special larval organs, since the eight normal lateral spiracles appear on each side of the abdomen in some forms (*Rhagoletis, Braula*) toward the end of the larval period.

The second thoracic spiracles are very small in some adult insects; in certain larvæ they are lacking. In caterpillars and in the larvæ of beetles, the site of each is marked externally by a minute disc in the cuticula just behind the intersegmental fold between mesothorax and metathorax, and the disc is connected by a degenerate tracheal strand with the main lateral trunk of the respiratory system; in the adults, these spiracles are restored as functional organs. The thoracic spiracles usually differ from the abdominal spiracles in some manner, either in the relative positions of their parts, in their structure, or ir the type of their closing apparatus, a condition as yet unexplained.

III. SPECIAL STRUCTURE OF A WING-BEARING SEGMENT

While the perfection of the legs as walking appendages affected principally the lower pleural and the sternal parts of the thoracic segments, the development of the wings as efficient organs of flight involved changes mostly in the tergal and the upper pleural regions of the two segments concerned, though the increased importance of the tergo-sternal muscles, and the need of solidarity in the wing-bearing part of the thorax have had a general effect on the entire thoracic structure.

Flying insects have evolved along two quite different lines, but the similarity in their general structure, and in the structure of the wings themselves shows that both resulting groups are descendents of a common ancestral form, which form had all the features distinguishing the Pterygota from the Apterygota. The two lines of differentiation in the Pterygota have been established through the adoption of different mechanisms for moving the wings. Among modern insects, one pterygote group is represented only by the Odonata, the other includes the rest of the winged orders.

In the non-odonate insects there are few special wing muscles, the muscles that effect the movement of the wings being chiefly the longitudinal dorsal muscles of the terga, the tergo-sternal muscles, and a set of muscles that originally were muscles of the coxæ. The tergal and the tergo-sternal muscles move the wings indirectly by the production of alternating changes in the shape of the thorax; the other muscles are more closely connected with the wings in the adult, but, being leg muscles in origin, they also are not primary wing muscles. It thus appears that when wings were developed and first became mobile appendages, they were moved by muscles already present in the segments bearing them. Only a few special wing muscles have since been acquired by most insects. In the Odonata, however, the wings are moved entirely by muscles inserted directly on the wing bases, and it is impossible to trace any homology between these muscles and the wing muscles of other insects. According to Poletaiew (1881) the wing muscles of the dragonflies are formed and developed during the nymphal stages of these insects. The wing mechanism of the Odonata, therefore, must be one secondarily acquired through the development of special wing muscles, which have supplanted the primitive musculature of the wing-bearing segments. For this reason, the following descriptions of the structure of a typical wing-bearing segment will be based on that of the mesothorax and metathorax of non-odonate insects.

GROUND-PLAN OF A WING-BEARING SEGMENT

Though the general structure of the thorax was determined through the specialization of this region of the body as the locomotor center of the insect, and through the transformation of the subcoxæ into chitinous pleura, probably long before the wings appeared, the special features of the thoracic segments in winged insects have undoubtedly been evolved as characters correlated with the development of the wings.

The paleontological history of insects shows that lateral tergal lobes were present on the prothorax of many of the earliest known winged

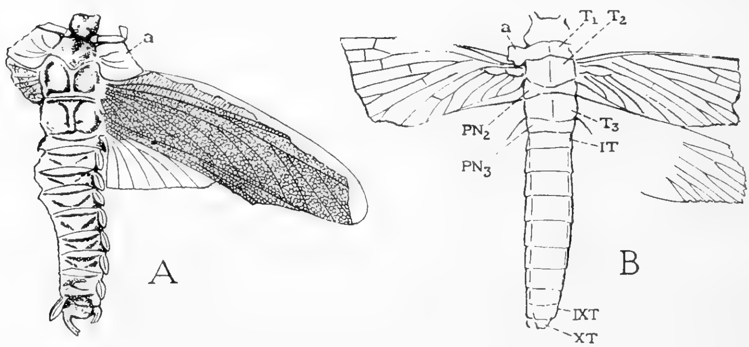

FIG. 19.—Carboniferous insects with tergal lobes on the prothorax (Palæodictyoptera).

A, *Stenodictya lobata* Brong., with large lobes (*a*) on protergum. (Brongniart, 1890.) B, *Eubleptus danielsi* Handlr. (drawn from specimen No. 35576, labeled holotype, in U. S. Nat. Mus.), showing small protergal lobe (*a*), well-developed postnotal plates (PN_2, PN_3) in mesothorax and metathorax, and ten abdominal segments.

species (fig. 19) ; but there is no fossil insect known from the geological period, probably the Silurian, when the wings were in the course of development. There can be little doubt, however, that the wings were evolved from lateral lobes of the dorsum in the mesothorax and metathorax. We can only speculate as to what service these lobes were to insects during their early stages of evolution. The most popular explanation is that they were gills, and that the tracheæ, which mark later the courses of the wing veins, penetrated the lobes first for respiratory purposes. This theory implies that the ancestors of winged insects passed through an aquatic period in their evolution after having acquired a tracheal system during a previous period when they dwelt on land. Osborn (1905), in proposing this explanation of the origin of insect wings, suggests that insects lived in the water during the Silurian age, and that the aquatic progenitors of the Pterygota were themselves descendents of primitive terrestrial tracheates of Ordovician times. This theory of the origin of insect wings is pretty safe from destructive criticism, but for the same reason little direct evidence can be shown in its favor. Bats and flying squirrels have not needed a baptism for the acquisition of wings, but their wings do not contain tracheæ. On the other hand, it is perhaps not certain that, phylogenetically, the veins of insect wings were preceded by the tracheæ. The Silurian insects, known only as the necessary ancestors of post-Silurian insects, do not attest an adaptation to life in the water in any of their descendents. If they were aquatic, they have left no direct descendents; and existing insects bear no stamp of an aquatic ancestry. The abdominal gill lobes of nymphs of Ephemerida, often cited as possible homologues of the hypothetical thoracic gill lobes from which the wings might be supposed to have developed, have been shown by Dürken (1907), from a study of their musculature, to have nothing in common with the wings. The oldest known insects are distinctly terrestrial, and they likewise give no evidence of a recent emergence from a water environment, except as adults from aquatic nymphs. For a more complete discussion of the arguments that have been made in favor of a gill origin of the wings, and of the facts indicating their paranotal origin, the student is referred to the paper by Crampton (1916) on this subject, in which will be found also a long bibliography.

If the gill theory of wing origin in insects is found eventually unacceptable in any form, it should not be hard to believe that the wing lobes in earlier stages enabled their possessors to glide through the air from elevated situations, and that the lobes were thus organs of sufficient importance to demand a considerable degree of reconstruction in the pleura, or subcoxal chitinizations, of the segments bearing them. There is no evidence that prothoracic lobes were ever developed into wing-like or even movable appendages, and there is no proof that they were present in the true ancestors of winged insects, or that the wing lobes are their homologues in any case. Yet, considering the essential identity of structure between the prothoracic pleuron and the pleura of the wing-bearing segments, it becomes evident that all the thoracic pleura must owe their specialized form to some common guiding influence, and that this influence must have determined the basic structure of the pterygote thoracic pleuron before the dorsal lobes of the mesothorax and the metathorax evolved into true wings. A reasonable postulate, therefore, is that the determining factor of the pleural structure in the thorax was the presence of potential wing lobes on each of the thoracic segments.

Carpentier (1921), in his study of the pleura of wingless Orthoptera, shows that the pleuron of the prothorax is identical in structure with the pleura of the other two thoracic segments, a condition suggestive of the former presence of wings on the prothorax, though

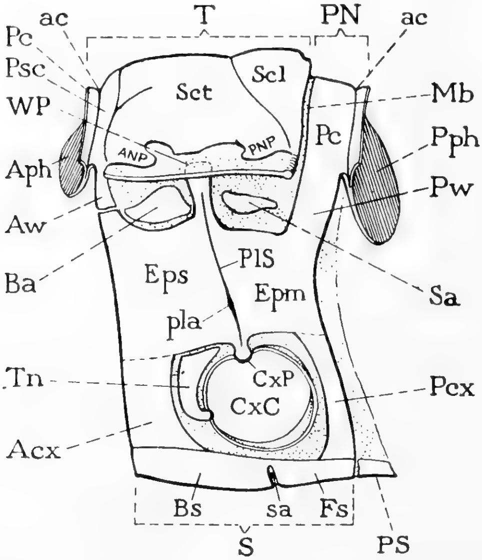

Fig. 20.—Diagrammatic structure of a wing-bearing segment with a phragma attached to each end; wing cut off at base; coxa removed.

ac, antecostal suture; *Acx*, precoxal bridge; *ANP*, anterior notal wing process; *Aph*, anterior phragma; *Aw*, prealar process, or bridge; *Ba*, basalare, episternal epipleurite; *Bs*, basisternum; *CxC*, coxal cavity; *CxP*, pleural coxal process; *Epm*, epimeron; *Eps*, episternum; *Fs*, furcisternum; *Mb*, remnant of intersegmental membrane; *Pc*, precosta; *Pcx*, postcoxal bridge; *pla*, external root of pleural apophysis; *PlS*, pleural suture; *PN*, postnotum (postscutellum); *PNP*, posterior notal wing process; *Pph*, posterior phragma; *PS*, poststernum; *Psc*, prescutum; *Pw*, postalar bridge; *S*, sternum; *Sa*, subalare, epimeral epipleurite; *sa*, external root of sternal apophysis; *Scl*, scutellum; *Sct*, scutum; *Tn*, trochantin; *WP*, pleural wing process.

Carpentier does not commit himself to this conclusion. The mental picture of a pair of fully-developed wings on each of three consecutive segments, however, is not convincing as a mechanical reality; but the degree of development in the prothoracic pleura may be taken to mean that the paranotal lobes of the prothorax once reached a stage of development in which they, as well as those of the mesothorax and metathorax, required the support of the pleura. Beyond this stage, the lobes of the second and third segments were evolved into freely movable wings, while those of the prothorax degenerated and were lost. In harmony with this view is the difference in structure between the tergum of the prothorax and that of a wing-bearing segment, and the differences in the segmental musculature. As the skeletal parts of the mesothorax and metathorax responded to the demand for mobility in the tergal lobes, the segmental muscles capable of moving the latter were developed accordingly.

The general structure of a wing-bearing segment is shown diagrammatically in figure 20. The dorsum of the segment may be occupied only by the true tergal plate *(T)*, or *notum*, as the tergum of a thoracic segment is often called; but the segment in which the wings are best developed usually has also a second smaller plate, the *postnotum (PN)*, lying immediately behind its true tergum. On the sides of the segment are the usual pleural plates of pterygote insects, the episternum (*Eps*) and epimeron (*Epm*), separated by the pleural suture *(Pls)*. At the upper end of the latter the dorsal edge of the pleuron is produced into a special *pleural wing process* (*WP*), which forms a fulcrum against the wing base. The tergum is often supported on the pleura by arms extending from its anterior lateral angles to the corresponding dorsal angles of the episterna, each arm constituting a *prealar bridge (Aw)*. The postnotum, when present, is generally connected likewise by lateral extensions with the epimera, each extension forming a *postalar bridge (Pw)*. Between the wing base and the upper edge of the pleuron there is an ample membrane in which are situated several small epipleural plates *(Ba, Sa)*. The ventral parts have no distinctive features in the wing-bearing segments and have been sufficiently treated in the description of the fundamental structure of the thoracic sterna (page 17). The details of the wing-bearing tergum, and certain features of the pleuron, however, need a more extensive special examination.

STRUCTURE OF A WING-BEARING TERGUM

The tergum of a wing-bearing segment preserves in its basic structure the elemental composition of the tergal plate in any segment where secondary segmentation has been established (fig. 2 B, C). It includes the intersegmental antecostal ridge preceding (fig. 21 B, *Ac*), and a precosta (A, B, *Pc*) demarked externally by the antecostal suture (A, *ac*). Its posterior edge is reflected ventrally in a marginal fold, or posterior reduplication (B, *Rd*). Between the tergum and the following precosta there is a transverse membranous area (fig. 23 B, *Mb*), functionally intersegmental, but which is morphologically the posterior part of the segment. Only in larval insects is the primary body segmentation (fig. 23 A) found in the thorax, and even here the union of the primitive terga with the chitinized intersegmental fold may establish a typical secondary segmentation. In the larva of *Scarites* (fig. 25), the fold between the protergum and the mesotergum is chitinized and united with the latter, forming thus an antecosta of the mesotergum. From the antecosta of each of the wing-bearing segments, and from that of the first abdominal segment there is usually developed a pair of thin chitinous lobes, the two constituting a *phragma* (fig. 21, *Ph*), which projects into the cavity

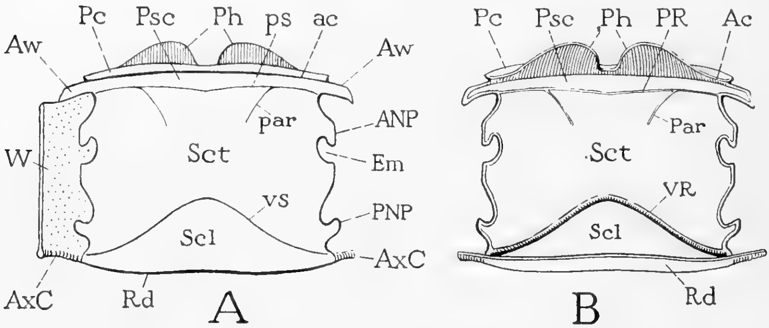

FIG. 21.—Diagrammatic structure of a wing-bearing tergum, not including a postnotum.

A, dorsal; B, ventral. *Ac,* antecosta; *ac,* antecostal suture; *ANP,* anterior notal wing process; *AxC,* axillary cord; *Aw,* prealar process; *Em,* lateral emargination of tergum; *Par,* parapsidal ridge; *par,* parapsidal suture; *Pc,* precosta; *Ph,* phragma; *PNP,* posterior notal wing process; *PR,* ridge between prescutum and scutum; *ps,* prescuto-scutal suture; *Psc,* prescutum; *Rd,* posterior reduplication of tergum; *Scl,* scutellum; *Sct,* scutum; *VR,* ridge between scutum and scutellum; *vs,* scuto-scutellar suture; *W,* base of wing.

of the thorax and furnishes an increased surface for the attachment of the dorsal longitudinal muscles.

The wings are hollow outgrowths from the lateral parts of the dorsum in each segment, between the prealar bridges and the posterior edge of the tergum (fig. 21 A, *W*). The posterior margins of the wings, therefore, are direct continuations from the posterior fold *(Rd)* of the tergum. The dorsal wall of each wing is continuous with the lateral margin of the tergum, the ventral wall is reflected into the pleural subalar membrane. The wings become movable by the membranization of their bases. The lateral edges of the adult tergum are produced into small lobes to support the dorsal articular elements of the wings; generally there are two lobes on each side, an *anterior* *notal wing process* (fig. 21, *ANP*), and a *posterior notal wing process (PNP),* though the latter is frequently lacking. Behind the first wing process there is a deep *lateral emargination* of the tergum *(Em).*

The surface of the wing-bearing tergum is differentiated into several areas, some being limited by the sutures of internal ridges, others being merely topographical in nature. The internal ridges are, therefore, the features of greatest importance in a study of the tergum. The most constant apodemal ridge has the form of an inverted *V* (fig. 21 B, *VR*), the arms of which arise near the posterior angles of the tergum and converge forward, the apex being usually behind the center of the tergum. This apodeme, which may be designated the *V-ridge,* forms a strong brace in the posterior part of the tergal plate, and sets off a posterior area of the tergum called the *scutellum (Scl).* All the muscles of the tergum arise upon the prescutellar area. The rear margin of the scutellum is deflected in the posterior reduplication *(Rd),* and its ends are prolonged in the axillary cords of the wings (*AxC*).

On the anterior part of the tergum, behind the antecostal suture (*ac*), there is often differentiated a narrow transverse strip, called the *prescutum* (fig. 21, *Psc*). The area is sometimes limited by a distinct suture (A, *ps*), with a corresponding internal ridge (B, *PR*), but the prescutum is seldom as definitely marked as the scutellum, and its separation from the rest of the tergum may be faint or obsolete. Anteriorly the prescutum is deflected into the antecostal suture (A, *ac*) over the base of the phragma *(Ph),* beyond which is the precosta *(Pc),* or anterior lip of the phragma base, always narrow, sometimes scarcely perceptible, except when enlarged to form a postnotum of the preceding segment (figs. 22, 23). Laterally, the prescutum ends in the prealar bridges (fig. 21 A, *Aw*), if such processes are present.

The application of the term "prescutum" as given here follows the evident intent of Audouin (1824), who defines the "praescutum" as "la pièce la plus antériure," and adds that "elle est quelquefois très grande et cachée ordinairement en tout ou en partie dans l'interieur du thorax." This is the part, however, called "acrotergite" by Berlese, and "pretergite" by Crampton (1919). As will be shown later, the triangular area of the tergum in some insects, usually regarded as a part of the prescutum ("protergite" of Berlese), is apparently a part of the scutum.

The area of the tergum between the prescutum and the scutellum is the *scutum (Sct).* The topography of the scutum is variable; its surface is often cut by sutures which arise from the secondary development of ridges on its under surface. The most important of these ridges are two known as the *parapsides* (fig. 21 B, *Par*), which arise laterally from the prescuto-scutal suture and converge posteriorly a varying distance in the scutum. The lateral margins of the scutum bear the anterior and the posterior wing processes *(ANP, PNP),* and are notched just behind the former by the lateral emarginations *(Em).* The wings *(W)* are extensions from the scutum and scutellum, their posterior, thickened edges (the axillary cords) being continued from the narrowed ends of the scutellum.

THE POSTNOTAL PLATES

Though the terga of the wing-bearing segments have acquired no new elements to enable them to play their parts in the wing mechanism, they have, however, in most cases lost the simplicity of segmental plates through a redistribution of some of the primitive elements. A primitive dorsal plate, bearing the wings and preserving the structure of a typical tergum, with an antecosta or phragma at the anterior end, occurs in the mesothorax and metathorax of Isoptera, and in the mesothorax of Orthoptera, Euplexoptera, and Coleoptera. In nearly all other instances, the dorsum of a winged segment contains two plates (fig. 22A), the first being the true tergum, or notum *(T),* the second the postnotum (*PN*). The postnotum occurs in typical form only in the adult insect; it consists of the greatly enlarged precosta, together with the antecosta and phragma, of the following tergum usually more or less separated from the latter and closely associated with the preceding tergum. The altered relation in the tergal parts of the wing segments is probably the result of a secondary modification, for, as we shall see, it constitutes a structure correlated with efficiency of wing motion. Presumably all the thoracic terga of the wingless ancestors of the Pterygota had the usual form of segmental plates (fig. 5), still retained in those of the Apterygota.

The nature of the redistribution of the tergal parts in segments having a postnotum is explained diagrammatically in figure 23. At A is shown the original primary segmentation, with the dorsal muscles (*LMcl*) attached to the intersegmental folds. In B the folds are chitinized to form antecostæ *(Ac),* each with a small precosta *(Pc)* before it. The posterior membranous parts of the segments *(Mb)* now become the flexible "intersegmental" regions, and the segmentation is typically secondary. Let us suppose that the dorsal plates (C, T_1–*IT*) are the terga of segments from the prothoracic to the first abdominal, inclusive, and that each antecosta has a phragma

(1Ph, 2Ph, 3Ph) bearing the muscle attachments. At C, a condition is given in which the antecosta of the first abdominal tergum *(IT)*, with its phragma *(3Ph)* and the precosta are separated from the principal part of the abdominal tergum and are more closely connected with the tergum of the metathorax *(T_3)*. The abdominal precosta and antecosta, or the base of the phragma, here constitute, then,

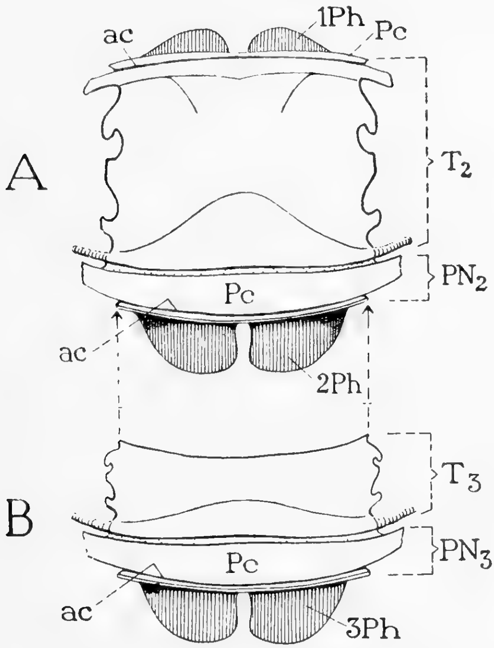

Fig. 22.—Diagram of wing-bearing terga with postnotal plates.

A, tergal plates of mesothorax; B, tergal plates of metathorax. Each postnotum (*PN_2*, *PN_3*) consists of precosta (*Pc*) and narrow postcostal piece detached from following tergum, with a phragma (*Ph*) developed from the antecostal ridge, the base of which is marked externally by the primarily intersegmental antecostal suture (*ac*).

the postnotum *(PN_3)* of the metathorax. The latter segment is now provided with two phragmata, an anterior phragma *(2Ph)*, and a posterior phragma *(3Ph)*, and its dorsal muscles become segmental instead of intersegmental. The relations between the mesothorax and the metathorax are here (C) of the normal type. The condition represented is characteristic of the Orthoptera, Euplexoptera, and Coleoptera, though in the first two orders the postnotum of the metathorax usually retains its connection with the first abdominal tergum.

In most other insects a postnotum is present in each of the wing-bearing segments, as given at D of the figure. In this case the mesothorax is provided with an anterior phragma *(1Ph)* and a posterior phragma *(2Ph)*, while the metathorax has only a posterior phragma *(3Ph)*. The first phragma *(1Ph)* is never transferred to the protergum. If the base of the middle phragma *(2Ph)* retains its connection also with the metatergum, the mesotergum and metatergum

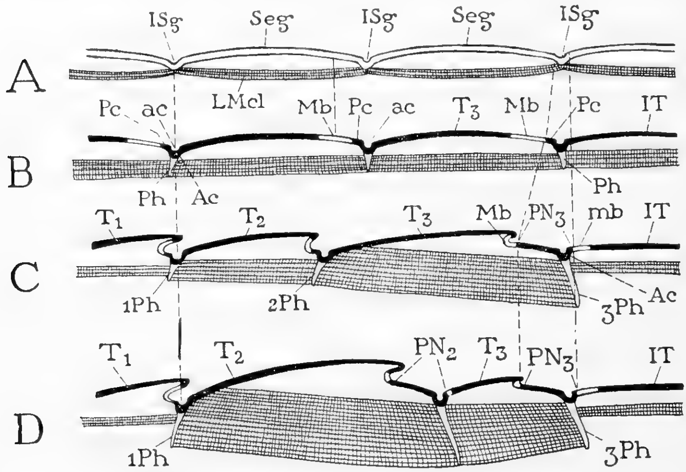

FIG. 23.—Diagrammatic lengthwise sections showing the nature of the phragmata and the thoracic postnotal plates.

A, primary segmentation in non-chitinous segments (*Seg*), with longitudinal muscles (*LMcl*) attached at intersegmental rings (*Isg*).
B, secondary segmentation: each tergal plate (*T*) including the chitinized antecosta (*Ac*) and narrow precosta (*Pc*); antecostæ bearing phragmata (*Ph*); the antecostal sutures (*ac*) are the original intersegmental grooves (A, *Isg*).
C, thorax with metathoracic wings chief organs of flight: third phragma (*3Ph*) separated from first abdominal tergum (*IT*) by secondary membrane (*mb*), and its precosta (B, *Pc*) enlarged to form the pre-phragma part in a postnotal plate (PN_3) of metathorax.
D, thorax with mesothoracic wings chief organs of flight: each wing-bearing segment with a postnotal plate (PN_2, PN_3) and a posterior phragma; the postnotal plates prevent telescoping of the segments (fig. 2 C).

are said to be "fused." Comparing C and D with A in figure 23, it is clear that the part of postnotal plate before the phragma belongs to the posterior part of the primary segment in which it occurs, and that only the narrow posterior lip of the phragma base has come from the following segment. It is thus true, as Berlese (1909) has shown, that the postnotum of a winged segment is the "acrotergite" of the tergum following.

The variation in the connections of the phragmata is correlated with the specialization of one pair of wings or the other as the chief organs of flight. If flight devolves principally upon the hind wings, as it does in the Orthoptera, Euplexoptera, and Coleoptera, the second phragma, is attached to the anterior part of the metatergum, and the third phragma, though it may not be separated from the first abdominal tergum, becomes functionally a part of the metatergum through the forward extension of its precosta as a postnotal plate of the metathorax. Where the fore wings are the most highly developed for flight, as they are in the majority of insects, the second phragma goes to the mesotergum. In other words, the segment containing the largest wing muscles has a phragma at each end, an arrangement which concentrates the force of the muscles upon the tergum of this one segment.

The postnotal plates are probably contemporaneous in their origin with the acquisition of motion by the wings. They are well developed in the oldest known fossil insects; in the Palaeodictyoptera there is a large postnotum behind each of the wing-bearing terga (fig. 19 B, PN_2, PN_3). The statement by Handlirsch (1908) that there are eleven abdominal segments in this group appears to be the result of counting the postnotum of the metathorax as the first abdominal tergum. In the Isoptera postnotal plates are lacking, but this condition is here correlated with the degeneration of the dorsal thoracic muscles and the weak nature of the termite flight. Postnotal plates are present in the Ephemerida and Odonata, though in the latter also the dorsal muscles have been lost.

It is not difficult to see a reason for the development of postnotal plates in wing-bearing segments. Where the primitive tergal plates are separated by membranous areas of the posterior parts of the segments (fig. 2 B, 23 B, *Mb*), a contraction of the dorsal muscles causes an overlapping of the terga (fig. 2 C), a result which must be counteracted if the muscles are to produce motion in the wings. The intersegmental membranes, therefore, must be reduced or obliterated, and their suppression has been accomplished in most cases by a forward extension of the precostal margins (fig. 23 C, D) until the resulting postnotal plate and the tergum in each segment form an uninterrupted arch between consecutive phragmata. The force of the muscle contraction is now expended against the tergal arch, with the result that its upward flexion gives a down-stroke to the wings. Thus, also, the longitudinal dorsal muscles become antagonists to the tergo-sternal muscles, if the latter muscles previously existed, or they call for the development of such muscles, which then become elevators of the wings.

MODIFICATIONS OF THE WING-BEARING TERGA

The structural variations in the terga of the mesothorax and metathorax of winged insects have furnished a problem that has caused much vexation to those who would like to have the parts of the terga in all insects conform with one simple plan of organization. The tergal parts probably do represent one plan of structure, but they do not always agree with the usual system of nomenclature applied to them. The trouble is that the fundamental structure, easily recognized in some cases, is so obscured in others that parts which appear to be the same in different insects are really not so.

The wing-bearing tergum, as we have seen (fig. 21), has an antecosta (B, *Ac*) on its front margin bearing a phragma (*Ph*), the base of which is marked externally by the antecostal suture (A, *ac*). The precosta (*Pc*), or anterior lip of the phragma base, before the mesothoracic tergum is but a narrow strip, often indistinguishable; that before the metatergum, however, is enlarged to form a postnotal plate of the mesothorax if the fore wings are chiefly functional in flight, and the precosta of the first abdominal tergum becomes usually a postnotal plate of the metathorax. Behind the antecostal suture in a tergum that retains the precosta and phragma preceding, there is usually differentiated a narrow prescutum (*Psc*) ending laterally in the prealar bridges or other lobes before the bases of the wings. A triangular scutellum (*Scl*) is set off on the posterior part of the tergum by the suture of the V-ridge (*vs* or *VR*), and the part of the tergum between the prescutum and the scutellum is the scutum (*Sct*). The difficulties encountered in the study of the wing-bearing terga of different insects arise from the obscuring of these landmarks, either through a partial or complete suppression of the marks themselves, or from their being subordinated to characters of secondary development.

The prescutum occurs in typical form in most of the Orthoptera, where it consists of a narrow transverse area of the anterior part of the tergum (fig. 24 B, C, *Psc*), ending laterally in the prealar processes, and usually expanded at the antero-lateral angles of the scutum. In *Blatta* the prescutum is separated from the scutum by a faint suture and internal ridge; in the Acrididae (fig. 24 C) it is demarked rather by the line of declivity at the anterior margin of the scutum; in *Gryllus* (B) it is scarcely distinct from the scutum medially. In Lepidoptera there is usually a small triangular prescutal plate in the mesothorax (G, *Psc*) set into a notch in the anterior border of the scutum. In the metathorax of Coleoptera the prescutum reaches its highest development (H, *Psc*), its median part being here often expanded posteriorly until it almost meets the apex of the scutellum (*Scl*). In Tipulidæ (D) and Tenthredinidæ (I), the prescutum is reduced to a narrow band (*Psc*) surrounding the convex anterior margin of the scutum, and extending backward on the sides to the bases of the wings. In some cases,

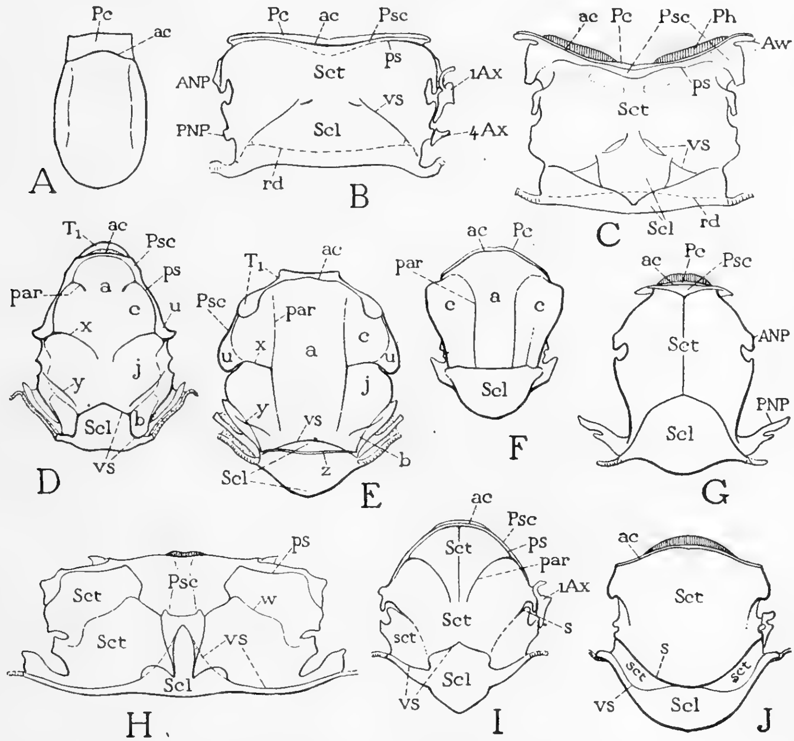

FIG. 24.—Modifications of the wing-bearing tergum.

A, mesotergum of *Japyx*, consisting of a simple segmental plate with a large precosta (*Pc*) separated by an antecostal suture (*ac*). B, metatergum of *Gryllus assimilis*, area behind antecostal suture (*ac*) partially divided into prescutum (*Psc*), scutum (*Sct*), and scutellum (*Scl*). C, mesotergum of *Melanoplus femur-rubrum*. D, mesotergum of *Holorusia rubiginosa;* prescutum (*Psc*) a narrow band terminating on each side in prealar lobe (*u*); scutum marked by three pairs of sutures (*par, x, y*); *a, c, j, b,* attachments of tergal muscles (fig. 34 D, *A, C, J, B*). E, mesotergum of *Tabanus atratus:* prescutum (*Psc*) fused medially with scutum; parapsidal sutures (*par*) extended posteriorly; scutellum divided by secondary groove (*z*). F, mesotergum of *Cynips:* prescutum and scutum fused; parapsidal sutures cut the scutum lengthwise into three parts (*c, a, c*). G, mesotergum of *Phassus argentiferus.* H, metatergum of *Calosoma scrutator:* scutum divided medially by approximation of prescutum and scutellum, and each half divided by suture (*w*) into anterior and posterior part (*Sct, Sct*). I, mesotergum of *Pteronidea ribesi:* prescutum (*Psc*) very narrow; parapsidal sutures (*par*) of scutum convergent; scutum cut by lateral sutures (*s*). J, mesotergum of *Apis mellifica:* prescutum and scutum united; scutum divided by secondary suture (*s*) into three parts (*Sct, sct, sct*).

even in segments having an anterior phragma, the prescutum entirely loses its individuality, as in the cicada and in the higher Hymenoptera (fig. 24 F, J). In the higher Diptera, remnants of the prescutum are distinguishable at the sides of the scutum (E, *Psc*) terminating in prealar lobes (*u*) corresponding with those of the Tipulidæ (D), but anteriorly the prescutum is not discernible in those Diptera in which the protergum (E, T_1) is fused with the mesotergum.

A prescutum is generally lacking as a defined area in metathoracic terga that have parted with the middle phragma (fig. 22, T_3), but this condition probably does not mean necessarily that the entire prescutal region has become detached with the phragma.

The separation of the scutellum from the scutum by the V-ridge and its suture is usually a very distinct one (fig. 24 D-J), but in some groups the boundary between these two areas of the tergum also is difficult to determine. In Blattidæ, the scutellum is of typical form, though its median part extends forward in a long narrow triangle almost to the prescutum. In *Gryllus* (fig. 24 B) the lateral arms of the V-ridge do not meet, and the scutum and scutellum are continuous medially. In Acrididæ, the V-ridge (C, *vs*) is interrupted by another ridge of similar shape but turned in the opposite direction. The arms of this second ridge, converging medially and posteriorly, bound the posterior margins of the shield-shaped elevation of the scutellum *(Scl)* that lies between the bases of the folded wings. A similar condition exists in the mesotergum of Hemiptera and Coleoptera. In the higher Diptera, the position of the V-ridge is less noticeable externally (E, *vs*) than is the secondary suture *(z)* that forms a deep groove across the anterior end of the scutellum. In the Tenthredinidæ a pair of sutures extends inward and posteriorly from the lateral emarginations of the mesotergum (I, *s*), which sutures become a continuous cleft in some of the higher Hymenoptera (J, *s*) that cuts the tergum into two pieces, the second of which includes the scutellum *(Scl)* and the posterior lateral parts of the scutum *(sct, sct)*. Systematists, for convenience, usually designate this secondary suture as the division between scutum and scutellum, a disposition entirely wrong from a morphological standpoint.

While, then, in terga of simple construction, it is not difficult to identify homologous regions if the internal structure is examined, complications are encountered within some of the orders, especially in the scutum (fig. 24 D-J), which have led to widely different interpretations. The following considerations, however, suggest an explanation of these tergal modifications which gives a simplified conception of their nature, and which when logically carried out does not lead to conflicting results.

In the mesothorax of Tipulidæ, the tergal area between the prescutum (fig. 24, D, *Psc*) and the scutellum *(Scl)* is partially divided into several regions by pairs of oblique lateral sutures. The sutures constituting the first pair *(par)* extend inward and posteriorly a short distance from the lateral parts of the prescuto-scutal suture *(ps)*; those of the second pair *(x)* arise before the bases of the wings and converge posteriorly and medially; those of the third pair *(y)* go from the region of the wing base posteriorly and medially toward the median field of the scutellum. Each suture is the external line of a corresponding internal ridge, and the spaces between the ridges are areas of muscle attachments. The anterior ends of the dorsal longitudinal muscles are attached on the median area *(a)* between the first pair of ridges *(par)*. The tergo-sternal muscles (fig. 34 D, *C*) are attached laterally on the spaces *(c)* behind these ridges; the tergomeron muscles (fig. 34 D, *J*) are attached on the lateral areas *(j)* between the second and third ridges; and the tergo-phragma muscles (fig. 34 D, *B*) are attached behind the third ridges. These lateral tergal muscles in the Diptera all act as elevators of the wings.

The first pair of lateral tergal ridges in the Tipulidæ (fig. 24 D, *par*) are clearly the homologues of the so-called parapsides, or parapsidal ridges, of other insects (E, F, I, *par*), which are usually regarded as defining a median triangular posterior extension of the prescutum (the *protergite* of Berlese). It is here proposed, however, that the parapsides are merely secondary ridges of the scutum, and that the median area between them is, therefore, a part of the scutum. The ridges are correlated with the extension of the anterior ends of the dorsal longitudinal muscles on the tergum: as these muscles enlarge, their anterior bases encroach first upon the prescutum, then upon the scutum (fig. 29, *A, A*), and they may finally come to occupy almost the entire median field of the latter (fig. 34 D, *A, A*). In the higher Diptera, in which the median part of the prescutum and scutum are not distinct (fig. 24 E), the anterior ends of the parapsidal sutures *(par)* are obsolete; their posterior ends unite with the next pair of lateral sutures *(x)*. In Cynipidæ, the parapsidal sutures (F, *par*) extend backward to the scuto-scutellar suture and cut the scutum lengthwise into three areas *(c, a, c)*. In the mesothorax of Cicadidæ and Tenthredinidæ, the parapsidal sutures define an anterior median triangular area of the scutum; in the former (fig. 29), the prescutum is not distinct, but in the latter family it is present though very narrow (fig. 24 I, *Psc*). In the mesothorax of Lepidoptera the scutum is strengthened by a median ridge on its inner surface, forming a median suture externally (fig. 24 G).

The mechanism of the wing-bearing tergum and its functional evolution in connection with the wings have been well protrayed in recent papers by Weber (1924, 1925). The tergum must be so constructed that it will bend upward in response to the contraction of its dorsal longitudinal muscles, in order to give the down-stroke to the wings. The evident purpose of the parapsidal ridges, when present, and of the V-ridge, as Weber points out, is to conduct the flexion of the tergum in an even curve toward the middle from the two ends of the segment, for without these gradient braces the pull of the muscles would simply deflect the anterior and posterior parts of the tergal plate, in most cases. In the higher Hymenoptera, however, the tergum becomes strongly chitinized and rigid. Here flexibility is supplied by the development of a secondary suture, which cuts across

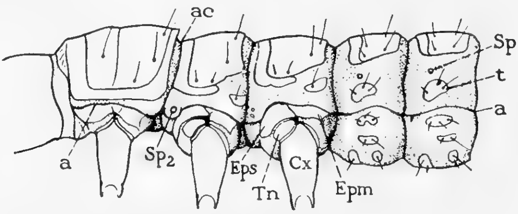

FIG. 25.—Thorax and base of abdomen of larva of *Scarites* (Carabidæ).

a, a, pleural fold; *ac,* antecostal suture of mesotergum; *Cx,* coxa; *Epm,* epimeron; *Eps,* episternum; *Sp,* spiracle; *t,* tergopleurites; *Tn,* trochantin.

the posterior part of the scutum (fig. 24 J, *s*) and divides the tergum into two pieces movable upon each other.

THE PLEURON OF A WINGED SEGMENT

The rôle of the pleuron in connection with flight is a more passive one than is that of the tergum, the chief function of the pleura in a wing-bearing segment being to support the bases of the wings and the tergal plates. The pleuron of a winged segment, therefore, shows fewer variations in relation to the wings than does the tergum, and the pleura of the mesothorax and metathorax do not differ in basic structure from the pleuron of the prothorax, though the actual difference may often be considerable on account of the degenerative tendency of the prothorax, and especially of the prothoracic pleuron.

The wing support of the pleuron of a winged segment consists of a short thick arm, the *pleural wing process* (fig. 20, *WP*), extending upward from the dorsal edge of the pleuron above the pleural suture

(PlS). It is braced internally by the upper end of the pleural ridge. The tergum does not always rest upon the pleura of its segment, but, when it does, the supports consist of the anterior lateral processes of the tergum that form the prealar bridges *(Aw)* to the episterna, and of the lateral extensions of the postnotum *(PN)* to the epimera that constitute the postalar bridges *(Pw)*. These props give effective resistance to the downward pull of the tergo-sternal and the tergo-coxal muscles.

The episternum and the epimeron (fig. 20, *Eps, Epm*) undergo numerous variations in form, and various subdivisions into secondary sclerites in the mesothorax and metathorax of the different winged orders, but their modifications are in general easy to follow, and are so well understood that they need not be reviewed here. The precoxal and postcoxal elements *(Acx, Pcx)* are usually well developed, though the second is generally the smaller, and may be absent. The trochantinal plate *(Tn)* is best developed in the more generalized Pterygota (figs. 13, 14, *Tn*), but shows always a tendency toward reduction, and is lost in the higher orders.

The small sclerites lying in the pleural membrane immediately beneath the base of the wing (fig. 20, *Ba, Sa*) serve in the adult as insertion points for two important muscles of the wings (figs. 28, 30 A, *E, F*). There are at most two of these sclerites above the episternum, and two above the epimeron, but more usually there is only a single plate in each position, one before the pleural wing process, the other behind it. Many entomologists, supposedly following Audouin (1824), have called the episternal sclerite the "parapteron," and Audouin says of the plate that he defines by this name, "elle a des rapports avec l'episternum et avec l'aile, toujours elle s'appuie sur l'episternum, se prolonge quelquefois inferieurment le long de son bord antérieure, ou bien, devenant libre, passe au devant de l'aile, et se place même accidentellment au-dessus." It is possible, therefore, that Audouin in some cases confused the plate ordinarily beneath the wing with the tegula, though of his "paraptere" he says, "toujours elle s'appuie sur l'episternum." Crampton (1914), however, claiming that Audouin first applied the term "parapteron" to the tegula, designates the episternal plates the *basalares* (*Ba*), and the epimeral plates the *subalares* (*Sa*). These terms commemd themselves because they carry specific distinction, though all the plates are subalar in position. Voss (1905) and other German writers call the sclerites the "pleural hinge plates" (Pleuralgelenkplatten), but they are not true articular elements of the wing base. Collectively, we may call the plates the epipleurites.

The epipleurites are derived from the episternum and epimeron. In a young nymph of *Dissosteira* or *Gryllus,* the basalar and subalar muscles (fig. 26 B, *E, F,*) are attached directly to the upper edges of the pleuron, one before the pleural ridge, the other behind it, and it is only in the adult stage that the areas of attachment are separated as the basalar and subalar plates. In some adult insects, however, the basalare is not distinct from the episternum, or it appears as a lobe of the latter (fig. 14, *Ba*). The subalare is always an independent plate in adult insects, but it may be reduced to a small chitinous disc in the membrane beneath the wing.

In nymphal insects having the epipleural muscles attached above to the pleuron and below to the coxa, the muscles evidently function as

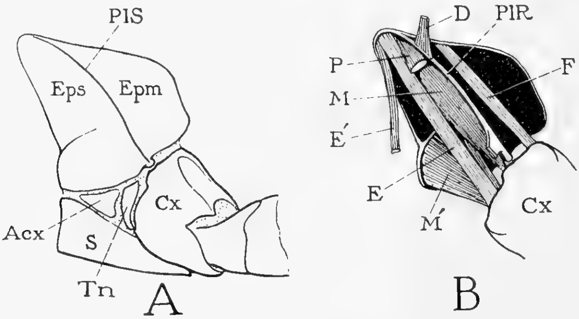

Fig. 26.—Mesopleuron and coxa of young nymph of *Gryllus assimilis.*

A, external view of left pleuron; B, internal view of right pleuron. *D,* base of muscle of third axillary; *E,* basalar muscle of coxa; *E′*, sternal branch of *E; F,* subalar muscle of coxa; *M, M′*, abductors of coxa; *P,* episternal branch of depressor muscle of trochanter.

leg muscles, though there is usually a branch of the basalar muscle to the sternum (fig. 26 B, *E′*). In the adult, the basalare is attached to the humeral angle of the wing base by a tendinous thickening of the cuticula (fig. 30 A, *a*), and the subalare is similarly connected (*b*) with the second axillary sclerite. In the adult winged insect, therefore, the epipleural muscles become muscles of the wing. In some of the higher insects, the coxal branch of the basalar muscle is lost, and the anterior branch alone remains, attached below to the sternum, or to the episternum. When a second subalar sclerite is present, it sometimes bears a small muscle arising upon the epimeron.

IV. THE WINGS AND THE MECHANISM OF FLIGHT

Morphologically, the insect wing is simply a flat, hollow outgrowth of the lateral marginal area of the dorsum that has become a motile appendage through the membranization of its basal part, and which has become movable in a definite manner through the close association of certain chitinous points in its base with special points on the edges of the tergum and pleuron of its segment. The wing is a secondary structure, acquired long after the legs were fully developed and the subcoxæ transformed into chitinous pluera. The first movements of the wings were made probably through successive alterations in the shape of the thorax produced by the contractions of body muscles already present; and insects in general have developed few muscles particularly for the movement of the wings. The Odonata stand alone among modern insects in having acquired special sets of wing muscles attached directly to the bases of the wings, which have completely replaced the older thoracic muscles. Since the dragonflies represent an ancient group of insects, it must be supposed that they developed their peculiar thoracic musculature during an early period of their history. According to Poletaiew (1881) the wing muscles of modern Odonata are formed in the individual during the postembryonic stages of growth and attain their definitive form only in the last nymphal instar.

GENERAL STRUCTURE OF THE WINGS

The insect wing is a flattened, double-layered expansion of the body wall, and, therefore, its own walls consist of the same elements as the body wall—cuticula, hypodermis, basement membrane—and its lumen contains tracheæ, nerves, and liquid of the body cavity.

Development of the wings.—Though the adult wing preserves the basic structure of the hollow immature wing pad, the progressive changes that take place within it during its growth so alter its tissues that the fully formed wing becomes practically a lifeless appendage serving as a propeller in the mechanism of flight. The histological details of the development of the wings, the formation of the wing tracheæ, and the relations of the tracheæ to the veins have been described by Weismann (1864), Gonin (1894), Mayer (1896), Comstock and Needham (1899), Mercer (1900), Tower (1903), Powell (1903), Marshall, (1915). The principal studies of the origin of the wing tracheæ from the trachea of the wing base are those of Chapman (1918), and Beck (1920).

The wings of insects with incomplete metamorphosis appear in the second or third nymphal instar as hollow, flattened outgrowths of the lateral parts of the dorsum in the mesothorax and metathorax, and they grow externally in the same manner as do the legs, mouth parts, or other appendicular organs of the body. In insects with complete metamorphosis the wings develop beneath the cuticula, usually in pouches of the hypodermis, their rudiments appearing first in different insects from a late embryonic period to the last larval stage. They are everted from the hypodermal pockets during the prepupal stage of the larva, and become exposed as external organs with the shedding of the last larval skin.

The relation between wing tracheæ and vein channels in wings that develop on the exterior of the body would appear to indicate that the positions of the veins are determined by the original courses of the tracheæ, and this consideration has given weight to the idea that the wings originated as gills. In the Holometabola, however, the vein channels are defined in advance of the growth of the tracheæ, and the latter, when formed, do not always enter veins corresponding with those they occupy in insects with incomplete metamorphosis. Development in the Holometabola, therefore, shows that veins may be laid down along definite lines in the wing without the guidance of tracheæ, and that the tracheal courses have no fixed relation to particular veins. The conditions met with in the Holometabola may easily be explained as secondary, but they allow us to question if tracheæ necessarily did determine vein formation or the vein positions in the phylogenetic development of the wings. Since the growing wing is a functionless organ in all insects, and follows a more or less aberrant course in its development, its ontogenetic stages are likely to have become adapted to the conditions of growth, and, for this reason, they cannot be taken as representative of the sequence of steps in the evolution of the wing. The veins may have originated independently as strengthening ribs in the primitive wing lobe, limiting to their channels, as the intervening areas became flattened, the courses of the tracheæ and the nerves penetrating the wing.

The adult wing.—The fully formed wing has the same fundamental structure in all insects, regardless of the method of development, or of the specialized form it attains in the imago. The wing of a roach developed externally arrives at the same structural pattern as that of a moth developed internally; the elytron of a beetle, the halter of a fly retain each the unmistakable features of a wing.

The typical wing of modern insects extends laterally from the edge of the dorsum where its base is articulated to the tergum above and to the wing process of the pleuron below. Its anterior margin arises behind the prealar bridge of the tergum, if this process is present (fig. 21A, *Aw*); its posterior margin is continuous with the posterior fold *(Rd)* of the tergum. The area of the wing is traversed by the *veins* and *cross-veins;* the thin intervening spaces, or *cells,* are occupied by the *membrane* of the wing. The wing base contains a number of small sclerites, the *axillaries,* or *pteralia* (fig. 27, *Ax*). At the base of the anterior margin of the wing there is usually a thickening, the *tegula (Tg),* commonly having the form of a small hairy pad, but sometimes developed into a large flat lobe overlapping the base of the wing. The rear margin of the basal membrane of the wing is generally corrugated and thickened, forming a posterior ligature of the wing, the *axillary cord (AxC).* The wing is held in

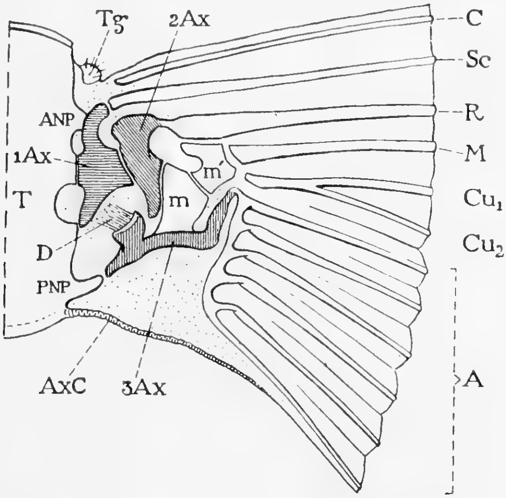

FIG. 27.—Diagrammatic structure of the wing base and its articulation with the tergum.

A, anal veins; *ANP,* anterior notal wing process; *1Ax,* first axillary; *2Ax,* second axillary; *3Ax,* third axillary; *AxC,* axillary cord; *C,* costa; Cu_1, first branch of cubitus; Cu_2, second branch of cubitus; *D,* flexor muscle of third axillary; *M,* media; *m, m',* median plates of wing base; *PNP,* posterior notal wing process; *R,* radius; *Sc,* subcosta; *T,* tergum; *Tg,* tegula.

various positions when at rest, but with most insects it can be flexed posteriorly against the sides of the body. When extended it is capable of a free up-and-down motion, and of a slight rotary motion on its long axis. The posterior part, or anal area, of the wing in some insects when flexed can also be folded or plicated along the lines of the veins. In two orders of insects the distal part of the wing can be variously folded.

The nomenclature of the wing veins given in figure 27 is that of Comstock and Needham, except that the vein ordinarily called "first anal" is represented as a proximal branch of the cubitus. (See Imms, 1924, fig. 28). A study of the wing base shows that this vein does not belong with the anal group attached to the third axillary, but that it is associated with, or attached to, the base of the cubitus. Its relation to the cubitus has been demonstrated by Tillyard (1919), who designates it the second branch of cubitus, and by Karny (1925), who calls it the "cubital sector." In the adult insect, the first vein of the wing, the *costa (C),* when present, usually lies in the anterior margin of the wing. The second vein, the *subcosta (Sc)* is associated at its base with the head of the first axillary sclerite *(1Ax).* The third vein, *media (M),* is usually associated with one or two small *median sclerites* (*m, m'*) of the wing base. The fourth vein, the *cubitus (Cu)* has no particular basal connections. The following veins, the *anals (A)* are definitely attached to the third axillary *(3Ax)* or to an arm of the latter.

The axillary plates of the wing base play an important part in the mechanism of the wing, for they not only serve to attach the wing to the body, but they determine the effect of the muscles that act upon the base of the wing. Three of these sclerites are almost always present, and have definite relations to one another, to the bases of the veins, and to the adjoining parts of the thorax. The first one, the *first axillary,* or *notopterale,* (fig. 27, *1Ax*), is a flat sclerite of the dorsal membrane of the wing base, and is possibly to be regarded as a tergal chitinization. It is hinged by its inner margin to the edge of the tergum, and has its anterior part supported by the anterior notal wing process *(ANP).* Its anterior extremity is usually more or less closely associated with the base of the subcostal vein *(Sc).* By its outer margin it articulates along an oblique line with the second axillary. The *second axillary,* or *intraalare (2Ax),* has both a dorsal and a ventral surface in the wing base, and may be derived from the proximal end of the radial vein *(R),* with which it is continuous. By the inner oblique margin of its dorsal part it articulates with the outer edge of the first axillary. Its ventral plate (fig. 30 A, *c*) has a convex surface that rests upon the wing process of the pleuron when the wing is extended. A tendon-like connection *(b)* with the subalar sclerite *(Sa)* below it makes the second axillary the objective of the subalar muscle *(F)* of the coxa. The *third axillary,* or *basanale* (fig. 27, *3Ax*), though developed mostly in the dorsal membrane of the wing, has also a ventral surface. It articulates with the posterior notal wing process of the tergum *(PNP),* except when a fourth axillary is present. Its long axis is obliquely transverse, and a lobe on its anterior margin gives attachment to the principal flexor muscle of the wing (fig. 30, A, *D*). The bases of the anal veins are associated with the distal end of the third axillary. A *fourth axillary* is sometimes present (Orthoptera, Hemiptera, Hymenoptera), but it is always a small sclerite of the dorsal surface of the wing base, intervening between the inner end of the third axillary and the edge of the tergum (fig. 24 B, *4Ax*). It is perhaps a detached piece of the posterior notal wing process. Lying in the space between the second axillary, the distal part of the third axillary, and the bases of the median and cubital veins, there are usually two sclerites of less definite form which may be termed the *median plates* of the wing base (fig. 27, *m, m'*). These sclerites serve to connect the median field of the wing with the true axillaries.

THE WING MUSCLES AND THE MECHANISM OF WING MOTION

The mechanism of insect flight was carefully studied by entomologists in the early part of the last century. Noteworthy papers published on the subject at that time are those of Chabrier (1820-'22), Jurine (1820), and Straus-Dürckheim (1828). Chabrier's work, the first of any importance on the wing structure of insects, contains detailed descriptions of the skeletal anatomy of the thorax, the structure and articulation of the wings, and the muscles and mechanism of flight—an extensive piece of original investigation, remarkable for its accuracy and for the understanding shown by the author for his subject. Following a general account, there is given detailed descriptions of the entire wing mechanism in Coleoptera *(Melolontha)*, Odonata *(Aeschna)*, and Hymenoptera *(Bombus)*. Jurine's paper, which describes the wing mechanism of Hymenoptera, appeared after the first section of Chabrier's work was published. The great work of Straus-Durckheim (or Straus-Dürckheim, as his signature appears beneath the dedication to Cuvier), published under the title, "Considérationes générales sur l'anatomie compareé des animaux articulés," is devoted principally to a study of *Melolontha vulgaris*. It is one of the finest monographs ever written on insect anatomy, and is accompanied by figures unsurpassed in clarity of detail by any methods of modern illustration. The thorax, the wing muscles, and the mechanism of flight are given full attention. These early works, unfortunately, are somewhat difficult for present-day students to read, because their authors used mostly individual systems of nomenclature, none of which has been closely followed by later entomologists.

The modern study of the wing mechanism begins with Lendenfeld (1881) and Amans (1883,'84, 1884, 1885), though again the nomenclature of these writers has not been generally adopted. Lendenfeld details the wing structure and all parts concerned with the wing action in the Odonata; Amans gives a comprehensive comparative study of the wing mechanism in the principal orders of insects. Following these papers, accounts of the structure, musculature, and mechanics of the wings of various insects are contained in the works of Luks (1883), Janet (1899), Petri (1899), Voss (1905, 1912), Dürken (1907), Berlese (1909), Snodgrass (1909), Bauer (1910), Gröschel (1911), Stellwaag (1910, 1914), Crampton (1914), DuPorte (1920), Weber (1924, 1925). The nature of the wing movements in insects has been studied particularly by Marey (1869, 1869,'72), Lendenfeld (1903), Stellwaag (1910, 1914), and Voss (1913,'14).

The wing of most insects has four cardinal movements: *elevation, depression, flexion, extension.* In addition, the wing is capable of a slight *rotation* on its long axis. Elevation and depression are vertical movements effected primarily by the longitudinal and oblique tergal muscles, and the tergo-sternal muscles of the thorax, but the coxal muscle of the epimeron becomes a strong accessory depressor of the wing in the adult. The flexor of the wing is the muscle of the third axillary sclerite of the wing base; the extensors are chiefly the muscles of the basalar and subalar sclerites. The partial rotary movement of the wings may be a mechanical result of the wing structure and of the reaction of the wing surfaces to pressure of the air during flight, but probably it is controlled by the epipleural muscles.

The tergal and tergo-sternal muscles of the thorax that principally effect the elevation and depression of the wings are known as the *indirect wing muscles,* because they produce wing movements through causing alternating changes in the shape of the thorax. The depressors consist of the pair of great dorsal longitudinal muscles, typically stretched between the phragmata (fig. 28, *A*), but often so large that they encroach a varying distance upon the anterior part of the scutum (fig. 29, *A, A*). The oblique dorsals, extending laterally from the posterior part of the scutum to the posterior phragma (fig. 28, *B*), are probably accessory to the longitudinals in some cases, but in others their positions become so nearly perpendicular to the tergum (figs. 29, 34 D, *B*) that they must act as elevators of the wings. These muscles are of extraordinary size in the cicada (fig. 29, *B*). The usual elevators of the wings include always the pair of large vertical muscles in the anterior part of the thorax (figs. 28, 29, *C*), attached dorsally to the scutum laterad of the longitudinals, and ventrally to the basisternum anterior to the coxa, but other muscles are often accessory to these. As just noted, the oblique dorsals may be wing elevators. In the mesothorax of Diptera the remotor of the coxa, which arises dorsally on the scutum and is attached ventrally on the meron of the coxa, becomes a wing elevator through the transfer of the meron from the coxa to the wall of the segment (fig. 34 D, *J*).

The epipleural (basalar and subalar) coxal muscles, and the muscles of the third axillary constitute the *direct wing muscles*, so called because they act more immediately on the wing, though the epipleural

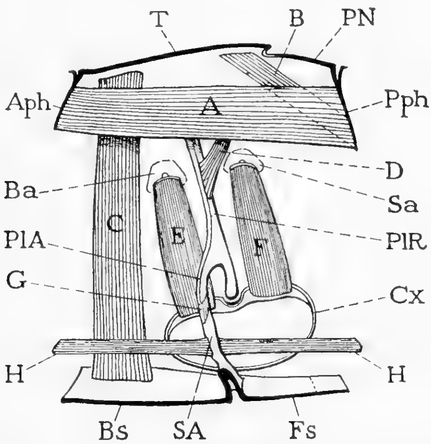

FIG. 28.—Diagram of the principal muscles of a wing-bearing thoracic segment, exclusive of the leg muscles, right side, internal view.

A, dorsal longitudinal muscle attached to successive phragmata, indirect wing depressor; *B,* oblique dorsal muscle from scutum to posterior phragma; *C,* tergosternal muscle from scutum to basisternum, indirect wing elevator; *D,* wing flexor of third axillary sclerite; *E,* basalar muscle of coxa, direct extensor of wing; *F,* subalar muscle of coxa, direct extensor and depressor of wing; *G,* pleuro-sternal muscle from pleural apophysis to sternal apophysis; *H,* longitudinal ventral muscles attached to sternal apophyses.

muscles are not inserted directly on the wing base, and, as we have seen, are primarily muscles of the leg. The basalar muscle (figs. 28, 30 A, *E*) arises ventrally on the lateral rim of the coxa *(Cx)* anterior to the pleural articulation; an anterior branch (fig. 30A, *E′*) may arise on the basisternum, on the precoxal bridge, or on the episternum. Since the basalar plate (fig. 30 A, *Ba*) or the corresponding basalar lobe of the episternum is connected with the anterior angle of the wing base by a ligament-like thickening of the uniting cuticula *(a),* its muscles have a direct functional relation with the anterior part of the wing base. The subalar muscle (figs. 28, 30 A, *F*) arises, in typical cases, from the coxal margin posterior to the pleural articulation, and the ligamentous connection (fig. 30 A, *b*) between the subalare *(Sa)* and the second axillary *(2Ax)* gives this muscle a functional relation to the median or posterior part of the wing base. The muscle of the third axillary (figs. 28, 30 A, *D*), often with several branches, arises from the pleural ridge or from neighboring parts of the pleuron, and goes obliquely dorsally and posteriorly to its insertion on the muscle process of the third axillary *(3Ax)*. In the Diptera there are two small muscles inserted on the first axillary, and in many insects there are various other small muscles associated with the wing base, but all of these muscles are of secondary importance and probably of a secondary origin.

It is difficult to demonstrate the action of the wing mechanism in a dead insect, but, allowing for much greater efficiency of the apparatus under the tension of living muscles, a pretty fair understanding of the various wing motions may be obtained from a study of freshly killed specimens. Take some large Diptera, for example (Syrphidæ, Muscoids). The wings of the dead fly are usually flexed. A lengthwise compression of the back of the mesothorax partly extends the wings and gives to each a downward motion accompanied by a strong deflection of the costal margin. A vertical compression of the thorax elevates the wings, and most strongly the costal margins. If a piece is cut out of the middle of the tergum, the wings no longer respond to pressure on the thorax in either direction, showing that the movements of the tergum, though slight, are sufficient to produce the wing motions. It is evident, too, that the nature of the wing articulation produces, in part at least, the compound character of the wing movements, but these movements are greatly accentuated by the action of other parts of the mechanism. The most decisive movement in the wing results from a downward pressure on the second axillary sclerite of the wing base, the wing being immediately extended, while the hind margin turns downward until the plane of the wing is almost vertical, with the costal margin uppermost. Complete extension of the wing in a horizontal plane results from pressure on the basalar plate or basalar lobe of the episternum. The wing of the freshly killed insect can thus be made to perform most of its movements by pressure on various parts of the thorax, and an understanding of the wing mechanism then becomes a matter of determining what muscles may produce the movements observed.

Since the Odonata, the Ephemerida, and the Palæodictyoptera do not flex the wings, the apparatus of elevation and depression by means of the indirect wing muscles was undoubtedly the first part of the wing mechanism to be developed by insects; but, in studying the movements of the wings of other insects, it will be most convenient to begin with those movements made in the horizontal plane, which are effected principally by the direct muscles.

The flexion of the wing is easiest to understand. When the wing, the hind wing of a grasshopper for example, is turned back toward the side of the body, the distal end of the third axillary (fig. 27, *3Ax*) turns upward, inward, and forward, carrying with it the anal area of the wing, which is folded and laid against the side of the abdomen. In life, the beginning of this action results probably from the natural

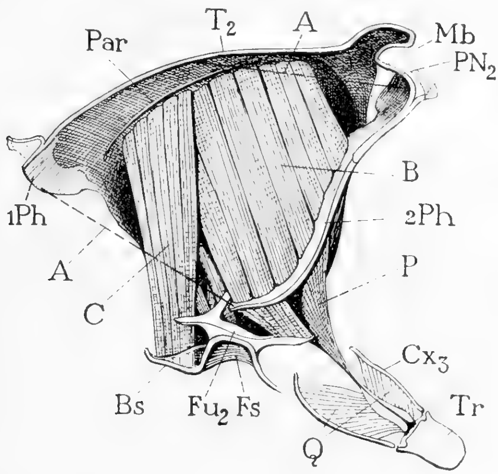

Fig. 29.—Muscles of right half of mesothorax of cicada (*Tibicina septendecim*), with metathoracic coxa.

A, A, position of longitudinal dorsal muscle; *B,* oblique dorsal muscle; *C,* tergo-sternal muscle; *P,* thoracic branch of depressor of trochanter of hind leg (*Tr*); *Q,* coxal part of depressor of trochanter.

elasticity of the wing base, which latter partially flexes when the muscles of extension are relaxed, but the contraction of the muscle of the third axillary undoubtedly completes the folding, and holds the wing tight against the body in its final position. The anterior part of the wing necessarily follows the anal area, but its movement is acclerated by the articular relations of the axillaries. The median plate *(m),* affected by the motion of the third axillary, pushes the second axillary *(2Ax)* medially and revolves it to a longitudinal position over the first axillary, as the latter *(1Ax)* turns vertically on its hinge with the tergum. By these multiple movements in the basal elements of the wing, the anterior veins overtake the anals and are folded above them against the side of the body. The flexion of the wing is simpler in wings with a small anal area, but is essentially the same in all insects.

In the Dermaptera and the Coleoptera the distal parts of the flexed wings are mechanically folded transversely in order that the wings may be concealed beneath the shorter elytra. The various types of this folding in the wings of Coleoptera have recently been described by Forbes (1926).

The positions of the axillaries relative to one another in the flexed wing are quite different from those which they have in the extended wing. The extension of the wing involves a restoration of the axillaries to a horizontal plane, in which the sclerites again assume their former relations. The key to the transposition from one state to the other is in the position of the second axillary. If this sclerite is forcibly depressed, all the axillaries go back to the horizontal plane, and the wing is necessarily spread. The depression of the second axillary is evidently accomplished by the contraction of the subalar muscle (fig. 30 A, *F*), since the subalar sclerite is closely connected with the ventral plate (*c*) of the second axillary. The epimeral muscle of the coxa (fig. 26 B, *F*), therefore, in the adult insect (fig. 30 A) becomes the *posterior extensor of the wing* (Ṣtraus-Dürckheim, Bauer). The final, complete extension of the wing is probably brought about by the contraction of the basalar muscles (fig. 30 A, *E, E'*), since the basalar sclerite, or corresponding lobe of the episternum, is in intimate connection with the anterior angle of the wing base. The basalar muscles are, therefore, the *anterior extensors of the wing*. Their function in this capacity, however, is sometimes difficult to demonstrate.

The wings in extension are ready to be acted upon by the indirect muscles of elevation and depression. These are principally the longitudinal and oblique dorsal muscles, and the vertical tergo-sternal muscles. The last (figs. 28, 29, 30 B, *C*), by contraction, flatten the arch of the tergum *(T)*, and the movement in the edges of the latter, bearing downward on the bases of the wings mesad of the pleural fulcra, gives the up-stroke to the distal parts of the wings (fig. 30 B). The longitudinal dorsal muscles (*A*) now act as antagonists to the verticals, since by their contraction they pull upon the two ends of the tergum and restore the curvature of the latter. The upward movement in the lateral tergal margins gives the down-stroke to the wings (fig. 30 D). The function of the oblique dorsal muscles (fig. 28, B) is not clear in all cases. Ordinarily these muscles appear to be accessory to the longitudinals; in the Diptera (fig. 34 D, *B*), however, they are clearly elevators of the wings, and in the cicada (fig. 29, *B*) their great size would indicate that they are the principal wing elevators.

The thoracic musculature of the Diptera is highly specialized in order to give power and efficiency to the wing movements, but at

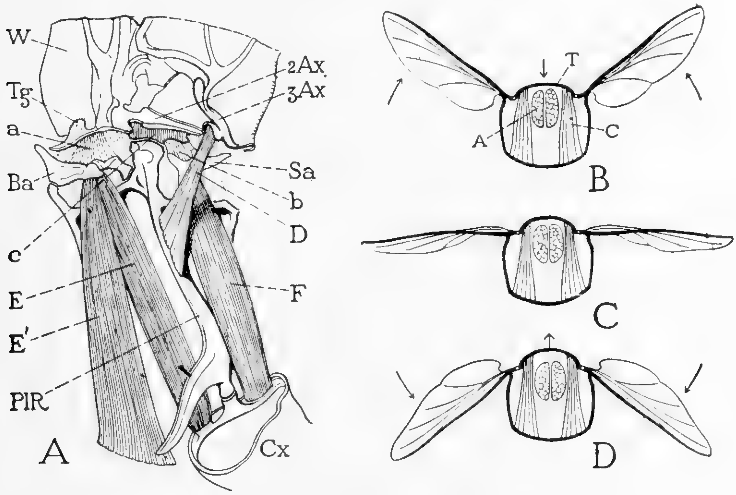

FIG. 30.—Mechanism of wing motion.

A, direct wing muscles of right fore wing and associated parts in a grasshopper (*Dissosteira*). *a*, tendinous thickening of cuticula uniting basalar sclerites (*Ba*) with anterior part of wing base; *2Ax*, second axillary; *3Ax*, third axillary; first and fourth axillaries removed; *b*, tendinous thickening of cuticula uniting subalar sclerite (*Sa*) with ventral plate (*c*) of second axillary; *Ba*, anterior basalare; *c*, ventral plate of second axillary; *Cx*, coxa of middle leg; *D*, muscle of third axillary, flexor of wing; *E*, basalar muscle to coxa, with branch (*E'*) to basisternum, extensor and deflexor muscles of wing; *F*, subalar muscle to coxa, extensor and depressor of wing; *PlR*, pleural ridge; *Sa*, subalare; *Tg*, tegula; *W*, base of fore wing, elevated.

B, C, D, diagrammatic illustration of action of indirect wing muscles in flight as seen in cross-section of thorax through bases of wings, anterior view. *A*, dorsal longitudinal muscles, attached to phragmata (see fig. 28); *C*, tergo-sternal muscles; *T*, tergum. The wings are elevated indirectly (B) by depression of tergum caused by contraction of tergo-sternal muscles; they are depressed (D) by elevation of tergum produced by contraction of longitudinal muscles.

the same time it is greatly simplified in comparison with that of an orthopteroid insect. In each side of the mesothorax there are three large, oblique dorsoventral muscles which serve as elevators of the wings (fig. 34 D). The first is the ordinary tergo-sternal muscle *(C)* attached below on the basisternum; the second *(J)* is the remotor of the coxa, attached below on the meron, which in the Diptera becomes a wing elevator through the transfer of the meron of the middle coxa (fig. 34 B, C, D, Mer_2) to the thoracic wall; the third (D, *B*) is the oblique dorsal muscle attached ventrally on the lateral extremity of the postnotum.

The tip of each vibrating wing describes a figure-8 curve, if the insect is held stationary, showing that the wing in motion undergoes alternating partial rotations on its long axis. Some writers have claimed that this movement results entirely from the pressure of the air on the wing surfaces as the wing vibrates, the flexible posterior margin of the wing being mechanically turned upward during the down-stroke, and downward during the up-stroke. The rotary motion of the wings, however, is necessary to give the forward movement to the insect in the air, and, as may be seen well in the wing of a fly, the nature of the wing articulation causes a deflection of the costal margin to accompany the down-stroke produced by the muscles of the tergum. In some insects, also, pressure at the anterior root of the wing base deflects the costal margin, and for this reason the basalar sclerite and its muscles have been termed the "pronator apparatus" of the wing (Amans). A strong posterior deflection of the wing accompanies pressure on the second axillary in Diptera, and it cannot be doubted, therefore, that in swiftly flying insects the muscle of the subalar sclerite, which pulls finally upon the second axillary, plays an important part in the posterior rotation of the wing during the up-stroke. The subalar muscle, therefore, would act as extensor, depressor, and rotator of the wing.

The mechanism for the control or modification of forward flight is not definitely known. Those who attempt to explain the tropistic reactions of insects usually assume a differential nervous regulation of the muscles on the two sides of the body; but this explanation could hardly apply to the indirect muscles of flight. It is probable, then, that the insect determines its course through the air by the control of its direct wing muscles, or by changing the slant of the body or the position of the legs, as suggested by Jousset de Bellesame (1879). Some insects are able to arrest their forward flight and suddenly reverse or go sidewise, without perceptibly changing the position of the body, and some are well known for their hovering powers. It is difficult to conceive how a wing structure and wing mechanism so clearly adapted to forward flight can also propel the insect backward or sidewise. The act of hovering on vibrating wings is explained by Straus-Dürckheim (1828) as accomplished through a continued contraction of the subalar muscles, thus checking the rotatory motion of the wings and preventing their forward drive. The lifting power, then, needs only to counterbalance the weight of the insect's body.

The wing musculature of the Ephemerida shows clearly that the mayflies belong to the non-odonate branch of the Pterygota. Their thoracic musculature, according to the account of Dürken (1907), includes typical longitudinal and oblique tergal muscles (fig. 28, *A*, *B*), and tergo-sternals *(C)*, the two sets constituting indirect depressors and elevators of the wings. The mayflies, however, do not flex the wings, and as a consequence the episternal and epimeral coxal muscles retain their primitive function as movers of the coxæ. The principal difference in the thoracic musculature of the Ephemerida and that of Orthoptera is in the greater number of muscles that arise on the epimeron, or on the epimeral region of the pleuron. There is no question of the truth of Dürken's statement that the musculature of the mayflies clearly separates the Ephemerida from the Odonata, but his claim that it separates them also from the Orthoptera does not appear to be warranted by his own descriptions. The Ephemerida are certainly, however, the most primitive of the non-odonate branch of the Pterygota.

The highly specialized wing musculature of Odonata has been described by Poletaïew (1881) and by Lendenfeld (1881). The usual tergal and tergo-sternal muscles are completely lacking in the thorax of the dragonflies, and each wing is provided with a set of direct muscles which effect all its movements. These muscles are of secondary development in the nymph, according to Poletaïew. They comprise identical sets of muscles in each of the wing-bearing segments, alike in all dragonflies. According to the elaborate descriptions of Lendenfeld, there are eight muscles to each wing. One of each set arises on the tergum, the others arise from ventral marginal ridges of the pleura or from processes of these ridges; they are all inserted either on the bases of the wing veins or on plates directly associated with the wing base.

In the Isoptera the dorsal longitudinal muscles of the thorax are degenerate, but the direct wing muscles, which are highly developed, show that the termite thoracic musculature is of the orthopteroid type. Fuller (1925) describes the muscles of the thorax of winged termites, but he does not explain how flight in these insects is sustained, even feebly, by a mechanism in which the principal motor elements appear to be lacking.

V. THE LEGS AND THEIR MUSCLES

In discussing the anatomy of an insect's leg, it will be convenient to limit the application of the term "leg" to that part of the appendage which ordinarily forms the free movable limb, ignoring for the present the theoretically basal subcoxa, but including the coxa in all cases, even when the latter is firmly fixed to the body wall.

STRUCTURE OF AN INSECT'S LEG

The typical and usual parts of the leg of an insect (fig. 31 A) are the *coxa (Cx)*, the *trochanter (Tr)*, the *femur (F)*, the *tibia (Tb)*,

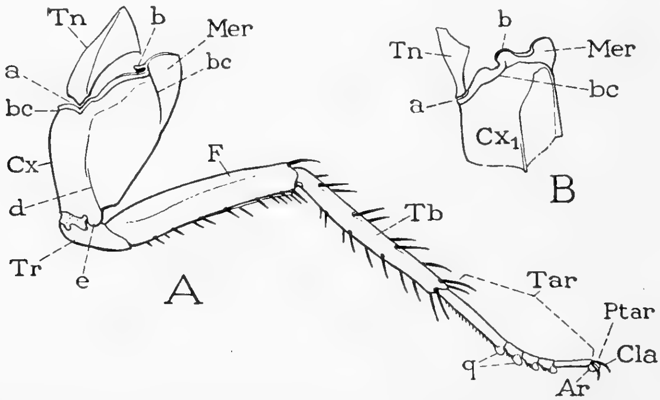

FIG. 31.—Structure of an insect leg, as represented by that of a roach (*Periplaneta americana*).

A, left mesothoracic leg and trochantin, anterior view; B, base of prothoracic coxa, with trochantin. *a*, articulation of coxa with trochantin; *Ar*, arolium; *b*, articulation of coxa with pleuron; *bc*, basicostal suture; *Cla*, claw; *Cx*, coxa; *d*, anterior coxal suture; *e*, anterior coxo-trochanteral articulation; *F*, femur; *Mer*, meron; *q*, ventral pads of tarsal segments, tarsal euplantulæ; *Tar*, tarsus; *Tb*, tibia; *Tn*, trochantin; *Tr*, trochanter.

the *tarsus (Tar)*, and the *pretarsus (Ptar)*. The several divisions of the leg are known as segments, or joints; the term *segment* will here be used for each piece of the leg, and the word *joint* limited to the articulation between adjoining segments. The surfaces of the leg are oriented for descriptive purposes when the limb is extended at right angles to the body, the outer surface then being dorsal, the inner ventral, and the other two anterior and posterior.

The movable base of the leg is ordinarily the coxa. The base of the coxa is inserted into a membranous area of the body wall between the pleuron and the sternum, which permits of whatever motions the closer articulations of the coxa with the surrounding chitinous parts allow. In pterygote insects the coxa is nearly always attached by an articular surface on its outer basal rim (fig. 33 A, *b*) to the coxal process of the pleuron (fig. 4). In most of the lower orders, the coxa has also an anterior articulation with the ventral end of the trochantin (fig. 31, *a*), but when the trochantin is absent, the coxa is suspended from the pleural process alone, except where it becomes articulated ventrally to a process of the furcisternum. Sometimes the coxa is not movable, as in the thoracic legs of caterpillars, and in the meta-thoracic leg of adult beetles. The leg, however, is always movable at the coxo-trochanteral joint, and if the coxa is distinguished as the leg *basis,* the part of the limb beyond it is the *telopodite.*

The joints of the leg consist of membranous rings of the leg wall between the chitinized areas that constitute the leg segments. Some-

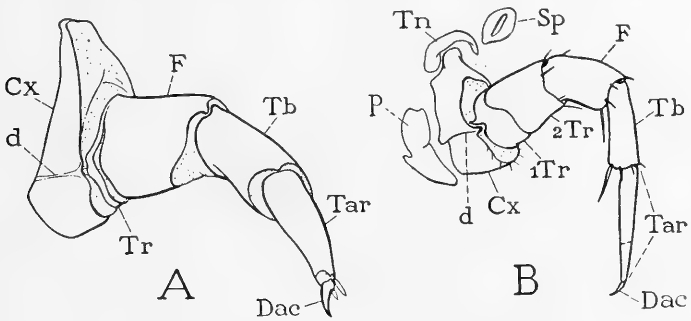

Fig. 32.—Leg of a caterpillar, and of a centipede.

A, left prothoracic leg of *Estigmene acraea,* anterior view; B, leg of *Lithobius sp.* Note similarity of structure in the coxæ (*Cx*), and in the dactylopodite-like terminal claws (*Dac*); trochanter (*Tr*) rudimentary in the caterpillar, represented by two segments in the centipede (*1Tr, 2Tr*).

times there is no close association between adjacent segments, but usually at one or two points the segments are hinged by chitinous processes, or condyles, or by other articulating surfaces on their opposing margins. Hinged joints are either *monocondylic* or *dicondylic,* according as they have one or two articular points. A single hinge is typically dorsal; in dicondylic joints, one hinge is anterior and the other posterior, except at the trochantero-femoral joint where the hinges, if present, are dorsal and ventral.

The structure of the hinges between the leg segments varies much at different joints and in different insects. Sometimes the two opposing surfaces simply touch by their points. In other cases the hinge is of the ball-and-socket type, a condyle of one surface fitting into a socket of the other, and in dicondylic joints of this kind the two hinges are frequently reversed in structure, but the condyle of the anterior hinge is generally on the proximal of the two articulating segments. The coxo-trochanteral joint is always dicondylic. In the telopodite, dicondylic hinges are characteristic of the legs of adult insects, monocondylic are usual in the legs of larvæ (fig. 32 A), but in the larvæ of Neuroptera and Trichoptera, the femero-tibial joint is dicondylic. An occasional special, or perhaps generalized, type of hinge consists of a flexible chitinous bar continuous from one segment to the other.

The Coxa.—In its most symmetrical form, the coxa has the shape of a short cylinder or truncate cone (fig. 31 A, *Cx,* fig. 33 A). Its proximal end is girdled by a submarginal *basicostal suture* (*bc*), which forms internally a low, circular ridge, or *basicosta* (fig. 33 A, *Bc*), and sets off a marginal flange, or *basicoxite* (*Bcx*), termed the coxomarginale by Crampton and Hasey (1915). The basicosta strengthens the base of the coxa, and serves also for the attachment of some of the coxal muscles. On the mesal half of the coxa, the basicosta is usually weak and often confluent with the coxal margin; on the outer surface, however, it commonly forms a strong ridge, (fig. 33 B, *Bc*), and in some cases a wide ledge (C) upon which muscles of this region are attached (fig. 37 B). The trochanteral muscles that arise within the coxa are attached distal to the basicosta (fig. 35 A).

The coxa has three constant articular surfaces, one proximal on the outer margin of its base (fig. 33 A, *b*) articulating with the coxal process of the pleuron, and two distal, one anterior (*e*) and the other posterior (*f*), by which the trochanter is hinged to the coxa. The pleural articular surface (*b*) is formed by an inflection of the wall of the basicoxite, and is supported on the basicosta (fig. 33 B, C). Besides these articulations, there is usually an anterior basal articulation with the ventral extremity of the trochantin (fig. 31 A, *a*), if the trochantin is present; when the trochantin is absent, there is sometimes a ventral articulation between the coxa and the furcisternum (fig. 18 I, *c*).

The walls of the coxa are often strengthened by internal ridges, the lines of which appear as sutures on the external surface. One ridge extending from the basicosta to the anterior trochantinal articulation, marked externally by a corresponding suture (fig. 33 A, *d*) is more constant than the others, though the position of its proximal end varies. In the legs of centipedes (fig. 32 B) and of caterpillars (A) it extends basally to the middle of the anterior margin of the coxal base. In the fore leg of a grasshopper (fig. 33 D, *d*) the ridge has a similar position, ending at the articulation of the trochantin

(*Tn*) with the coxa. This position suggests that the ridge may be a primitive coxal structure forming a brace between the anterior trochantinal and trochanteral articulations. In many cases, however, the ridge extends basally to the pleural articulation (fig. 33 A, *d'*),

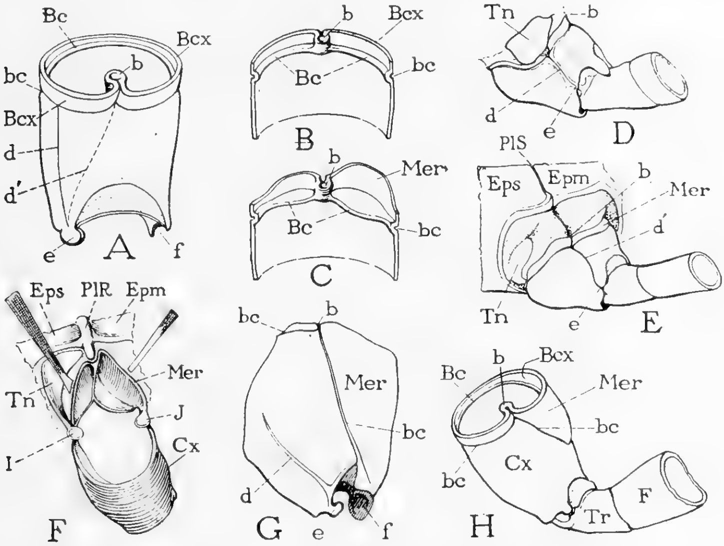

FIG. 33.—Structure of the coxa.

A, diagram of coxal structure, lateral view, showing marginal basicoxite (*Bcx*) separated from body of coxa by internal basicostal ridge (*Bc*) and external basicostal suture (*bc*): *b*, pleural articulation; *d, d'*, varying positions of anterior coxal suture; *e, f*, anterior and posterior trochanteral articulations.

B, basal part of external wall of coxa, inner surface: showing pleural articulation (*b*) supported on basicosta (*Bc*).

C, same parts of a coxa with part of basicoxite posterior to pleural articulation (*b*) enlarged to form the basal coxal lobe known as the meron (*Mer*).

D, base of fore leg of grasshopper (*Dissosteira*): anterior suture (*d*) extending between trochantinal and trochanteral articulations.

E, middle leg of same; anterior suture (*d'*) continuous above with pleural suture (*PlS*).

F, base of right middle coxa and associated pleural parts, inner view, of cicada (*Tibicina septendecim*): showing point of attachment of promotor muscle (*I*) on trochantin (*Tn*), and of remotor (*J*) on meron (*Mer*).

G, middle coxa of peach borer moth (*Aegaria exitiosa*): meron (*Mer*) greatly enlarged; anterior suture (*d*) partly suppressed.

H, Diagram of coxal structure with meron (*Mer*) extended distally, and anterior suture (A, *d*) lacking.

as in the middle leg of a grasshopper (E, *d'*), and its suture then falls in line with the pleural suture (*PlS*). The latter condition has given rise to the idea that the coxa is formed of an anterior and a posterior part corresponding with the episternum and the epimeron, but it is clear that this conception is based on a superficial character, which is also a variable one. The coxal ridge is sometimes incomplete basally (fig. 33 G, *d*), and probably in the majority of insects it is lacking (H).

The inflection of the outer wall of the basicoxite to form the pleural articular surface of the coxa (fig. 33 A, *b*) divides the basicoxite externally, and the two lateral basicoxal parts often beome enlarged in the form of two lobes on the coxal base (fig. 33 C), one before the pleural articulation, the other behind it. The posterior lobe, which is usually larger than the other, is the *meron* (*Mer*), though, as presently will be shown, quite different parts of the coxa have been confused under this term. The basicoxal lobes are well developed on the middle and hind legs of a cicada (figs. 16 D, 33 F), the meron of the hind leg of an adult cicada bearing a large hollow spine-like process.

The meron is often much enlarged through being extended distally on the posterior part of the coxa (figs. 31 A, 33 H), but even if it reaches almost to the end of the coxa (figs. 33 G, 34 A), it still preserves the relation of a basal lobe to the rest of the coxa, for it never takes part in the trochanteral articulations. The suture limiting the meron is always an extension of the basicostal suture (*bc*), and its internal ridge separates the bases of the coxal muscles of the meron from those of the trochanteral muscles attached within the body of the coxa. By this test, the meron of a coxa lacking a true lateral suture (fig. 33 H), and the posterior part of a coxa divided by this suture (E, *d'*) should be easily distinguished, but the mistake of identifying one with the other has often been made. In the middle and hind legs of Blattidæ (fig. 31 A), the distal part of the basicostal suture (*bc*) defining the elongate meron is obsolete, giving the meron the appearance of being a part of the coxa, but in Termitidæ, with a similar meron, the suture is complete, and the meron is a typical basicoxal lobe.

In adult Neuroptera, Mecoptera, Trichoptera, and Lepidoptera, the meron of the middle and hind legs is particularly large, often reaching to the distal end of the posterior face of the coxa (figs. 33 G, 34 A, *Mer*), though in the larval stages it is an inconspicuous lobe on the coxal base, or is not distinguishable (Lepidoptera). The growth of the meron takes place during the pupal stage, and its apparent continuity at this time with the epimeron above it, in Neuroptera and Trichoptera, led the writer, in a former paper (1909), to the conclusion that the adult meron in these orders is derived from the epimeron. A study of the musculature, however, shows the identity of the large adult meron with the inconspicuous posterior basicoxal lobe of the larva. The continuity of the meron and the epimeron during the pupal stage is, therefore, but a secondary and temporary union of these parts in the Neuroptera and Trichoptera, as claimed by Crampton and Hasey (1915), but it fore-

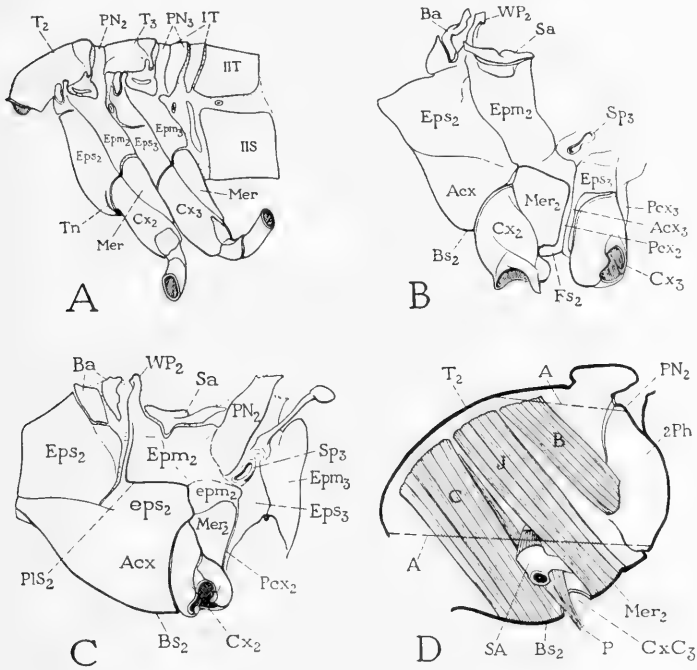

FIG. 34.—Modifications by which the mesothoracic meron, normally a basal lobe of the coxa, in the Diptera becomes a plate of the body wall.

A, mesothorax, metathorax, and base of abdomen of *Panorpa consuetudinis:* meron (*Mer*) forming a large lobe on posterior face of each coxa.
B, mesothoracic and metathoracic pleura and coxæ of a tipulid fly (*Holorusia grandis*): meron of mesothorax (Mer_2) a large coxal plate projecting into pleural wall.
C, mesothoracic and metathoracic pleura and middle coxa of horse fly (*Tabanus atratus*): mesothoracic meron (Mer_2) detached from coxa (Cx_2), and incorporated into body wall.
D, median section of thorax of a syrphid fly (*Eristalis tenax*): the remotor muscle of middle coxa (*J*) becomes a wing elevator, by transfer of the meron (Mer_2) from coxa to body wall.

shadows a permanent displacement of the meron in the mesothorax of Diptera.

The meron region of the coxa bears the ventral attachment of the subalar epipleural muscle (fig. 37 B, *F*), and of the remotor of the coxa (*J*). A plate in the ventrolateral wall of the mesothorax of Diptera, lying above and behind the base of the coxa, constituted a puzzle for insect morphologists until it was shown by Crampton and Hasey (1915) and by Crampton (1925, 1925a) to be the meron of the middle leg. In the Tipulidæ, the plate in question (fig. 34 B, Mer_2) is attached to the middle coxa (Cx_2) and is quite distinct from the postcoxal bridge of the mesothorax (Pcx_2). To its upper part is attached the muscle from the subalar plate (*Sa*), and to its lower part the tergal remotor of the coxa. The plate is, therefore, the meron, and its relations to the coxa are the same as those of the meron in *Panorpa* (fig. 34 A), though it forms a part of the segmental body wall in the Tipulidæ. In the higher Diptera, the corresponding plate (fig. 34 C, Mer_2) is detached from the coxa, and is closely united with a part of the epimeron above it (epm_2), and with the very narrow postcoxal bridge (Pcx_2) behind it. The body of the coxa (Cx_2) is independently movable on a vertical axis. The base of the subalar muscle in the higher Diptera has migrated upward upon the true pleural region, and is attached to the horizontal part of the pleural ridge behind the base of the pleural arm. The remotor muscle of the coxa (fig. 34 D, *J*), however, remains attached ventrally to the transposed meron (Mer_2) and becomes thus an elevator of the wings, being the middle muscle of the three large wing elevators (*C, J, B*) in each side of mesothorax. The transposition of the mesothoracic meron in the Diptera from the coxa to the body wall is clearly a device for increasing the power of flight by transferring one of the leg muscles to the service of the wing.

The trochanter.—The trochanter is ordinarily a small segment, usually fixed more or less firmly to the base of the femur (fig. 31 A, *Tr*). Structurally it resembles the coxa, having a strong basicostal ridge (fig. 35 A, *g*) bearing the coxal articulations, but its motion is limited by the latter to movements in a vertical plane. Being the base of the telopodite, however, its articulation with the coxa is one of the important hinges of the insect leg. The ventral lip of the trochanter base usually projects into the coxa as a strong process for the attachment of the extensor muscles (fig. 35 A, *P, Q*). The trochantero-femoral joint, though usually having but little motion, differs from all other joints of the insect leg in that, when movable, it bends forward and backward on a vertical axis. A reductor muscle of the femur (fig. 35 A, *R*) arises in the trochanter and is inserted on a basal thickening (basicosta) of the femur (*i*). By this character, the true trochantero-femoral suture may be identified where it might otherwise be confused with certain other sutures that sometimes occur near it.

In a few insects the trochanter appears to be double. In some of the Hymenoptera (Ichneumonidæ, Braconidæ), for example, two pieces of the leg occur between the coxa and the femur which are called "first trochanter" and "second trochanter." That the first alone is the trochanter (fig. 35 B, *Tr*), however, is shown by the fact that the reductor femoris muscle (*R*) is inserted on a plate (*i*) inflected from the base of the second (*F'*). The latter is, therefore, a basal subsegment of the femur (*F*), separated by a secondary suture

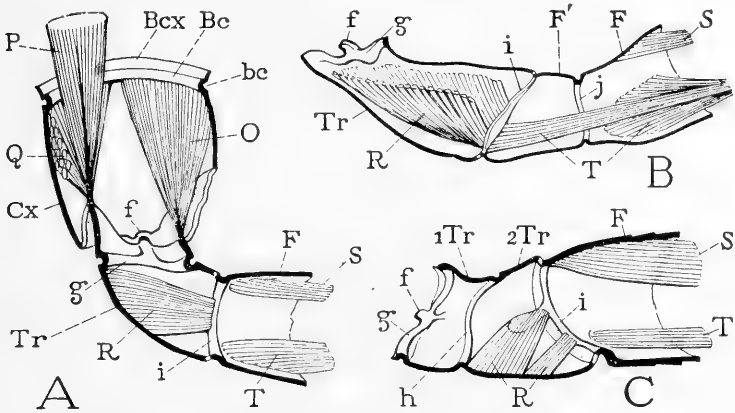

FIG. 35.—Structure and musculature of the coxa, trochanter, and base of femur.

A, diagram of typical musculature of coxa, trochanter, and base of femur; B, trochanter and base of femur of an ichneumonid (*Megaryssa*), showing basal subdivision (*F'*) of the femur (*F*); C, trochanter and base of femur of middle leg of dragonfly nymph (Aeschnidæ), showing double structure of the trochanter (*1Tr, 2Tr*).

Bc, basicosta of coxa; *bc,* basicostal suture; *Bcx,* basicoxite; *Cx,* coxa; *F,* femur; *F',* basal subdivision of femur; *f,* posterior coxo-trochanteral articulation; *g,* basicosta of trochanter; *h,* ridge between subdivisions of trochanter; *i,* basicosta of femur; *j,* femoral ridge setting off basal subdivision of femur; *O,* levator muscle of trochanter; *P,* thoracic branch of depressor of trochanter; *Q,* coxal branch of depressor of trochanter; *R,* reductor muscle of femur; *S,* levator of tibia; *T,* depressor of tibia; *Tr,* trochanter; *1Tr, 2Tr,* first and second subdivisions of trochanter.

and ridge (*j*). A branch of the tibial flexor (*T*) crosses the ridge and is attached at the anterior end of the true femoral base.

In the Odonata, both nymphs and adults, there appear likewise to be two trochanteral segments (fig. 35 C, *1Tr, 2Tr*). The structural relations here, however, are quite different from those in the hymenopteran leg (B). The reductor femoris muscle (*R*) of the dragonfly arises in the second trochanter, and the ridge (*i*) upon which it is inserted is clearly the basicosta of the femur (*F*). The ridge (*h*) with its external suture between the two parts of the trochanter is, therefore, a trochanteral structure, and its presence furnishes a reason for believing that in the dragonflies the two parts of the trochanter (*1Tr, 2Tr*) represent two primitive segments of the leg, as claimed by Verhoeff (1903 a, 1903 b). Gründberg (1903), on the other hand, sees here only a secondary division of the trochanter, and he would homologize the dividing ridge (*h*) with the more basal ridge of the trochanter in other insects. He fails to note, however, that the latter ridge (*g*) is also present and well developed in the Odonata, and bears the coxal articulations (*f*). Verhoeff calls the first trochanter the "true trochanter" and the second the "praefemur." He believes that the first disappears in most insects other than the Odonata, and that the so-called trochanter of insects is the homologue of the praefemur of the Chilopoda. The disappearance of the first trochanter segment, however, would involve a replacement of the articular elements in the coxo-trochanteral joint, an unlikely transformation. It seems more reasonable, therefore, that the two trochanteral segments have been united into one in most insects (fig. 42). The basal lip of the trochanter (fig. 35 A), when unusually wide, often gives the trochanter a false appearance of being a double segment.

The femur.—This, the third segment of the insect leg (fig. 31 A, *F*), is usually the longest and strongest part of the limb; but it varies in size from that of the huge hind femur of leaping Orthoptera to that of the small femoral segment in the leg of a sawfly larva (fig. 16 B), which is much inferior to the coxa. The femoro-tibial joint, or "knee" of the insect leg, is typically dicondylic in adult insects and in the nymphs of Hemimetabola; but in holometabolous larvæ it is usually monocondylic (figs. 16 A, 32 A), as it is in the Chilopoda (fig. 32 B). In the larvæ of Neuroptera and Trichoptera it is dicondylic.

The tibia.—The tibia (fig. 31 A, *Tb*) is characteristically a slender segment in adult insects, only a little shorter than the femur, or the combined femur and trochanter. Its proximal end forms a more or less distinct "head" bent toward the femur, a device which allows the tibia to be flexed close against the ventral surface of the femur, and one often not expressed sufficiently in insect drawings to suggest the essential mechanism of the femoro-tibial articulation. The tibio-tarsal joint is dicondylic in adult insects, unless articular points are lacking, but it is always monocondylic in holometabolous larvæ. Sometimes the tibia and tarsus are united, forming a tibio-tarsal segment (figs. 16 B, 43 B).

The tarsus.—In adult insects, the tarsus comprises from one to five small pieces (fig. 31 A, *Tar*). In holometabolous larvæ, however, it consists of a single leg segment (figs. 16 A, 32 A, 41 B, *Tar*), as it does in adult Protura (fig. 41 A), which segment is probably the propodite of the generalized arthropod limb (fig. 42). The subsegments, or articles, of the adult tarsus, conveniently called tarsal "segments," therefore appear to be subdivisions of a single primitive shaft; they have no articular hinges with each other, though they are usually freely movable by inflected connecting membranes (fig. 39), and they never have individual muscles. The tarsus is moved as a whole by muscles inserted upon its base, or by tension of the claw muscles on the tendon which traverses it (fig. 39, *x*). Tarsi having fewer than five segments, therefore, represent either a stage of progress in the division of the primitive segment, or a retrogressive condition in which some of the articles of a five-segmented tarsus have been lost or have coalesced. The tarsi of the Apterygota may be supposed to be of the first class, as may likewise those of the Odonata with three segments, but in the rest of Pterygota, the adult tarsus appears to have been standardized with five segments, and all reductions from this number are most likely of a secondary nature.

The basal segment of the tarsus is often larger than the others, and is distinguished as the *basitarsus,* metatarsus, or planta, the first term being preferable. On the under surfaces of the segments, except the last, there are sometimes small pads, the *euplantulæ* (Crampton, 1923), or tarsal pulvilli (fig. 31 A, *q*).

The pretarsus.—Entomologists generally have not found it necessary to refer collectively to the terminal parts of the insect leg (fig. 31 A, *Ar, Cla*), and consequently we have no satisfactory name for the group of organs at the end of the tarsus, which in some cases might appropriately be termed the "foot," but not with those insects that place a part or all of the tarsus on the supporting surface. The group of terminal foot structures is called the *unguis* or *ungula* by Schiödte, the *prætarsus* by de Meijere, the *articularis* by MacGillivray, and the *Krallenglied* by Arnhart. Since de Meijere (1901) has given the most comprehensive description of the parts in question, his name for them, *prætarsus,* is adopted in the Americanized form of "pretarsus" in the present paper, though not without regret that de Meijere did not invent a more fitting term.

In its simplest form the terminal part of the insect leg consists of a small, claw-like segment similar to the dactylopodite of a crustacean or chilopod limb (fig. 32 B, *Dac*). A pretarsus of this kind occurs in adult Protura (fig. 41 A), in some Collembola, in the larvæ of most beetles (fig. 43), and in the larvæ of Lepidoptera (figs. 32 A, 41 B) and Tenthredinidæ (fig. 16 B). A one-clawed pretarsus is found also in a few adult pterygote insects, as in the Coccidæ, Pediculidæ, and the mammal-infesting Mallophaga, but the structure of the foot in such cases has probably resulted secondarily from the suppression of one claw in an original pair of claws.

The pretarsus of an adult insect, in its typical form (fig. 36 A, B), arises from the end of the last tarsal segment by a membranous base,

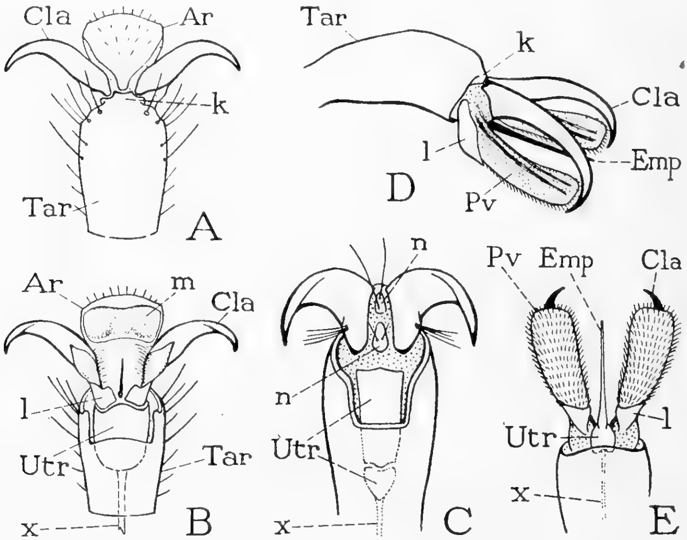

FIG. 36.—Structure of the insect foot (pretarsus).

A, end of tarsus (*Tar*) and foot of a roach (*Periplaneta americana*), dorsal view: claws (*Cla*) articulated to unguifer process (*k*) on end of last tarsal segment; arolium (*Ar*), a median lobe between claws.

B, the same, ventral view; showing ventral pad (*m*) of arolium, auxiliary plates (*l*) at bases of claws, and unguitractor plate (*Utr*) to which is attached tendon (*x*) of retractor muscles of claws (fig. 39, *X*).

C, foot of a cicada (*Tibicina septendecim*): arolium lacking, or represented by small plates (*n*) between claws.

D, foot of an asilid fly, lateral view: arolium lacking; lateral, lobe-like pulvilli (*Pv*) arising from auxiliary plates (*l*) beneath claws, and median spine-like empodium (*Emp*) arising from unguitractor plate.

E, the same, ventral view.

upon which are supported a pair of movable lateral *claws* (*Cla*), and a median lobe, the *arolium* (*Ar*). The claws are hollow, multicellular organs, their cavities being continuous at their bases with the lumen of the base of the pretarsus. Each is articulated dorsally to the *unguifer* (A, *k*), a median process of the distal end of the last tarsal segment (*Tar*). The arolium, likewise a hollow lobe, is a direct continuation of the median part of the pretarsal base; it may be entirely membranous, or its walls may be partly chitinous. On the ventral surface is a large basal plate, the *unguitractor* (B, *Utr*), which is partially invaginated into the end of the tarsus (*Tar*), where the flexor, or retractor, "tendon" of the claws (*x*) is attached to its proximal end. The unguitractor may consist of two pieces (C, *Utr*), or sometimes there is a second plate, the *planta,* distal to the unguitractor at the base of the arolium, and there may be lateral plates, the *auxiliæ* (*l*), at the bases of the claws. In the honeybee, a transverse chitinous band lies beyond the planta in the ventral wall of the arolium.

All parts of the pretarsus are subject to much variation. The claws sometimes have each two points; sometimes the claws are of unequal size, one claw becoming reduced and occasionally obliterated, the result being a one-clawed foot. Again, both claws become very small, and both may be lacking. In the Physopoda, the claws are minute, and the foot consists principally of the large bladder-like arolium. In some of the Thysanura there is a third, median claw between the two lateral claws, well developed though small in *Lepisma* (fig. 44, C, D, *Dac*) rudimentary in *Japyx* (fig. 44 A, *p*). This median claw is probably not analogous to the lateral claws, being more likely a remnant of the primitive dactylopodite. The pretarsus of first-stage larvæ of Meloid beetles, the triungulins, also apparently has three claws, a large median one and two slender lateral ones; but there is some doubt as to the nature of the lateral claws of the triungulin foot, Böving (1924) pointing out that they are claw-like setæ rather than true claws. In a lampyrid larva with three claws on each foot, the lateral claws appear to be outgrowths of the dactylopodite, since they have no articulations with the tarsus.

The arolium (*Ar*) varies in size and in form from a small simple lobe to a large complex appendage; or again it may be rudimentary or entirely lacking (fig. 36 C). In the Diptera there are two lateral ventral foot lobes, the *pulvilli* (fig. 36 D, E, *Pv*), which arise from the auxiliæ (*l*), one beneath the base of each claw. The arolium is rudimentary or absent in most Diptera; only in the Tipulidæ, according to de Meijere, is it well developed. In other families a median process, the *empodium* (*Emp*), or "processus plantaris" of de Meijere, is commonly developed from the distal end of the unguitractor plate. The empodium may be spinelike (fig. 36, D, E), or lobelike and similar to the lateral pulvilli.

MUSCLES AND MECHANISM OF THE LEG

Though the legs of different insects are adapted in their structure to a great variety of uses, their motions are made according to the simplest of mechanical principles, for, with the exception of the movements of the coxa on the body, the action at each of the flexible joints is merely that of a hinge working in a single plane.

In insects, and in most other arthropods, the functional base of the leg is the coxa, and the appendage as a whole moves on the articulation of the coxa with the body. In the more generalized orders, where the coxa is suspended freely from the pleuron, the leg may swing forward and backward on a transverse (or vertical) coxal axis

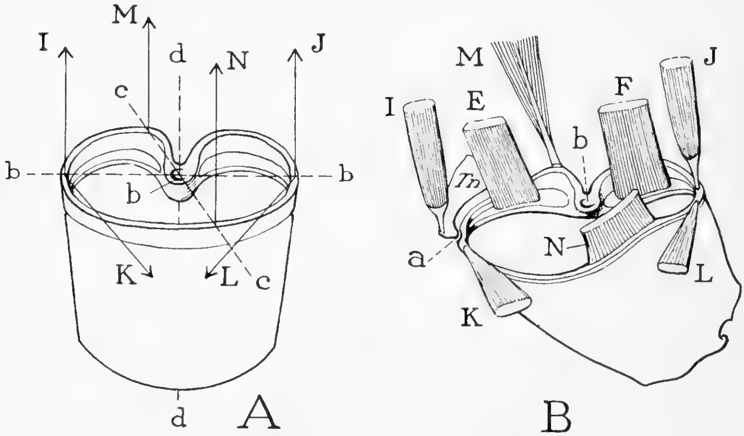

Fig. 37.—The cardinal axes of motion, and the corresponding muscles of a coxa freely articulated to the pleuron.

A, diagram of the mechanism of coxal motion on the pleural articulation (*b*), inner view. The cardinal movements are: (1) *abduction* and *adduction* on longitudinal axis (*b b*) by means of abductor and adductor muscles (*M, N*); (2) *promotion* and *remotion* on transverse axis (*c c*) by promotor and remotor muscles (*I, J*); and (3) *rotation* on vertical axis (*d d*) by anterior and posterior rotator muscles (*K, L*).

B, diagram of coxal musculature, inner view of base of right coxa: *E, F,* basalar and subalar muscles of wing attached on coxa (fig. 28); *I,* promotor of coxa, tergum to trochantin; *J,* remotor, tergum to coxa; *K,* anterior rotator, sternum to coxa; *L,* posterior rotator, sternum to coxa; *M,* abductor, episternum to coxa; *N,* adductor, sternum to coxa.

(fig. 37 A, *cc*), outward and inward on a longitudinal axis (*bb*), or it may turn in the plane of its base on an axis through the middle of the coxa (*dd*). The possible elemental movements of the coxa and of the leg as a whole are, therefore, *promotion* and *remotion, abduction* and *adduction,* and *rotation;* but, if the coxa has a free articulation, the actual movements of the leg base are unlimited, since, by simultaneous contraction of two or more sets of the coxal muscles, there may result compound movements in any direction. In conformity with its motile possibilities, the coxa has a much more elaborate musculature than that of any other segment of the leg: where its movements are unrestricted, it is provided with antagonistic sets of muscles corresponding with its three primary axes of motion. It has *promotors* and *remotors* (fig. 37 A, *I, J*), *abductors* and *adductors* (*M, N*), and *anterior* and *posterior rotators* (*K, L*).

If the coxa represents the base of the primitive arthropod limb, we have only to assume that its muscles were directly fitted to its needs. We have seen, however, that there is reason for believing that the original limb had its base in a subcoxal segment, which became incorporated into the pleural wall of the body to form a support for the rest of the limb, the latter acquiring a new functional base in the coxa. This theory can not be supported on external features alone; the transformations that it assumes could not but involve changes in the leg musculature, and it must be shown at least that there is nothing in the arrangement of the muscles in modern insects that is incompatible with the theory—if positive evidence can be found of shiftings in the muscle attachments in accord with the assumed changes in the skeletal parts, the theory will be so much the more acceptable.

A primitive segmental limb, perhaps of a parapodial nature, must have turned forward and backward on its base in the lateral wall of its segment. It, therefore, possessed promotor and remotor muscles, probably dorsal and ventral promotors (fig. 38, A, *I, K*) and dorsal and ventral remotors (*J, L*). According to Börner (1921) the parapodium of an annelid worm (*Nereis*) has a musculature of this sort by which it is turned anteriorly and posteriorly. If, then, the arthropod subcoxa turned on a vertical axis, it follows that the coxal movement on the subcoxa was most probably in a vertical plane on a horizontal axis. The coxa, therefore, had abductor and adductor muscles (*M, N*) arising on the dorsal and the ventral wall of the subcoxa.

Something analogous at least to this theoretical musculature of the primitive limb base (fig. 38 A) may be seen in the Acarina. In the Ixodidæ the movable part of each leg is supported on a large basis that spreads out as a wide plate in the ventral wall of the body (fig. 17, *Scx*), but which also is narrowly continuous around the dorsal side of the first free segment of the leg. These leg bases are provided with anterior and posterior dorsal muscles, and the bases of the first pair of legs in *Dermacentor* and *Amblyomma* at least are slightly movable in the living tick, turning on an obliquely transverse axis. The next piece of the leg is a free, cylindrical segment (*Cx*), hinged to the basis by anterior and posterior articulations on an axis at right angles to that of the basis with the body, the anterior articulation being at the ventral anterior angle, and the axis extending obliquely dorsally and posteriorly to the rear articulation. The third segment, a small trochanter-like piece (*1Tr*), is hinged to the second on a longitudinal axis with typical coxo-trochanteral articulations. The structure of the proximal part of the acarine leg, therefore, strongly suggests that the ventrally expanded basis is the subcoxa, and that the following two segments are the coxa and the first trochanter. Though the axis of the subcoxo-coxal joint is somewhat oblique, its movements are essentially those of abduction and adduction, since the coxal muscles consist of dorsal and ventral antagonists, both attached here on the ventral plate of the subcoxa, probably on account of the reduction of the lateral wall of the latter. The obliquity of the subcoxo-coxal hinges in the Acarina is clearly an adaptation to allow the legs to move in the plane of the flattened body.

Assuming, then, a subcoxal segment functioning as the leg base at some remote time in the ancestry of insects, we must postulate either that the present coxal musculature is a new development, or that it has been evolved through a transfer of the subcoxal muscles to the coxa. There is no evidence in support of the first supposition; there is nothing to contradict the possibility of the second. Abundant evidence is at hand to show that the bases of insect muscles may undergo considerable migrations. If the dorsal promotor and remotor muscles of the subcoxa (fig. 38 A, *I, J*) were transferred to the coxa, they would become promotors and remotors of the coxa (B) when the posterior coxal articulation (A, *b*) assumed its dorsal lateral position (B, *b*); but a transfer of the ventral promotors and remotors of the subcoxa (A, *K, L*) to the coxa (B) would convert these muscles into anterior and posterior rotators of the coxa. The dorsal promotor (*I*), however, remains attached to the trochantin (B, *Tn*), a piece of the subcoxa, as long as this sclerite persists; only when the trochantin is greatly reduced or is lacking does it become attached to the coxa. The flexibility of the free part of the trochantin, or its detachment from the rest of the pleuron allows the trochantinal muscle to function as a coxal promotor. The trochantinal hinge with the coxa (*a*) thus becomes a lifting point rather than an articulation, as has been noted by Crampton.

The primitive abductors and adductors of the coxa (fig. 38 A, B, *M, N*) retain their original function, but the second becomes attached to the sternum with the suppression of the ventral wall of the subcoxa and is eventually supported on the sternal apophysis (*SA*) to give it more efficient action. The forward migration of the posterior coxal articulation to a mid-lateral position (B, *b*) has crowded the base of the coxal abductor (*M*) to the forward part of the eupleural region of the subcoxa, which later becomes the episternum, and upon this plate arise the abductors of the coxa in all modern insects, except where the pleurum becomes rudimentary. Placed at a mechanical disadvantage by the new position of the coxal articulation, the abductor has regained efficiency in part from the inflection of the pleural articular surface toward the center of the coxal base (fig. 37 A).

The above outline of what may have taken place in the theoretical transformation of the leg base is purely hypothetical, but it accounts

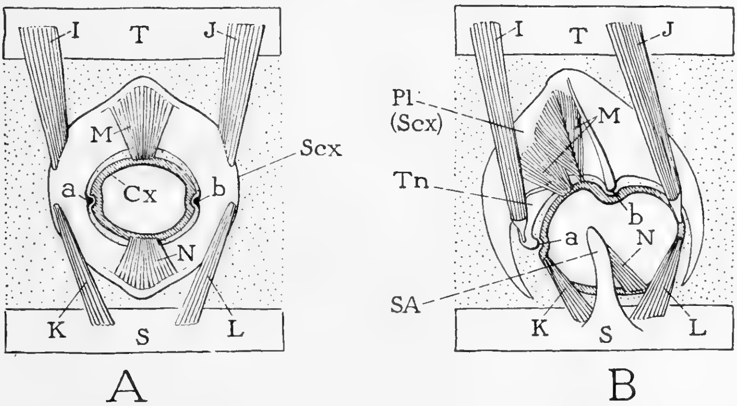

FIG. 38.—Theoretical derivation of modern coxal muscles from primitive coxal and subcoxal muscles.

A, Diagram of theoretical primitive musculature of subcoxa and coxa: *a*, *b*, horizontal axis of coxa on subcoxa; *I*, *J*, tergal promotor and remotor muscles of subcoxa; *K*, *L*, sternal promotor and remotor muscles of subcoxa; *M*, *N*, abductor and adductor muscles of coxa, arising within subcoxa.

B, muscles transposed, posterior coxal articulation (*b*) shifted to dorsal position: *I*, becomes promotor of coxa; *J*, becomes remotor of coxa; *K*, *L*, become rotators of coxa; *M*, *N*, remain abductor and adductor of coxa.

for the present complicated musculature of the coxa in the more generalized pterygote insects, and it explains those features that give the coxal musculature an appearance of having been secondarily adapted to the purposes of the coxa.

A typical generalized coxal musculature of the leg of a wing-bearing segment is shown at figure 37 B; it is approximately that of the middle leg of a grasshopper (Acrididæ), except that some of the single muscles in the figure are represented by several groups of fiber bundles in the grasshopper. The principal tergal promotor (*I*) is nearly always a single muscle inserted below on the trochantin (*Tn*), or on the anterior coxal rim when the trochantin is absent.

The remotor (*J*) may comprise several tergal muscles inserted on the meron region of the coxa. Besides the principal abductor (*M*), there are usually several smaller muscles from the episternum to the anterior lateral part of the coxal rim, some of which are probably accessory promotors. The adductor (*N*) and the rotators (*K, L*) arise upon the sternum or upon the sternal apophysis. The posterior rotator may be broken up into a group of muscles. In addition to the muscles just described the coxal musculature of a wing-bearing segment includes the epipleural muscles (*E, F*), already described in connection with the wings. The first (*E*) may be regarded as a part of the abductor system of the leg in its origin, but the second (*F*), having no representative in the prothorax, would appear to be a secondarily developed muscle. Both the epipleural muscles are present in nymphal Orthoptera, where they apparently function as leg muscles, since the basalar and subalar plates are here not separated from the pleuron (fig. 26 B).

The actual arrangement of the coxal muscles and their attachments to the base of the coxa are seldom so diagrammatically simple as shown in figure 37 B. There are likely to be several muscles in each set, and again it is not always possible to find a representative of each group. The coxa itself is usually turned more or less at an angle to the body, and its base is seldom a symmetrical plane at right angles to its length. It is, therefore, often difficult to determine the exact function of any particular muscle or set of muscles. Moreover, it appears that the action of individual muscles may be changed in consequence of modifications in the coxal articulations. When the coxa, for example, is hinged to the sternum, and has its motions limited to a forward and backward turning on a transverse or vertical axis, its musculature is correspondingly reduced, and such muscles as remain become either promotors or remotors. In the Dytiscidæ the hind coxæ are immovable, constituting solid bases for the telopodites of the hind legs, which are the swimming organs. In *Dytiscus*, according to Bauer (1910), each hind coxa retains, besides the subalar wing muscles, only two of the normal coxal muscles, and these, having their origin on the tergum, serve probably as accessory elevators of the wings. Since the data for a comparative myology of insects are not yet at hand, no attempt can be made here to follow the modifications of the coxal musculature in the various groups of insects.

In the telopodite, or that part of the leg beyond the coxa, the joints bend either forward and backward, or up and down. The most precise terms for the motions at the two types of joints are *produc-*

tion and *reduction,* and *elevation* and *depression,* respectively. Joints of the first type are provided with *productor* and *reductor muscles;* those of the second type with *levator* and *depressor muscles.* Some writers use the terms "flexor" and "extensor," or "abductor" and "adductor" as synonymous with levator and depressor, regardless of the nature of the respective movements; others call that muscle the "extensor" which accomplishes the principal work of the leg segment distal to the joint, and name its antagonist the "flexor." The last system is appropriate for designating function, but for ana-

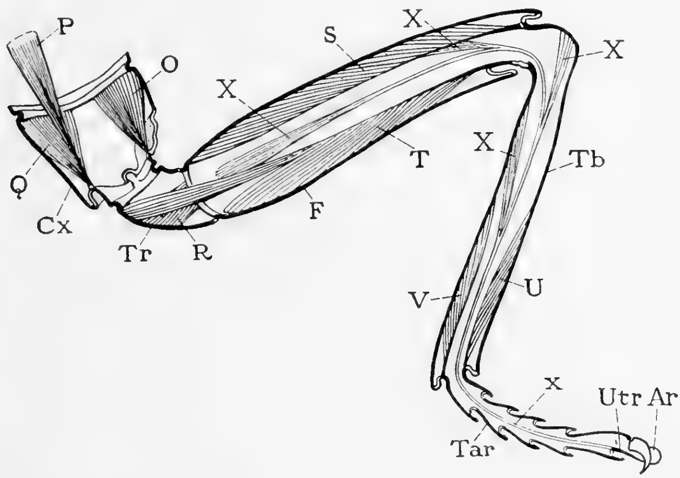

Fig. 39.—Diagram of typical leg musculature, left leg, anterior view.

O, levator of trochanter; *P, Q,* thoracic and coxal branches of depressor of trochanter; *R,* reductor of femur; *S,* levator of tibia; *T,* depressor of tibia; *U,* levator of tarsus; *V,* depressor of tarsus; *X, X, X, X,* branches of depressor of pretarsus (retractor of claws); *x,* tendon of claw retractor muscles, attached to unguitractor plate (*Utr*).

tomical descriptions "levator" and "depressor" are to be preferred, because they lead to no ambiguity and can be applied always to homologous muscles. In the telopodite of the insect leg, only the trochantero-femoral joint bends forward and backward, the other three are movable in a vertical plane.

The muscles that move the trochanter are also levators and depressors of the entire telopodite, since the trochanter usually has but little if any motion on the femur. The levator of the trochanter (figs. 39, 40, *O*) arises in the dorsal part of the coxa and is inserted on the dorsal lip of the trochanter base, usually by a chitinous tendon. The depressor, in pterygote insects, has both coxal and thoracic branches. The coxal branch (*Q*) spreads out in a broad fan on the ventral wall of the coxa; the thoracic branch (fig. 39, *P*) includes one or two long muscles from the tergum, one from the arm of the pleural ridge, and sometimes one from the episternum (fig. 26 B, *P*), the fibers from all sources converging upon a large apodeme that arises from the ventral lip of the trochanter or from the articular membrane close to it. The great size of the depressor muscles of the trochanter gives the leg a strong movement of extension, which is that by which it accomplishes its principal work. The ample membrane above the trochanteral articulation allows the trochanter and femur to be freely flexed upward.

The trochantero-femoral joint of the insect leg, though usually having little if any motion, is often slightly movable and sometimes freely so, as in the bees. Its movements are always forward and

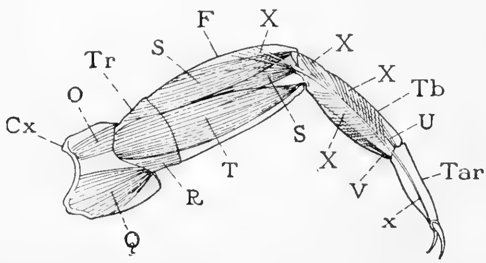

FIG. 40.—Muscles of right hind leg of *Japyx*, posterior view (lettering as on fig. 39).

rearward (production and reduction). In the higher Crustacea, which have two articulated trochanteral segments (basis and ischium, fig. 42 A), the second trochanter and the femur are each provided with productor and reductor muscles (Schmidt, 1915). In the Chilopoda and Hexapoda the second trochanter, or the single compound trochanter of most Hexapoda, has no muscles, but it contains a reductor femoris (figs. 35, 39, *R*) inserted on the posterior rim of the femoral base. In the leg of a caterpillar (fig. 41 B) a very small femoral reductor (*R*) goes from the upper anterior end of the incomplete trochantin (*Tn*) to the upper posterior part of the base of the femur. In the Protura, Prell (1912) describes a reductor femoris arising within the distal end of the coxa (fig. 41 A, *R*). Ordinarily the femur has no other muscle than the reductor, but both Berlese (1909) and Prell (1912) describe in the Protura a levator of the femur arising in the base of the coxa (fig. 41 A, *lf*). Berlese describes also a femoral depressor, but Prell does not mention or figure such a muscle.

The musculature of the femoro-tibial joint is variable. In adult insects, except Protura, however, it consists of a levator and a depressor of the tibia (fig. 39, *S, T*), the former often double (fig. 40, *S, S*). Both muscles are large and arise within the femur, though the depressor commonly has an anterior branch arising on the ventral wall of the trochanter (fig. 39, *Tr*). The fibers are usually inserted on apodemes springing from the dorsal and ventral lips of the tibial base, or arising from the membrane of the knee joint, the base of the depressor apodeme often forming a large chitinous plate in the ventral membrane of the joint. In the Protura, according to Prell (1912), there are no levator muscles in the telopodite beyond the trochantero-femoral joint, though Berlese describes a levator (abductor) of the tibia and of the tarsus. The depressor of the tibia in the Protura (fig. 41 A, *T*) consists of several branches arising in the femur and in the trochanter. In the leg of a caterpillar the tibia has a levator (fig. 41 B, *S*) arising in the base of the femur, and a depressor of three large branches (*T*), two branches from the femur and one from the trochanter, the group suggesting that of the tibial depressors in *Eosentomon* (A, *T*). Apparently all insect larvæ have both levator and depressor muscles of the tibia regardless of whether the femoro-tibial articulation is dicondylic or monocondylic.

The tarsus of typical adult insects is provided with both levator and depressor muscles arising within the tibia (figs. 39, 40, *U, V*). In the Protura (Prell, 1912) there is no tarsal levator, and the depressor usually arises by several heads in the tibia, femur, and trochanter, the distribution varying according to the species. In *Eosentomon* there is but one long depressor of the tarsus with its origin in the trochanter (fig. 41 A, *V*). In the caterpillar of *Estigmene* (fig. 41 B) there is no tarsal levator, but a simple depressor (*V*) arises on the anterior ventral wall of the tibia. In all insect larvæ the tibio-tarsal joint is either monocondylic or lacks articular points. In a trichopteran larva, as figured by Börner (1921), the tarsus has only a depressor muscle; but in coleopteran larvæ with a tarsus distinct from the tibia, there are both levators and depressors of the tarsus (fig. 43 A, *U, V*). In adult insects the tarsus is freely flexed upward, but can usually be extended only in line with the axis of the tibia; in larval insects the tarsus has a greater downward motion.

The subsegments of the tarsus are never provided with muscles, evidence that the articles are not true segments. Du Porte (1920) has described and figured levator muscles of the tarsal subsegments in *Gryllus,* but this is certainly an error. Likewise, muscles of the foot, or pretarsus, never have their origin in the tarsus in insects, though in some other arthropod groups the muscles of the dactylopodite arise in the propodite.

The insect pretarsus is provided only with depressor muscles, called usually flexor or retractor muscles of the claws, and in this feature it resembles the terminal leg segment of the Chilopoda. In the Crustacea, Pycnogonida, and Arachnida, however, the dactylopodite has both levator and depressor muscles. Du Porte (1920) describes an " extensor " of the claws in *Gryllus,* but here again his observation is clearly at fault.

In insects and in the chilopods, the pretarsal muscles have their origin in the leg segments proximal to the tarsus, and they are all

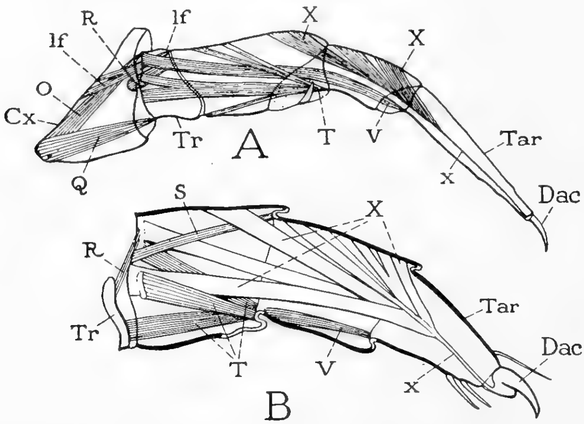

Fig. 41.—Leg of proturan and of caterpillar, showing similarity of musculature.
A, hind leg of *Eosentomon germanicum* (Prell, 1912); B, right hind leg of caterpillar of *Estigmene acraea,* posterior view. (Lettering as on fig. 39, except *lf,* levator of femur.)

inserted on a long " tendon " arising on the base of the pretarsus and extending through the tarsus (fig. 39, *x*). In insects, the fibers of the pretarsal muscles form several or numerous bundles (figs. 39, 40, 41, 43, *X*) arising in the tibia and the femur, and sometimes in the trochanter, the number of the bundles and the points of their origin varying much in different species. Where the pretarsus has the form of a simple dactylopodite, as in Protura (fig. 41 A) and in certain holometabolous larvæ (figs. 41 B, 43), the apodeme, or " tendon," of the pretarsal muscles arises directly from its base—in *Lepisma* it arises from the base of the median claw (fig. 44 C, E, *x*); but in other insects in which there is a special unguitractor plate, the tendon arises from the proximal end of this sclerite (figs. 36 B, 39, 44 B, *Utr*). The pull of the muscles on the unguitractor plate turns the claws downward on their dorsal articulations with the unguifer process at the end of the tarsus (fig. 36 A, D, *k*). The claws are extended by the elasticity of their basal connections when the flexor muscles relax, or by the weight of the insect on the supporting surface.

MORPHOLOGY OF THE LEG

Entomologists can not resist the temptation of endeavoring to trace the evolution of the insect leg from a biramous appendage such as is supposed to have been the ancestral form of all arthropod limbs. The plan of this hypothetical generalized appendage, as conceived principally by the carcinologists (fig. 42 A), includes a basal stalk, or

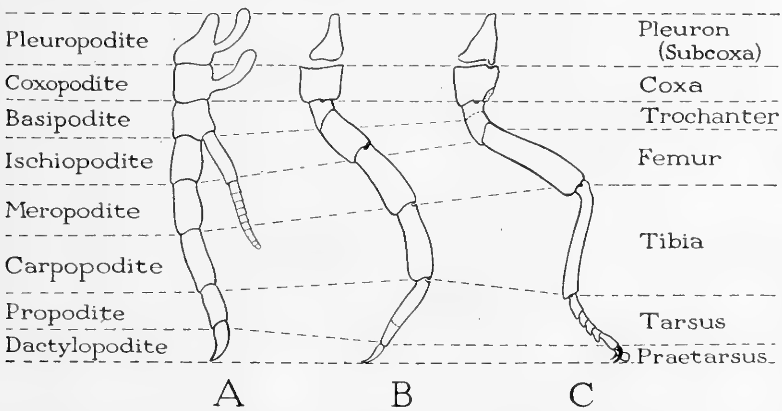

Fig. 42.—Diagram suggesting homologies of segments in arthropod limbs. A, generalized crustacean limb; B, leg of a chilopod (centipede); C, leg of an insect.

protopodite, and two distal branches, an *exopodite* and an *endopodite.* The stalk is divided into three segments (formerly only two were recognized), a *pleuropodite,* a *coxopodite,* and a *basipodite.* The exopodite has a number of small subdivisions, fortunately not named individually; the endopodite consists of five segments, an *ischiopodite,* a *meropodite,* a *carpopodite,* a *propodite,* and a terminal *dactylopodite.* The basal two segments of the stalk may bear external appendages called *epipodites;* lobes on the inner margins of the segments are *endites.*

The only fact that can be construed as evidence of a biramous origin of insect appendages is the presence of styli on the coxæ of the middle and hind legs of *Machilis* and related genera (fig. 12, *Sty*). No insect appendage develops in the embryo with a biramous structure; the lobes of the maxillæ are now recognized as being endites of a uniramous stalk. The leg styli of *Machilis* have apparent homologues in similar styli on the legs of Symphyla, in the paired styli occurring on a number of the abdominal segments of *Machilis, Lepisma, Japyx,* and other thysanuran genera, and in those of the ninth abdominal segment of the males of certain pterygote insects. The abdominal styli of *Lepisma* are said by Heymons (1897) to appear and to develop during the postembryonic life of the insect, a period rather late for a primitive organ to become first apparent. Moreover, the leg styli of *Machilis* and *Scolopendrella* occur on the coxæ, while the seat of a true exopodite is the basipodite, a segment either lacking in most insects or included in the trochanter (fig. 42 C). There is, therefore, reason for doubting that the styli of insects are exopodites. Unquestionably they are organs possessed by the ancestors of both the Apterygota and the Pterygota, but that they are other than secondary structures is yet to be demonstrated.

When the exopodite disappears from a biramous limb, as it commonly does in the evolution of an appendage that takes on a special function, there is left a uniramous shaft of eight segments. The basal segment, pleuropodite, or subcoxa (fig. 42), according to the theory adopted and elaborated in this paper, becomes incorporated into the body wall to form the pleuron in the Insecta and Chilopoda. In the Crustacea, Borradaile (1917) says, the pleuropodite "may or may not have originally existed as a free joint in every biramous limb, but has now always disappeared, either by fusion with the trunk or with the second joint, or perhaps sometimes by excalation." In the Arachnida the pleuropodite has entirely disappeared. In the Pantapoda (Börner), and in the Acarina it apparently remains as a basal segment or support of the leg. In those arthropod groups that lose the pleuropodite, or subcoxa, as a free part of the limb, the rest of the appendage with its new base in the coxopodite becomes the functional leg.

In entomological terminology the pleuropodite (subcoxa) becomes the pleuron (fig. 42 C), the coxopodite is the coxa, the basipodite and the ischiopodite united form the trochanter, the meropodite is the femur, the carpopodite is the tibia, the propodite the tarsus, and the dactylopodite the pretarsus. This, at least, is a reasonable scheme of homology, though confessedly a theoretical one, and may be applied consistently in the several arthropod groups. The leg segmentation of a chilopod (fig. 42 B) conforms with it, as does also that of the Acarina (fig. 17) and the Arachnida. Exceptional opinion will be noted presently.

There is such uniformity of structure in the articulation between the usual first and second segments of the leg that this joint may be taken as invariably separating the coxa and the first trochanter. There is no apparent reason for doubting that the second and third segments of the chilopod leg (fig. 42 B) correspond with the basipodite and ischiopodite of the crustacean leg (A). The first of these segments lacks muscles in the Chilopoda, but this is explained by Verhoeff (1903a) as a device for allowing the leg to be broken off without injury to the animal, the natural break taking place at the base of the segment in the Pleurostigma and at the distal end in the Notostigma. In insects there is reason for believing, as already shown (page 78), that the basipodite and ischiopodite, or first and second

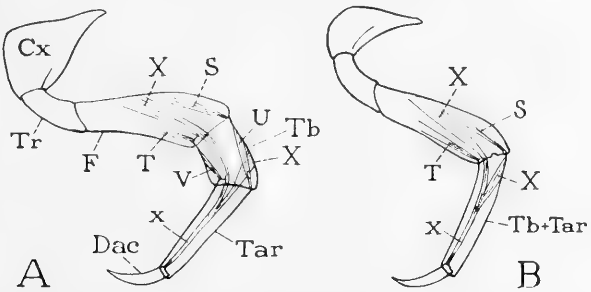

FIG. 43.—Segmentation and musculature of legs of coleopteran larvæ. (Figures from Jeannel, 1925, but differently interpreted, and re-lettered.)

A, leg of larva of *Trechus,* with usual six segments; B, leg of larva of Bathisciinæ, with five segments. *Cx,* coxa; *Dac,* dactylopodite; *F,* femur; *S,* levator of tibia, *T,* depressor of tibia; *Tar,* tarsus; *Tb,* tibia; *Tb + Tar,* tibiotarsus; *U,* levator of tarsus; *V,* depressor of tarsus; *X, X,* branches of depressor of dactylopodite; *x,* tendon of *X,* inserted on base of dactylopodite.

trochanter, have united to form the usual single trochanter (fig. 42 C). The presence of a reductor femoris muscle in the trochanter identifies the trochantero-femoral joint with that between ischiopodite and meropodite in Crustacea and Chilopoda (A, B).

The principal bend, or "knee," in the telopodite of the arthropod leg is regarded by Börner as being in all cases the joint between meropodite and carpopodite. Jeannel (1925) takes exception to this view, since he believes that in insects the tibia and the tarsus are subdivisions of the propodite, and that the carpopodite has been lost from the leg of all insects, except in those coleopteran larvæ of the Adephaga group that have six segments in the leg (fig. 43 A). In other larvæ, he claims, the six segments result from a division of the propodite into tibia and tarsus. Jeannel would find a remnant of the carpopodite in the small sclerite of the ventral membrane of the knee joint to which the flexor muscle is here often attached. As already pointed out, however, this interpretation seems entirely unnecessary, since there is no evidence that the tibia and tarsus are not primitive limb segments, as the tarsal muscles indicate. In coleopteran larvæ with a five-segmented leg (fig. 43 B), therefore, it is most probable that the tibia and tarsus are united, as also is indicated by the attachment of the first branch of the pretarsal muscle (*X*). Muscle insertions in many places are upon small chitinizations of an articular membrane, rather than directly upon the part to be moved by the muscle.

The idea that the pretarsus of the insect represents a primitive leg segment has not been generally accepted, some entomologists regarding it as a sixth segment of the tarsus, while others see in the terminal

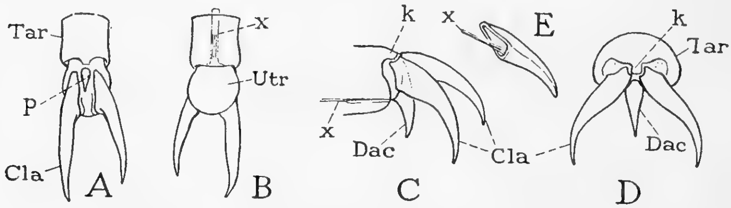

Fig. 44.—Terminal foot structures of Thysanura.

A, hind claws and end of tarsus of *Japyx*, dorsal view, showing rudimentary median claw (*p*). B, same, ventral view, showing large unguitractor plate (*Utr*). C, foot of *Lepisma*, lateral, with dactylopodite-like median claw (*Dac*) to which is attached tendon (*x*) of depressor muscle. D, same, end view. E, median claw, or dactylopodite, of *Lepisma*, with piece of depressor tendon (*x*).

structures only special developments of the last tarsal segment. The present writer, however, would now adopt the view so well stated and so fully illustrated by de Meijere (1901), that the pretarsus, including the claws, the arolium, and all accessory parts of the foot is a development of the dactylopodite of the generalized arthropod limb.

A pretarsus having the form of a simple claw-like dactylopodite occurs in the Protura, in some of the Collembola, in caterpillars, sawfly larvæ, and in most beetle larvæ. In the Lepismidæ each pretarsus has three claws, there being a slender decurved median claw between the two lateral claws (fig. 44 C, D, *Dac*). The median claw is a hollow structure (E) with the unguitractor tendon (*x*) attached to its base, and, if the lateral claws were lacking, it would constitute a miniature but typical dactylopodite. In *Japyx* the ventral part of the pretarsus apparently has become developed into a large unguitractor plate (fig. 44 B, *Utr*), while a point that is perhaps its tip remains as a rudimentary median claw (*p*). In *Campodea* and *Machilis* the median claw has disappeared and only the lateral claws remain. The median arolium of many pterygote insects might be regarded as the transformed body of the dactylopodite, though it appears more likely that arolium, empodium, and pulvilli are all secondary formations.

The origin of the two lateral claws of the insects pretarsus should be determined by a study of the transformation of a single-clawed larval pretarsus, such as that of a caterpillar, into the two-clawed structure of the adult, but this has not been done. De Meijere believes that the claws are merely outgrowths of the base of the dactylopodite, though he admits no evidence of this has been found in insects, but he points out that the possibility of claws arising thus is shown by the presence of dorsal claw-like structures on the dactylopodite of certain isopods (*Iaera, Janira, Munna*). The articulation of the claws to the end of the tarsus might suggest that they belong to the tarsus, as claimed by Jeannel (1925), but the fact that the cavities of the claws open through their wide bases into the lumen of the pretarsus shows that the claws belong to the terminal segment. The tarsal articulation of the claws, then, becomes of no more significance than the articulation of any other leg segment to the segment proximal to it. That the claws are not transformed setæ is demonstrated by their multicellular structure, and by the frequent occurrence of true setæ upon them.

There still remains to be discussed the question as to what was the nature of the first articulations between the segments of the insect leg. Börner (1921) believes that the double, or dicondylic, hinge is the primitive one, and that the single articular point, or monocondylic hinge, has resulted from a dorsal migration and union of anterior and posterior condyles. Prell (1912) argues the reverse, basing his claim on the fact that the joints of the telopodite in the Protura have each a single dorsal articulation, and are provided with flexor muscles only. The coxo-trochanteral joint is so constantly dicondylic in arthropods that there is no reason for supposing it ever had any other structure; but the common occurrence of monocondylic articulations at the other joints in the legs of larvæ of holometabolous insects, and their association with a dactylopodite-like end segment, as in the Chilopoda (fig. 32), furnishes a basis for believing that the primitive joints in the telopodite of the insect leg were of the monocondylic type. Further evidence of this is to be seen in the fact that the segments of the maxillary and labial palpi are provided each with only one muscle, a condition seldom found in connection with dicondylic joints.

Though the leg of a caterpillar, both in its structure, as compared with the leg of a centipede (fig. 32), and in its musculature, as compared with that of a proturan (fig. 41), irresistibly suggests that it is a primitive organ, it must yet be noted that, in the larvæ of Neuroptera and Trichoptera, the adults of which certainly stand below the Lepidoptera, the legs have a dicondylic knee joint and two terminal claws. The same apparent phylogenetic discrepancy is to be observed in the Coleoptera, where the larvæ of most Adephaga have two claws, and those of other groups only one claw. It should be recognized, however, as shown by Berlese (1913), that the larvæ of different insects do not necessarily represent equivalent ontogenetic stages, nor, therefore, equivalent phylogenetic stages. The larvæ of more generalized adults are likely to have acquired many adult characters, while those of more highly specialized adults may be of an earlier ontogenetic stage and, consequently, may retain more primitive characters.

VI. SUMMARY (EVOLUTION OF THE THORAX)

A brief review of the principal points elaborated in the preceding discussions may be presented in the form of an outline of the probable evolution of insects, since the specializations of the thorax and its appendages constitute the most distinctive characters of insects.

1. In the primitive, segmented, but soft-bodied ancestors of the arthropods, the limits of the body segments coincided with the lines of attachment of the principal dorsal and ventral longitudinal muscles. Modern adult arthropods, however, with solid body wall plates, have developed a secondary segmentation, to allow a forward contraction of the body, through the union of the muscle-bearing ridges of the body wall with the segmental plates following, thus converting the membranous posterior parts of the segments into the functional but secondary intersegmental areas.

2. In the evolution of insects, as shown by ontogeny, and probably of all arthropods, the earliest differentiation in the long, segmented body consisted of the union of the anterior two or three segments to form a primitive head, or procephalon, containing the first three nerve centers condensed into a brain.

3. The distinctive character of insects began with the development of the thorax as the locomotor center of the body, this being accompanied by the reduction of the appendages on most of the segments following, and the transformation of those on the three segments immediately preceding into gnathal organs, the segments of which later unite with the procephalon to form the definitive head. The newly

localized center of gravity from now on determined the general form and proportions of the body parts. The specialization of the thorax before wings appeared consisted of structural changes better adapting its segments to the functions of supporting the legs and of giving more efficient attachment and action to the leg muscles.

4. The limbs of primitive arthropods were probably rather simple appendages growing outward from the lateral or pleural areas of the segments between the dorsum and the venter. They probably turned forward and backward on their bases, each being moved by promotor and remotor muscles, fibers of each set arising on the dorsum and on the venter, or on the tergum and the sternum when segmental plates were developed. The second segment of the limb most likely moved in the opposite direction from the basal one, *i. e.,* it turned dorsally and ventrally by a longitudinal axis on the first, and was provided with abductor and adductor muscles. The third segment moved in the same plane as the second, on a longitudinal axis with the latter. The proximal three segments of the primitive limb were the subcoxa, the coxa, and the first trochanter.

5. As the evolving limb came to need more solid support, the subcoxa became flattened out in the pleural wall of its segment, and lost its power of motion. A dorsal piece of the distal rim of the subcoxa, bearing the anterior and the posterior articulations with the coxa, separated from the basal part, and the ventral region of the latter degenerated, or united with the edge of the sternum. The subcoxa thus became reduced to a basal eupleural arch and a distal trochantinal arch, the two lying concentrically over the base of the coxa, and having now the status of chitinous elements in the pleural wall of the body segment.

6. The coxa, thus forced to replace the subcoxa as the functional base of the limb, had to adapt itself to its new responsibilities. By a shifting of its posterior articulation with the trochantin to a dorsal position, it preserved for the limb the power of forward and backward movement. With the change, however, the coxa, acquired in addition the possibility of a partial rotary motion, but, while it retained its transverse movements, its abductor muscles lost efficiency through the altered position of the articulation. The assumption by the coxa of the former duties of the subcoxa involved a transfer of the subcoxal muscles to the coxa. The dorsal promotor and remotor muscles functioned still as such when attached to the coxa, but the ventral muscles became rotary muscles, since the coxa was now free to turn on its dorsal articulation. The abductor and adductor muscles of the coxa, the first retaining its origin on the subcoxa (now

the pleuron), but the second being transferred to the sternum, still act in their original capacities. The dorsal promotor is the last subcoxal muscle to be given over to the coxa, being retained by the trochantin until this sclerite becomes rudimentary or disappears.

7. Before the wings appeared, or while they were developing into organs of flight, the tendency of the subcoxa, now the chitinous pleuron of the segment, apparently was to break up into various pieces that would allow flexibility to the lateral segmental wall. In the Apterygota, the eupleural and trochantinal arches remain separate, and both have become variously reduced. In the Protura the eupleural arch has broken up into a number of sclerites corresponding in a general way with the eupleural plates of the Pterygota, perhaps indicating that the proturan ancestors were nearly related to the ancestors of the Pterygota; but in the other Apterygota the eupleuron has become degenerate, and suggests no evolution toward the pleural pattern of the Pterygota. In the early Pterygota, the eupleural arch became divided into a dorsal plate, an anterior plate before the coxa, and a posterior plate behind the coxa. The trochantin, still carrying the coxal articulations, remained an independent sclerite for a while, but its dorsal part later united with the dorsal eupleurite. The compound plate thus formed then became strengthened by an internal ridge extending upward from the dorsal articulation of the coxa, and the corresponding external suture divided the plate into episternum and epimeron. The anterior part of the trochantin has become detached in many insects to form a free sclerite still bearing the anterior coxal articulation. In the higher pterygote groups the evolution of the pleuron has been toward a reunion of the sclerites to form a solid segmental wall, especially in the wing-bearing segments. Where the free remnant of the trochantin is lost, the coxa may acquire a ventral articulation with the sternum, as in some of the Apterygota.

8. When the thorax became set apart as a locomotor region, the overlapping of its segmental plates and the telescoping of its segments became a handicap to its functional development. To counteract its mechanical weakness, the muscle-bearing parts of the sterna were transferred from the anterior margins of the sternal plates to the posterior margins of those preceding, thus bringing about a reversal in the segmental relations of the ventral muscle attachments in the thorax from those in the abdomen. When furcal arms were later developed, the muscle attachments were farther transferred in part or entirely to these processes, and the poststernal parts were then lost or absorbed into the posterior margins of the principal sternal plates.

9. The wings, developed as lateral outgrowths of the dorsum, entailed the development of a second set of modifications in the thoracic structure, superposed on those already acquired in connection with the development of legs as efficient organs for terrestrial or arboreal progression. The wing lobes served at first probably as planing surfaces that enabled their possessors to glide through the air from elevated positions; there is no good evidence that they ever had any other function.

10. The wings of all insects except the Odonata are still moved principally by muscles present in the thorax when the wing lobes were first acquired. The evolution of the wings involved the development of a supporting apparatus from the dorsal part of the pleuron, changes in the terga bearing them, and a general consolidation of the mesothorax and metathorax. Since the up-and-down motions of the wings are produced by movements of the terga, the development of wing motion demanded from the first a suppression of the flexible overlapping of the terga, and this was accomplished, as in the sterna, by a transfer of the precostal margins of the third and fourth terga, together with their muscle-bearing ridges or phragmata, to the segments preceding, where they constitute the postnotal plates. The dorsal longitudinal muscles could now effect an upward bending of each tergum, giving a down-stroke to the wings, and the tergo-sternal muscles could act antagonistically as elevators of the wings by flattening the tergal arches. Since the wings have not been developed alike in the two wing-bearing segments of all the orders, the tergal readjustments vary accordingly.

11. The ridges on the under surfaces of the wing-bearing terga have been developed in response to the needs of the terga as parts of the wing mechanism. The tergal areas between the ridges, defined on the exterior by the corresponding sutures, are therefore in no sense primitive component elements of these terga, and are not to be homologized with tergal " divisions " in the other segments.

12. But few new muscles have been developed in most insects in connection with the wings. In the Odonata, however, the primitive musculature has been suppressed, and has been replaced by sets of special wing muscles attached directly to the wing bases. The Odonata, therefore, represent a highly specialized line of descent that branched off from the main pterygote stem at an early period, but apparently since the time of the oldest insects known from the paleontological records.

13. The legs of insects have undergone an evolution that has resulted in the typical leg structure of the adult, but various developmental stages are preserved in the legs of some of the lower insects, and in those of certain larval forms. The third and fourth segments of the primitive limb, the basipodite and the ischiopodite, have united into a single small segment, the trochanter. The trochantero-femoral joint, when movable, preserves its vertical axis of motion, with dorsal and ventral articulations. A reductor femoris muscle persists, but there is no productor. The femoro-tibial and tibio-tarsal joints have lost their primitive monocondylic structure in most adult insects, and have become dicondylic through the development of anterior and posterior articulations, with the acquisition of levator muscles. The tarsus, or propodite of the primitive limb, has become fragmented into a series of sub-segments, typically five, but none of these sub-segments have acquired muscles. The terminal leg segment, the dactylopodite, has developed into the complicated pretarsus of most adult insects through the suppression of the original median claw, and the development of lateral claws, a median arolium, or various other accessory lobes. A levator muscle of the dactylopodite is lacking in all insects; the depressor, with branches arising in the tibia, femur, and even the trochanter, is retained as the "retractor" of the claws, the fibers of its branches being inserted on the retractor apodeme, or "tendon," attached to the unguitractor plate in the base of the pretarsus, possibly a remnant of the original dactylopodite.

ABBREVIATIONS USED ON THE FIGURES

A, anal veins.
longitudinal dorsal muscle, indirect depressor of wing.
Ab, abdomen.
Ac, antecosta.
ac, antecostal suture.
Acx, precoxal bridge.
ANP, anterior notal wing process.
Ant, antenna.
Aph, anterior phragma.
Apl, anapleurite.
Ar, arolium.
Aw, prealar process, or bridge.
Ax, axillaries. *1Ax*, first axillary; *2Ax*, second axillary; *3Ax*, third axillary; *4Ax*, fourth axillary.

B, oblique dorsal muscle.
Ba, basalare, episternal epipleurite (parapteron).
Bs, basisternum.

C, costa, first vein of wing.
tergo-sternal muscle, indirect elevator of wing.
Cla, claw.
Cu, cubitus, fifth vein of wing.
Cv, cervix, neck.
Cx, coxa.
CxC, coxal cavity.
CxP, pleural coxal process (*b*).

D, muscle of third axillary, flexor of wing.
Dac, dactylopodite.

E, basalar coxal muscle, direct extensor of wing.
Epl, eupleuron.
Epm, epimeron.
epm, subdivision of epimeron.
Eps, episternum.
eps, subdivision of episternum.

F, subalar coxal muscle, direct extensor and depressor of wing.
femur.
Fs, furcisternum.
Fu, furca, the sternal apophyses united on median base.

G, muscle from pleural apophysis to sternal apophysis.
Gc, jaw segments of head, gnathocephalon.

H, head.
longitudinal ventral muscle.

I, promotor muscle of coxa.
I-XII, abdominal segments.
IS, first abdominal sternum.
ISg, intersegmental groove.
IT, first abdominal tergum.

J, remotor muscle of coxa.

K, anterior rotator muscle of coxa.

L, leg.
posterior rotator muscle of coxa.
LMcl, longitudinal muscles.

M, abductor muscle of coxa.
media, fourth vein of wing.
Mb, "intersegmental" membrane.
mb, secondary "intersegmental" membrane behind base of phragma.
Mer, meron.
Mth, mouth.

N, adductor muscle of coxa.

O, levator muscle of trochanter.
Op, operculum.

P, thoracic branch of depressor muscle of trochanter.
Par, parapsis, parapsidal ridge.
par, parapsidal suture.
Pc, precosta, anterior marginal lip of segmental plate before antecostal ridge and suture.
Pcx, postcoxal bridge.
Ph, phragma.
Pl, pleuron.
PlA, pleural apophysis.
pla, external root of *PlA*.
PlR, pleural ridge.
PlS, pleural suture.
PN, postnotum (postscutellum) postalar tergal plate of winged segment, bearing phragma, consisting of precosta and posterior lip of phragma, usually detached from following tergum.
PNP, posterior notal wing process.
Pph, posterior phragma.
PR, ridge between prescutum and scutum.
Prc, procephalon (primitive head, not including jaw segments).
PS, poststernum (postfurcisternum and spinisternum).
ps, prescuto-scutal suture.
Psc, prescutum.
Ptar, pretarsus.
Pw, postalar bridge.

Q, coxal part of depressor muscle of trochanter.

R, radius, third vein of wing.
reductor muscle of femur.
Rd, posterior fold, reduplication, of tergum.
rd, anterior ventral margin of *Rd*.

S, levator muscle of tibia.
sternum.
SA, sternal apophysis.
Sa, subalare, epimeral epipleurite (parapteron).
sa, external root of sternal apophysis.
Sc, subcosta, second vein of wing.

Scl, scutellum.
Scx, subcoxa.
Sct, scutum.
sct, subdivision of scutum.
Seg, segment.
Sp, spiracle.
Spn, spina, median process of poststernum.
Sty, stylus.

T, depressor muscle of tibia.
tergum.
Tar, tarsus.
Tb, tibia.
Tg, tegula.
Th, thorax.
Tn, trochantin.
Tr, trochanter.

U, levator muscle of tarsus.

V, depressor muscle of tarsus.
VR, ridge between scutum and scutellum.
vs, scuto-scutellar suture.

WP, pleural wing process.

X, depressor muscle of dactylopodite, retractor of claws.
x, "tendon" of *X.*

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A GROUP OF SOLAR CHANGES

BY
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A GROUP OF SOLAR CHANGES

By C. G. ABBOT

The author recently published[1] a new method of testing the variability of the sun. Heretofore such variation has been indicated only by successive observational values of the solar constant of radiation. The new method depends on the selection of moments when the sun is equally high above the horizon, the atmosphere equally clear, the quantity of atmospheric water vapor identical, and the month of the year the same, so that the temperature conditions will be substantially comparable, both around the recording instrument and in the atmosphere itself.

Under such circumstances, if they could be met ideally, the atmosphere, although it reduces the intensity of the sun's radiation, reduces it in the same proportion on every chosen occasion. Accordingly, the pyrheliometric measurements of total solar radiation made at such moments should show the same percentage variations of the sun as the solar constant observations, in which atmospheric influences are, as we suppose, eliminated. Since the most critical selection must admit some inequality in sky conditions, the new method is not applicable to individual days, but gives good results only for means of fairly numerous groups of days, such as occur in the course of a month of observing.

The new test of comparative pyrheliometry on selected days was applied to the observations of the months of July from 1910 to 1920,[1] omitting the years 1912 and 1913 when the great volcanic eruption of Mt. Katmai, Alaska, rendered the atmosphere so hazy that no suitable days could be found for comparison. The results are shown in figure 1, in which the single smooth curve represents the selected pyrheliometric observations, the dotted curve represents the hitherto published solar constant work, and the double full curve represents the variation of the Wolfer sun-spot numbers. It will be seen that, except for the year 1914, the new test is closely confirmatory of the solar variation shown by the published solar constant work, and that there is an exceedingly close correspondence between

[1] See Monthly Weather Review, May, 1926.

the variations of the sun's total radiation and the variation of the visible spottedness.

A second trial of the new method of testing solar variation was undertaken with the observations of the Smithsonian station at Mt. Montezuma, in Chile, from 1920 to 1926. The work was carried through for each of the twelve months of the year. In this method of working, one determines the general mean values, including all the selected days for all the months of a given name, as, for instance, the month of January, both for the selected pyrheliometry and for the published solar constant values. He then determines the percentage differences of the mean values of each individual month of

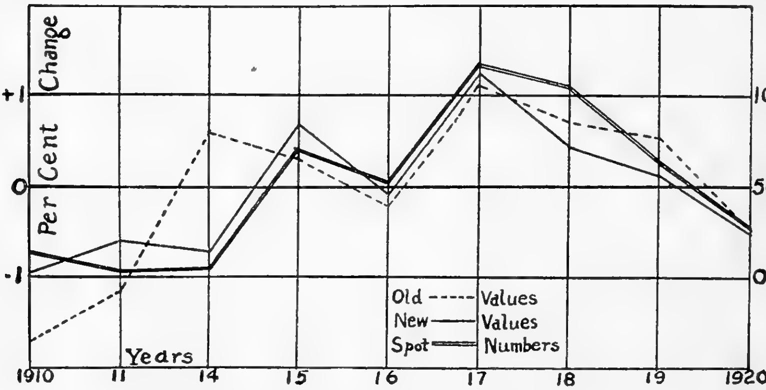

FIG. 1.—Selected pryheliometry, solar constant, and sun-spot numbers compared. Mt. Wilson work, Julys 1910-1920.

January for the series, from the appropriate general mean. If no changes of scale in the solar constant observations occur, the two series (pyrheliometric and solar constant) ought to show, within experimental error, the same march of the percentage deviations; but if, owing to the introduction of new observers, new methods of observation, or of reduction, the scale of the solar constant values is altered from time to time, then the correspondence between the two series is impaired. Such, indeed, proved to be the case at Montezuma. The accompanying table gives the collected results on selected pyrheliometry and solar constants for all months from 1920 to 1926.

I give the weights and the weighted mean percentage departures in each instance. It will readily be seen by comparing the differences of percentage departures, as given in italic type, that for considerable intervals these differences run along roughly alike from month to month and then abruptly change. In this way they indicate that several small changes of scale occurred in the solar constant observations.

TABLE 1.—*Percentage Departures of Selected Pyrheliometry and Solar Constant Values from General Means Montezuma, 1920 to 1926*

Weights assigned regarding numbers of days and character of observations

	1920					1922					1924					1926				
	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant
January	....	....	....	....	....	5	+.11	+.91	+*.80*	+.50	7	+.50	−.21	−*.71*	+.15	5	+.41	+.06	−*.35*	+.41
February	....	....	....	....	....	3	−.39	+.14	+*.53*	−.27	7	−.45	−.11	+*.34*	−.39	4	+1.20	+.36	−*.84*	+.71
March	....	....	....	....	....	7	−.10	+.46	+*.56*	+.05	17½	−.38	−.04	+*.34*	−.32	11	+.48	+.36	−*.12*	+.71
April	....	....	....	....	....	3	−.35	+.10	+*.45*	−.31	16	−.58	−.33	+*.25*	−.65	22	+.03	−.12	−*.15*	+.23
May	....	....	....	....	....	2	−.55	.00	+*.55*	−.41	24	−.37	+.17	+*.54*	−.11					
June	....	....	....	....	....	2	+.38	−.05	−*.43*	−.46	16	−.28	.00	+*.28*	−.28					
July	....	....	....	....	....	....	....	....	....	....	18	−.68	−.17	+*.51*	−.45					
August	17	−.25	+.12	+*.37*	−.36	....	....		....	....	12	−.78	−.43	+*.33*	−.71					
September	14	+.42	+.65	+*.23*	+.17	2	−1.64	−.52	+*1.12*	−.93	13	−1.16	−.89	+*.35*	−1.09					
October	13	−.56	+.61	+*1.17*	+.13	5	−.72	−.38	+*.34*	−.79	17	−.23	−.11	+*.12*	−.39					
November	5	+.10	+.43	+*.33*	−.05	3	−1.26	−.48	+*.78*	−.89	16	−.09	−.28	−*.19*	.56					
December	6	+.58	+.59	+*.01*	+.11	....	....	....	....	....	11	−.80	−.31	+*.49*	−.59					

	1921					1923					1925				
	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant	Weight	Pyrheliometry	Solar constant	Solar constant minus pyrheliometry	Corrected solar constant
January	....	....	....	....	....	4	+.08	.00	−*.08*	+.36	8	−.64	−.54	+*.10*	−.82
February	....	....	....	....	....	2	−.15	−.26	−*.11*	+.10	....	....	....	....	....
March	....	....	....	....	....	9½	+.22	−.65	−*.87*	−.29	8	−.02	+.26	+*.28*	−.02
April	....	....	....	....	....	14½	+.05	−.54	−*.59*	−.18	18	+.62	+.70	+*.08*	+.42
May	....	....	....	....	....	8	−.24	−.64	−*.40*	−.28	23	+.49	+.42	−*.07*	+.77
June	2	−.05	+.52	+*.57*	+.04	10	−.28	−.41	−*.13*	−.05	22	+.31	+.20	−*.11*	+.55
July	3	+.64	+.67	+*.03*	+.67	6	+.41	−.26	−*.67*	+.10	10	+.79	+.29	−*.50*	+.64
August	....	....	....	....	....	5	+.55	+.23	−*.32*	+.59	17	+.66	+.12	−*.54*	+.47
September	4	+1.44	+.89	−*.55*	+1.25	17	−.24	−.07	+*.17*	+.29	23	+.47	+.03	−*.44*	+.38
October	7	+.38	+.13	−*.25*	+.49	14	−.25	−.45	−*.20*	−.09	16	+1.04	+.14	−*.90*	+.49
November	9	+.23	+.40	+*.17*	−.01	15	−.25	−.11	+*.14*	+.25	17	+.64	+.32	−*.32*	+.67
December	7	+.13	+.21	+*.08*	−.20	3	+.13	−.34	−*.47*	+.02	9	+.46	−.06	−*.52*	+.29

Weighted Differences

1920 Aug. to 1921 June....	+*.48*
1921 July	*.00*
1921 Sept. to 1921 Oct......	−*.36*
1921 Nov. to 1922 Dec.....	+*.41*
1923 Jan. to 1924 Jan......	−*.36*
1924 Feb. to 1925 Apr.....	+*.28*
1925 May to present	−*.35*

These changes in scale of solar constant values have been determined by averaging the differences (given in italics in table 1) throughout such intervals as they remained similar in magnitude. These intervals were found to coincide closely with intervals between known changes of procedure, which might have affected the scale of solar constant values. Based upon these facts, and allowing also for small watch errors, the corrections of table 2, in percentages, and in calories per square centimeter per minute, have been determined to reduce all Montezuma observations to the scale which prevailed from August, 1920, to June, 1921, and which is believed to accord closely[1] with the Mount Wilson scale of 1905 to 1920.

These corrections of scale depending on changes of procedure, and whose respective influences extend continuously for definite intervals of many months, having been applied to the percentage changes of solar constant values given in table 1, the resulting curves of solar variation for the twelve months of the year are given in figure 2, both as depending on selected pyrheliometry, and as depending on corrected solar constant values. The agreement between these curves is really extraordinary. It will be seen that a general similarity of the curves to those of the sun-spot variation is found, but it is not for all months as close as was found for the months of July, 1910, to 1920.

As meteorologists in various parts of the country are interested in theoretical and practical studies of the variation of the sun, I have thought best to furnish the following table 2 of monthly mean solar constant values as originally published and now corrected by taking account of the aforesaid changes of scale and of eccentricity of the watches of observers. The table begins with August, 1918, and ends with December, 1926. These values are not the final definitive ones which we shall publish soon, when the laborious recomputation of all recent solar constant results is completed, but they will probably differ very little from the final values. They lead to the curve given at the top of the accompanying figure 3. The Wolfer monthly mean sun-spot numbers for the same interval of years are plotted in the second line. It will be seen that while there is a general tendency for higher solar radiation when sun spots are numerous,

[1] Thus from Monthly Weather Review, May, 1925, it appears that the method of selected pyrheliometry verifies the corrections of solar constant at Mount Wilson of 1919 and 1920, as given on pages 177 to 180 of Annals of the Astrophysical Observatory, Vol. IV. These citations indicate for Mount Wilson (mean of 100 values of 1918 to 1920, excluding July, 1918, and September, 1920) 1.950 calories. Correspondingly, table 2 gives 1.946 calories.

yet the correspondence of the two groups is not exceptionally close.

Figure 4, which was prepared some years ago to represent the relationship between solar constant values and sun-spot numbers, from all of the Mt. Wilson, Calama, and Montezuma observations at that time available, indicates that the increase of solar radiation

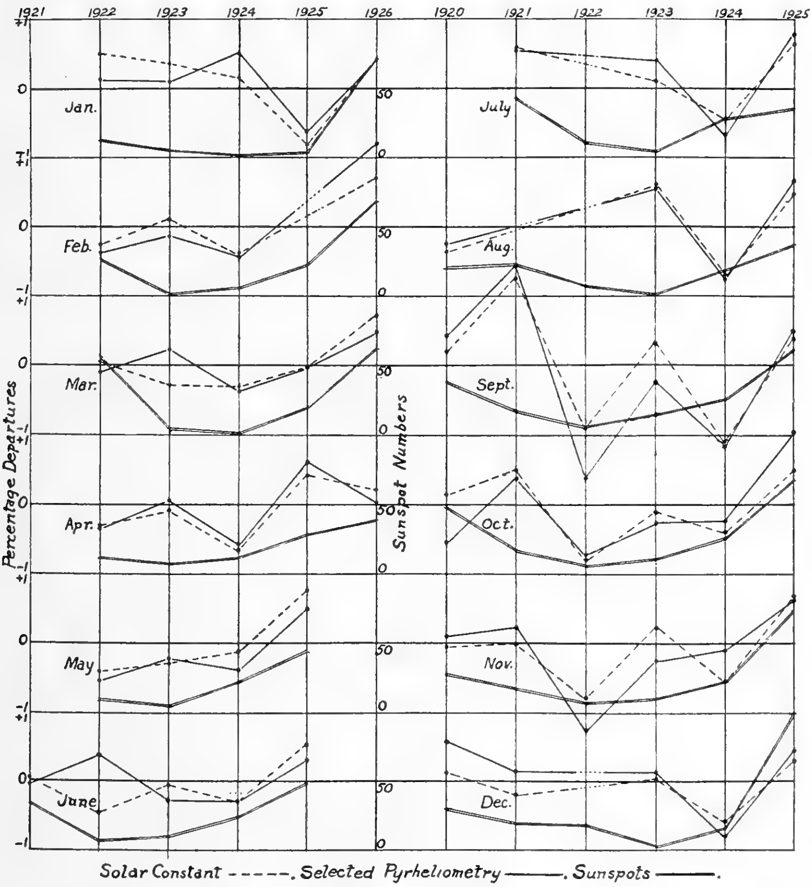

FIG. 2.—Montezuma observations, all months, 1920 to 1925.

attending a given increase of sun-spot numbers is decidedly greater when the total spottedness is small than when it is large. If this consideration is kept in mind in examining figure 3, it will be seen, in part, why the correspondence of the two curves is less marked than perhaps might have been expected.

However, a new, and, as it seems to me, very important consideration also influences the relationship between the two curves of

TABLE 2.—*Monthly Mean Solar Constant Values from Chilean Stations*

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1918	Published	.....	.....	.....	.....	.....	.....	.....	1.954	1.944	1.939	1.941	1.962
	Corrected	.....	.....	.....	.....	.....	.....	.....	1.954	1.944	1.939	1.941	1.962
1919	Published	1.943	1.949	1.941	1.953	1.940	1.955	1.954	1.953	1.939	1.953	1.953	1.950
	Corrected	1.943	1.949	1.941	1.953	1.940	1.955	1.954	1.953	1.939	1.953	1.953	1.950
1920	Published	1.964	1.956	1.945	1.952	1.953	1.939	1.945	1.930	1.947	1.944	1.948	1.957
	Corrected	1.964	1.956	1.945	1.952	1.953	1.939	1.945	1.930	1.947	1.944	1.948	1.957
1921	Published	1.955	1.956	1.949	1.944	1.943	1.939	1.947	1.935	1.953	1.946	1.950	1.952
	Corrected	1.955	1.956	1.949	1.944	1.943	1.939	1.956	1.944	1.969	1.962	1.951	1.953
1922	Published	1.947	1.942	1.937	1.930	1.924	1.913	1.911	1.918	1.922	1.926	1.928	1.914
	Corrected	1.948	1.943	1.938	1.931	1.925	1.914	1.912	1.919	1.923	1.927	1.929	1.915
1923	Published	1.930	1.912	1.912	1.912	1.916	1.918	1.926	1.931	1.934	1.930	1.931	1.923
	Corrected	1.946	1.930	1.932	1.932	1.936	1.928	1.936	1.941	1.944	1.940	1.941	1.933
1924	Published	1.931	1.922	1.919	1.917	1.922	1.929	1.922	1.918	1.920	1.929	1.930	1.931
	Corrected	1.941	1.920	1.927	1.925	1.930	1.937	1.930	1.926	1.928	1.937	1.938	1.939
1925	Published	1.925	1.936	1.931	1.933	1.931	1.927	1.933	1.930	1.936	1.934	1.936	1.936
	Corrected	1.925	1.936	1.931	1.933	1.943	1.939	1.945	1.942	1.948	1.946	1.948	1.948
1926	Published	1.938	1.927	1.929	1.921	1.922	1.925	1.928	1.930	1.929	1.926	1.918	1.921
	Corrected	1.950	1.939	1.941	1.933	1.934	1.937	1.940	1.942	1.941	1.938	1.930	1.933

Reduction to 1920 Depending on Comparison of Solar Constants with Selected Pyrheliometry

Between dates	Per cent	Calories
1920 Aug. 1 to 1921 June 30	0.00	0.000
1921 July 1 to 1921 Aug. 31	+0.48	+0.009
1921 Sept. 1 to 1921 Oct. 31	+0.84	+0.016
1921 Nov. 1 to 1922 Dec. 31	+0.07	+0.001
1923 Jan. 1 to 1924 Jan. 31	+0.84	+0.016
1924 Feb. 1 to 1925 Apr. 30	+0.20	+0.004
1925 May 1 to present time	+0.83	+0.016

Further Reduction to 1920 Depending on Eccentricity of Second-hands of Watches Used in Pyrheliometry

Between dates	Per cent	Calories
1923 Feb. 1 to 1923 May 31	+0.2	+0.004
1923 June 1 to 1924 Feb. 29	—0.3	—0.006
1924 Mar. 1 to 1924 Dec. 31	+0.2	+0.004
1925 Jan. 1 to 1926 Dec. 31	—0.2	—0.004

figure 3. It is this: The results given in table 2 show a strongly marked periodicity of $25\frac{2}{3}$ months. I mentioned this discovery to Dr. Dayton C. Miller. At his invitation, I submitted, for harmonic analysis and synthesis by his celebrated machines, 77 successive months of solar constant results from June, 1920, to October, 1926. These he used as they are given in table 2, except that smoothed curves are drawn in some months of few observations. Dr. Miller's work is graphically shown in figure 5. The dotted curve is that which

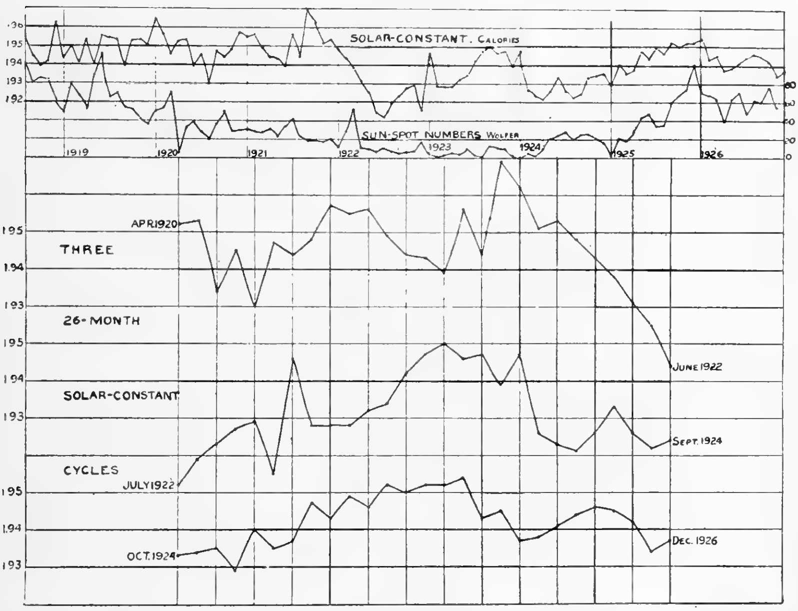

FIG. 3.—Monthly mean solar constant values, August, 1918, to December, 1926; sun-spot numbers; and indications of approximate 26-months regular periodicity in solar radiation.

I supplied. The full curve above it is synthesized from the first 30 harmonic components of it as determined by means of his machine. The first and second components are of little interest, as they give merely the effort of the machine to represent the 11-year sun-spot cycle with only $6\frac{1}{2}$ years of data. Periods of 77/3, 77/5, 77/6, 77/7, 77/9, 77/10, 77/12, 77/14 and 77/15 months, however, stand out with more or less distinctness. By far the strongest of them is the one of 77/3 or $25\frac{2}{3}$ months, but it seems to be associated with "overtones" (to borrow an expression from sound) of $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{5}$ its period. This fundamental period of nearly 2 years and 2 months has been mentioned by many authors as associated with weather and crop harvests.[1]

The period 77/5, or $15\frac{2}{5}$ months, is approximately equal to that which Professor Dinsmore Alter has been discussing as $\frac{1}{9}$ the sun-spot period, in his publications on world precipitation. It appears also in its "overtones" of $\frac{1}{2}$ and $\frac{1}{3}$ period.

Finally there is the period of 77/7, or 11 months, which Clayton and I called attention to several years ago[2] as occurring in the solar

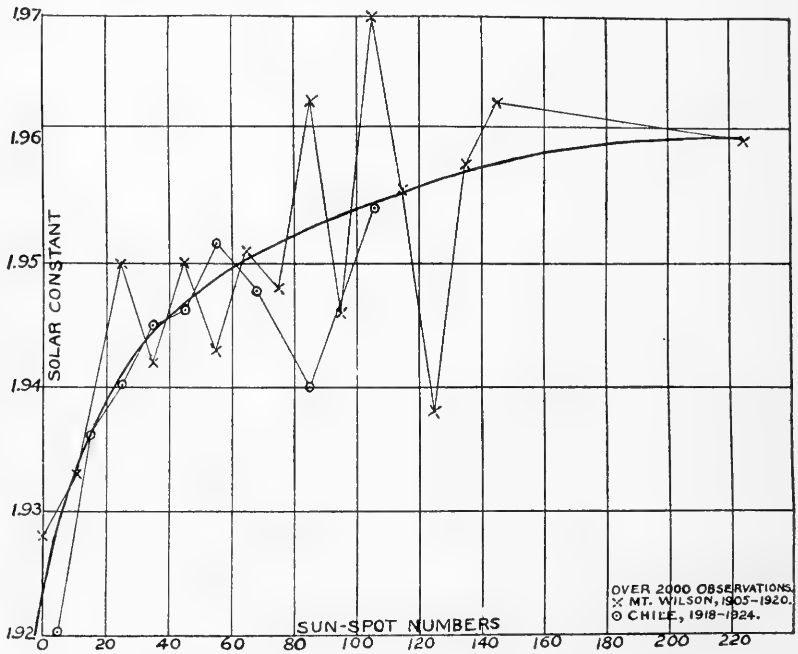

FIG. 4.—Increased sun-spot activity brings higher solar constant values.

radiation. Periods approximating this are also noted by several authors in weather phenomena.[3] An "overtone" of $\frac{1}{2}$ the period of 11 months is also distinguishable.

With his synthesizing machine, Dr. Miller built up the top curve of figure 5, and exterpolated it for several months beyond the data furnished him. Thus far the results from Montezuma have agreed well with this forecast of Dr. Miller which foretold a sharp rise of the solar constant. If, in the next few years, it should be found

[1] See Brunt, Quart. Journ. Roy. Met. Soc., Vol. 53, p. 16, and others.

[2] See Smithsonian Misc. Coll., Vol. 77, No. 5, p. 9, 1925.

[3] See Brunt, just cited, page 23.

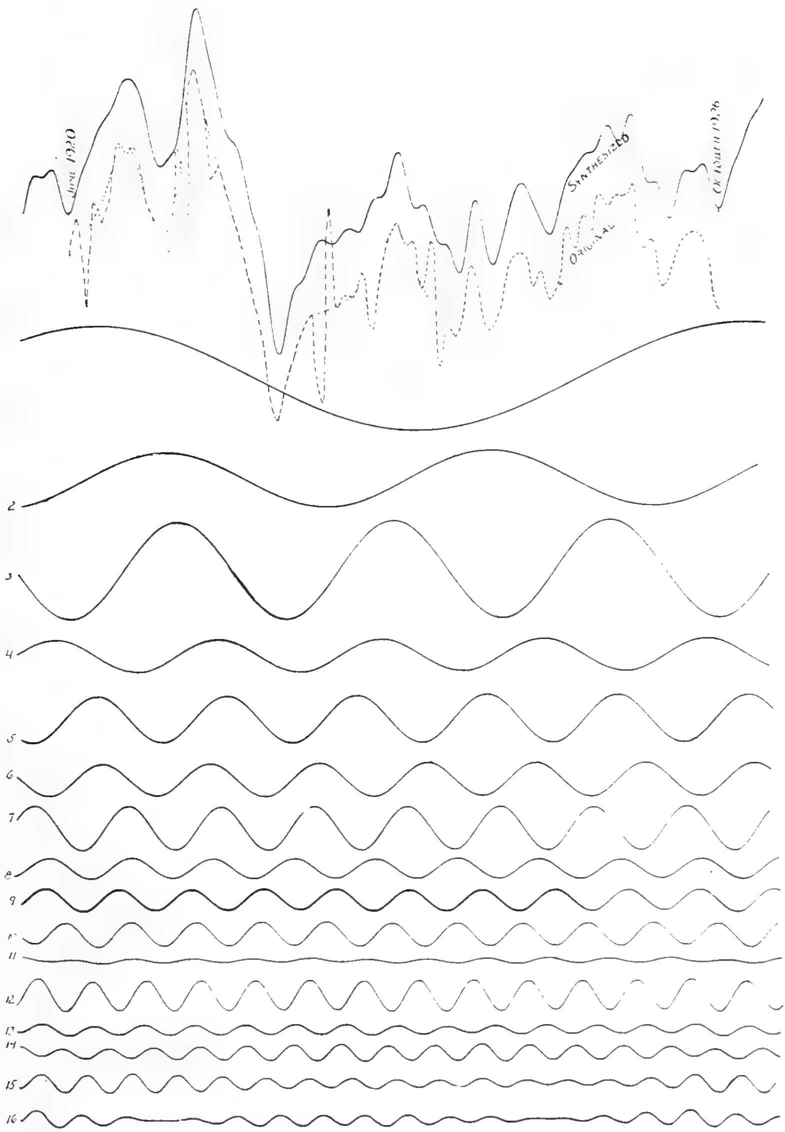

FIG. 5.—Harmonic analysis of monthly mean solar constant values.

that these definite uniform periodicities continue in solar variation, we shall be encouraged to predict the radiation of the sun for years in advance. If successful in such predictions, all that may hang upon solar variation will become equally predictable.

Contemplating the variation of the sun, one is inclined to ask whether all wave lengths take part proportionally in producing it, or whether, as one would naturally expect, the variation grows greater and greater towards shorter wave lengths. This question we answered in the latter sense several years ago, by the curves of figure 6. This indicates that, in fact, the red and infra-red vary almost not at

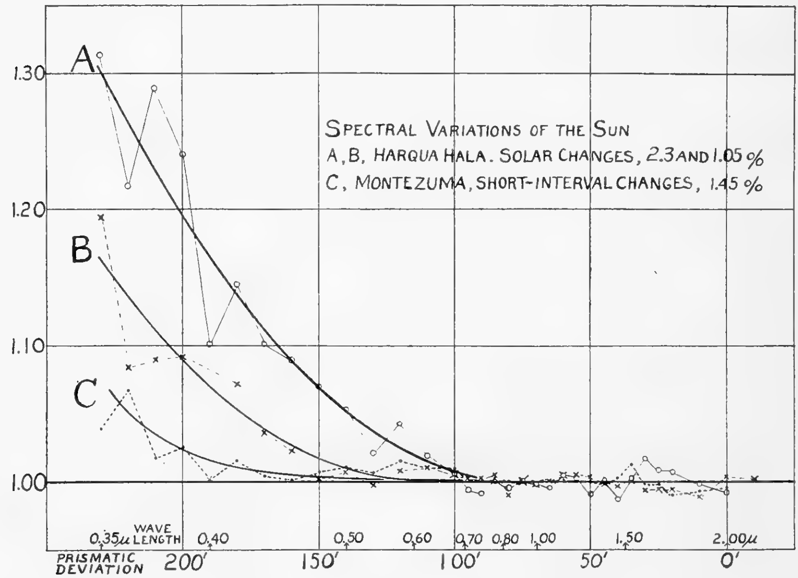

FIG. 6.—Solar variation localized in the violet and ultra-violet.

all; but that the solar variation keeps increasing, and very rapidly, as we go to the shorter and shorter wave lengths. With a range of only 2.3 per cent in total radiation, the ultra-violet, at wave length 0.35 micron, shows a variation in figure 6 of about 30 per cent. It would be supposed, in view of this, that if our observations should be continued to the limit of the solar spectrum, at 0.29 micron, we should find there, perhaps, as much as 100 per cent change. In other words, if the eye were sensitive to these extremely short wave lengths, it would see the sun twice as bright on some days as on others.

This expectation is confirmed by the observations of Dr. Pettit at Mount Wilson Observatory. By silvering a quartz lens, which thereby became opaque, except for a narrow range of wave lengths centering about 0.316 micron, he was able to select a very narrow region of ultra-violet spectrum, and compare its intensity outside the atmosphere with the intensity of the solar radiation in the green. The ratios of violet to green, in Pettit's monthly mean values, show a range of 60 per cent at a mean wave length of 0.316 micron.

It would naturally be expected that these large ultra-violet variations observed by Pettit would accompany exactly in point of time the variations of total radiation as determined by Smithsonian observations. Pettit has kindly communicated some of his results to me, and in figure 7 the two sets of observations are brought

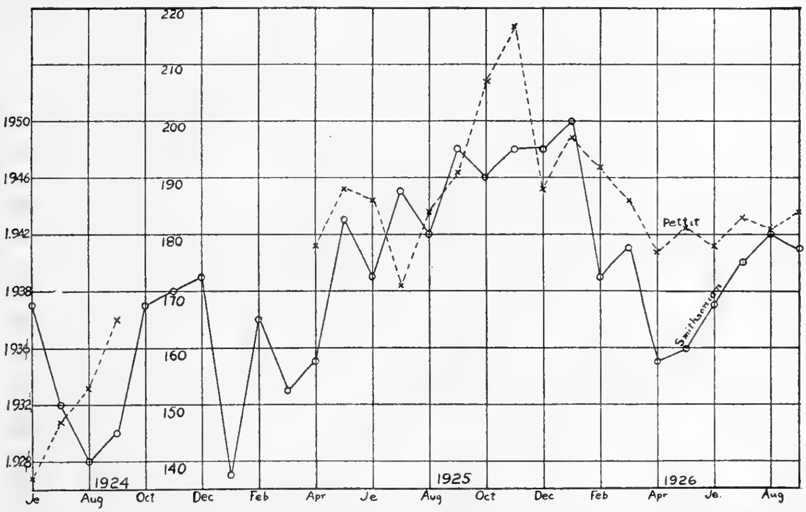

FIG. 7.—Comparison of Smithsonian monthly mean solar constant values with ultra-violet solar radiation values of Pettit.

together, with the scale of the ordinates of the Smithsonian work expanded to match that of Pettit. The agreement between the two series seems very satisfactory, in view of the fact that the range of total solar radiation is only about 1.5 per cent, so that one can not hope that the accuracy of the Smithsonian determinations is sufficient to give perfect correspondence on this very wide scale. Furthermore, Pettit has observed only on four days per month in the earlier part of his investigation; while in the latter part he has included every possible day, and among them some of doubtful uniformity of sky. In view of these circumstances it is not to be supposed that his monthly results are without considerable error.

Also, interestingly associated with solar variation are results recently communicated to me by Dr. Austin on the variation of inten-

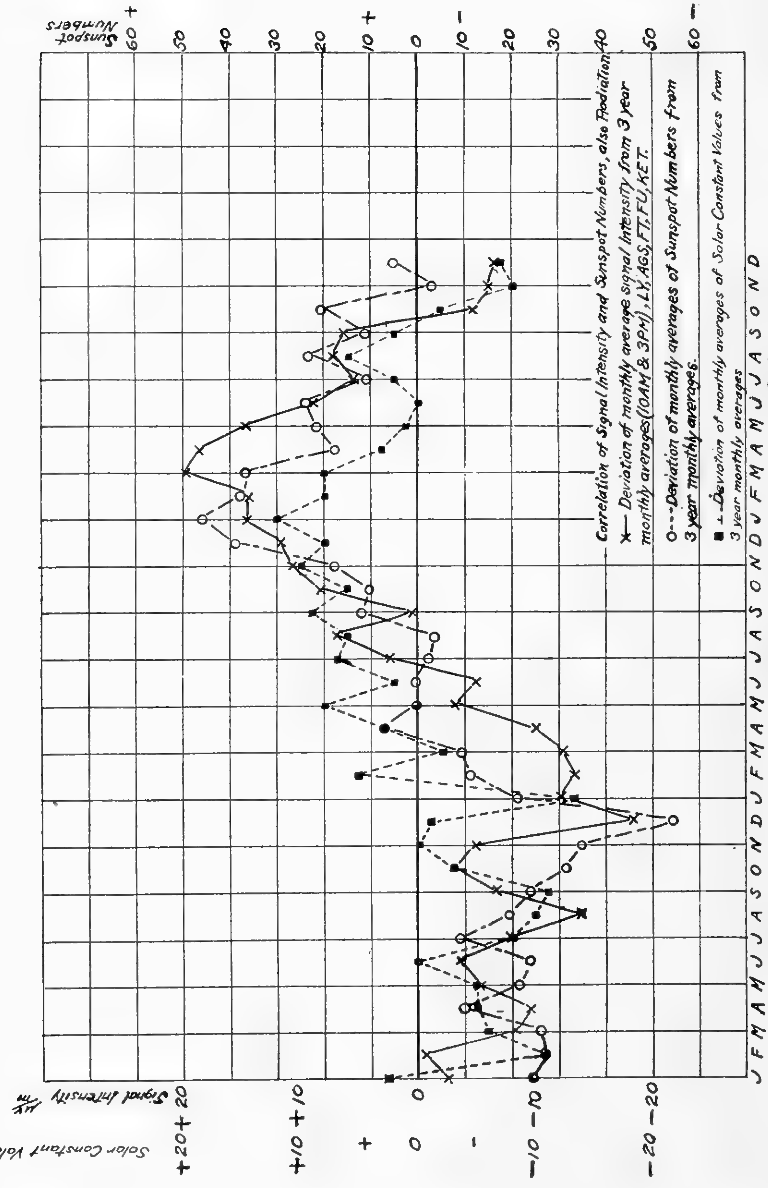

FIG. 8.—Correlation of long-range radio-signal intensity (Austin) with Wolfer sun-spot numbers, and Smithsonian monthly mean solar constant values.

sity of reception of long-range radio-transmission. Figure 8 gives three curves, as plotted by Austin. The first represents the monthly mean departures from a three-year's mean of the radio reception at Washington from several distant stations. The second curve shows similar departures of the Wolfer sun-spot numbers, and the third, the corresponding departures of the Smithsonian provisional solar constant values, given above in table 2. Dr. Austin has informed me that the probable error of his observations of individual days on radio reception is from 10 to 20 per cent, so that in the monthly means it must be from 2 to 4 per cent. The general accord of the three curves seems to indicate that the departures of monthly mean radio reception from average values are almost wholly dependent on the state of solar radiation.

In what has been said, we have been concerned only with long-interval changes of the solar radiation, and associated terrestrial phenomena. My colleagues and I have long believed that these changes are due to changes in the effective temperature of the sun's radiating surface, which depend on the activity of convection in the sun's substance. We have noted, also, solar fluctuations of such short intervals as a few days. These we attribute to the rotation of the sun which brings successively opposite to the earth regions of unequal radiating power, or perhaps, rather, of unequal absorbing or scattering power, on the sun's surface.

In harmony with this idea, the planets, which lie in different directions, viewed from the sun, will *successively* feel the changing influence of each inequality of the solar surface, as the rotation of the sun brings such inequalities into line with the planets successively. As the sun's equator is inclined to the ecliptic, the interval of time to be allowed differs a little from that which would be the case if the inclination were zero. Furthermore, if one observes from the earth some effect upon a distant planet, due to a variation of solar emission, the time of observation will be influenced by the time required for light to travel out to the distant planet and return to the earth. For the causal irregularity of the solar surface is moving by solar rotation while the light is on the way.

In Volume IV of the annals of Astrophysical Observatory, page 190, figure 13, a not unfavorable test of this hypothesis is given, depending on a comparison of observations by Guthnick of the planet Saturn as compared with Smithsonian observations of the solar constant of radiation.

While we are considering short interval solar variations, I give in figure 9 a series of curves taken from table 6 of Clayton's paper

TABLE 3.—*Mean Barometric Pressure Following Different Intensities of Solar Radiation*

Winter Half-Years 1918-1922

Station: / Normals:		Winnipeg .08						Chicago .18						New York .08					
Solar constant in calories	Number of cases	0	Days after 1	2	3	4	5	0	Days after 1	2	3	4	5	0	Days after 1	2	3	4	5
Above 1.971	37	.09	.05	.05	.03	.08	.05	.08	.11	.13	.06	.00	.01	.06	.09	.12	.19	.06	.05
1.961 to 1.970	71	.04	.04	.03	.06	.99	.05	.00	.06	.09	.07	.05	.07	.07	.08	.10	.18	.12	.14
1.951 to 1.960	127	.05	.05	.04	.03	.07	.08	.07	.05	.09	.09	.07	.09	.04	.07	.04	.05	.09	.07
1.941 to 1.950	114	.05	.03	.05	.10	.09	.06	.08	.09	.06	.10	.12	.10	.10	.14	.11	.10	.10	.13
1.931 to 1.940	64	.01	.00	.06	.02	.05	.00	.11	.08	.09	.06	.09	.13	.09	.10	.08	.07	.07	.07
1.921 to 1.930	41	.92	.97	.97	.97	.06	.06	.05	.05	.02	.04	.11	.09	.08	.02	.10	.04	.08	.16
Below 1.920	38	.96	.02	.00	.06	.04	.98	.04	.04	.00	.05	.10	.06	.10	.07	.07	.04	.12	.09

NOTE:—When the first figures in the table are .9, add 29 inches; when they are .0 or .1, add 30 inches to give the total barometric pressures.

entitled "Solar Radiation and Weather, or Forecasting Weather from Observations of the Sun,"[1] in which the barometric pressure for the cities of Winnipeg, Chicago, and New York, are compared, corresponding to conditions of high, medium, and low solar constant values. The data from which these curves are plotted are given in table 3. In plotting the figure, the dotted curves represent the march of barometric pressure corresponding to high solar constant.

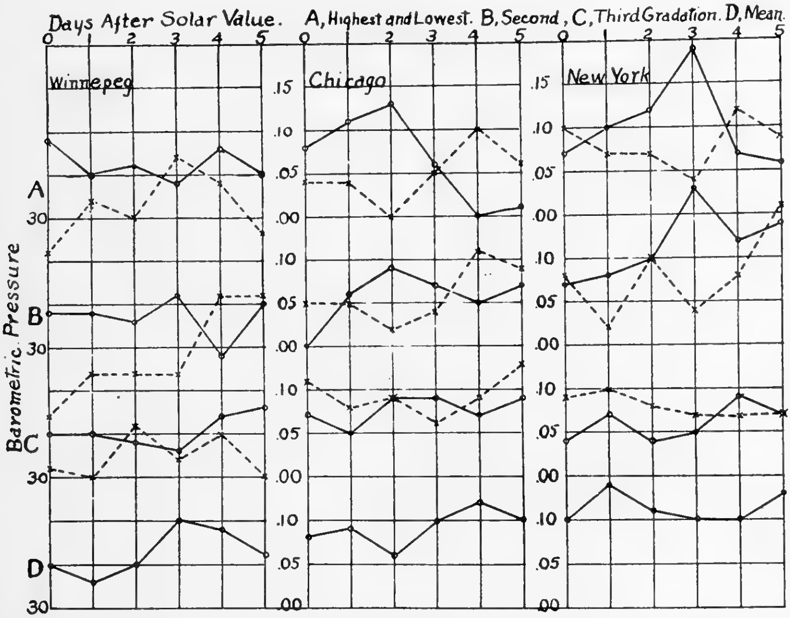

FIG. 9.—Barometric pressures attending and following high and low states of solar radiation.

In order to bring out what seems to me a strong case of continuity, I have brought together the pairs of barometric curves corresponding to the largest solar constant differences at the top of the figure, those corresponding to the smaller intervals lower down, and the mean at the bottom. It will be seen that for each of the cities the greatest deviation in barometric pressure corresponds to the greatest in solar constant, the next smaller to the medium in solar constant, and the least to the smallest difference in solar constant. The reader will perceive also that generally the full and the dotted curves run contrastingly like the right hand to the left. He will also see that the

[1] Smithsonian Misc. Coll., Vol. 77, No. 6, 1925.

largest pressure difference occurs at Winnipeg on zero day, at Chicago on the second day, and at New York on the third day after the solar constant event.

It is, of course, to be expected that any wave of disturbance of barometric pressure appearing in winter at Winnipeg on a certain day would drift eastward, and appear at Chicago and New York after about the intervals of time here shown. This is only ordinary well-known meteorological experience, and proves nothing as to the influence of solar variation. But that in the mean results of such numerous groups of cases there should remain residuals of the order of 0.15 inch in barometric pressure, and residuals so well exhibiting the principals of continuity and proportionality relative to a supposed cause seems to be, at least, very harmonious to the hypothesis that the assumed cause, solar variation, has a real relationship to the observed effects.

As it has been suggested to me that these results of Clayton's would perhaps be essentially modified had he been advised of the corrections to scale, mentioned in connection with table 2, I may add that his results concern only solar constant observations of the winter half-years between October 1, 1918, and March 31, 1922, during which only the few values of October, 1921, would be appreciably affected by the new changes of scale. It will appear, too, by inspection of figure 3, that this period was one of unusual freedom from great swings of the solar constant such as we attribute to general changes of the solar surface temperature, so that the fluctuations which he discusses will have been principally those of short interval.

From the various evidences assembled in this paper, added to many others previously published, my colleagues and myself are more and more encouraged to believe that our long investigation of solar variation will yield useful positive results.

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FOSSIL FOOTPRINTS FROM THE GRAND CANYON: SECOND CONTRIBUTION

(With 21 Plates)

BY
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Curator of Vertebrate Paleontology,
United States National Museum

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INTRODUCTION

In continuation of an investigation of the fossil footprints of the Grand Canyon, so successfully begun in 1924,[1] I was enabled, through an allotment granted by the Marsh Fund committee of the National Academy of Sciences, to visit the Canyon again in the early spring of 1926. This expedition had as its purpose the acquisition of additional fossil tracks from the Coconino and Hermit formations, and the extension of the investigation into the older Supai formation in which the discovery of fossil tracks had been reported by Mr. J. R. Eakin, Superintendent of the Grand Canyon National Park. The expedition was successful far beyond expectations, the collection made for the United States National Museum comprising a series of slabs some 2,700 pounds in weight, on which are animal tracks from three distinct and successive geological formations.

The old locality in the Coconino sandstone on the Hermit Trail was explored laterally and a large series of beautifully preserved tracks and trails secured, including many forms new to this ichnite fauna, and the Hermit shale, some 1,400 feet below the level of the Canyon rim, yielded both fossil tracks and plants. The discovery of a wing impression of a large dragonfly-like insect records for the first time the presence of such forms in the latter formation. Finally in the Supai formation at a level about 1,800 feet below the rim, another footprint horizon was located and a few poorly preserved tracks were collected from this level on both the Hermit and Yaki trails. It is upon these collections that the systematic part of the present paper is based. Even with the diversity of forms now available, it is still quite evident that further collecting will add many more varieties to the known ichnite faunas of these three formations.

I am under especial obligations to Dr. John C. Merriam and his associates on the Marsh Fund committee of the National Academy of

[1] Gilmore, Charles W., Fossil footprints from the Grand Canyon. Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, pp. 1-39, 12 plates and 23 text figures.

Sciences for the financial assistance which made this investigation possible. The loan of type specimens by Dr. R. S. Lull, Peabody Museum of Natural History, Yale University, Dr. Witmer Stone of the Philadelphia Academy of Natural Sciences, and Dr. John J. Tilton of the University of West Virginia, was of the greatest assistance in the study of the material. I wish also to express my appreciation for the help and many courtesies rendered by the various members of the Park organization. To Superintendent J. R. Eakin I am deeply indebted for the use of equipment, and assistance of personnel; to Mr. E. T. Scoyen, chief ranger, for the detail of ranger assistants, and for his personal interest on many occasions; and to Mr. G. E. Sturdevant, ranger naturalist, whose efficient help and familiarity with fossil localities contributed so much to the successful outcome of the expedition. Mr. Arthur Metszer, who acted as my assistant on this as well as on my previous trip, furnished intelligent and industrious help in making the collections, and throughout the work exhibited a personal interest in the success of the expedition second only to my own.

GEOLOGICAL OCCURRENCE OF FOSSIL TRACKS

In the Grand Canyon National Park, the tracks of extinct animals occur in three distinct geological formations which, named in descending order, are the Coconino, Hermit, and Supai. Credit for the discovery of fossil tracks in the Grand Canyon goes to Professor Charles Schuchert of Yale University, who, in 1915, while making a study of the geology of the Hermit Trail section, noted the presence of tracks in all three formations.[1] After reading his account of their occurrence it is quite apparent that he was unaware at the time of their great abundance and variety. Fossil tracks occur in considerable abundance in all of these formations and at several levels. These later investigations show that in the great variety of footprints found and in the perfection of their preservation, there are few localities that outrank this one. It is further unique in being probably the only place in the world where fossil tracks of three successive faunas may be found in one nearly vertical geological section, separated by such great geological intervals.

Tracks occur throughout a zone 130 feet thick in the lower part of the Coconino (see fig. 1), the bottom 20 feet being barren of impressions. In the Hermit shale, tracks, plants, and insects were found in the hollows or troughs eroded in the top of the underlying

[1]Amer. Journ. Sci., Ser. 4, Vol. 45, 1918, pp. 350, 354, and 357.

Supai sandstone from 30 to 40 feet above the Hermit-Supai contact. In the Supai, two levels some 25 or 30 feet apart near the middle of that formation are track-bearing. Thus these evidences of past life range through over 800 feet of strata. These horizons lie, roughly stated, as follows: Coconino, 900 to 1,030 feet; Hermit, 1,350 to 1,400 feet; and Supai, 1,760 to 1,800 feet below the top of the Canyon wall.

At the present time tracks are known in these formations on the Yaki and Hermit Trails only, but doubtless their geographical range will be rapidly extended now that their precise levels have been ascertained. A more detailed discussion of the occurrence and character of the beds in which the tracks are found is given below.

Coconino sandstone.—The Coconino sandstone and the manner of occurrence of its fossil footprints was discussed at some length in my previous paper,[1] and at this time it seems only necessary to record such observations as resulted from my later visit to the Canyon.

The curious fact that the trend of nearly all of the tracks and trails was in one direction, that is, up the slope of the crossbedded sandstones, has previously been noted, and examination of many additional hundred square feet of track-covered surface of the Coconino verifies this original observation. In all of the hundreds of trails seen, only three exceptions were found. It should also be mentioned that where tracks were seen *in situ* on the Yaki Trail, this same condition obtained.

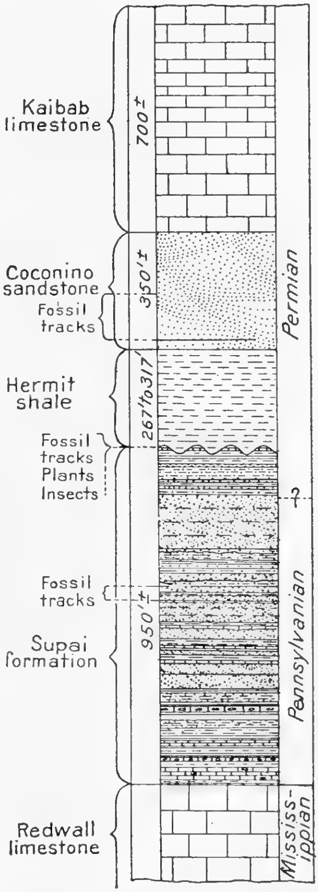

FIG. 1.—Upper part of the geological section on Hermit Trail. Position and extent of track-bearing strata indicated. (Section (modified) after Noble.)

The vertical range of tracks in the Coconino seems to be confined to the basal 150 feet of the formation of which the lowermost 20 are barren, and this same condition was found to prevail in the newly

[1] Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, pp. 1-41, pls. 1-12.

discovered locality on the Yaki Trail. More extended exploration of the Hermit Trail locality shows that tracks are abundant on both sides of the trail wherever physical conditions are such as to allow search being made for them. The track called *Laoporus noblei* Lull is the predominating species and is apparently present wherever tracks are found. Footprints of several of the species described in my former paper were recognized in the field, but only exceptional examples of these were collected as the object in mind was to secure as many different kinds as possible, in order that the complete fauna might be made known. In this we were successful to the extent of procuring specimens sufficiently well preserved on which to base three genera and ten species all new to the fauna, thus nearly doubling the faunal list; but, as stated before, it is quite apparent from a study of the new materials that a considerable number of undescribed forms may yet be found.

The ichnite fauna of the Coconino now consists of the following described genera and species:

VERTEBRATES

Agostopus matheri Gilmore
Agostopus medius n. sp.
Agostopus robustus n. sp.
Allopus ? arizonae Gilmore
Amblyopus pachypodus n. gen. and sp.
Barypodus palmatus Gilmore
Barypodus tridactylus n. sp.
Barypodus metszeri n. sp.
Baropus coconinoensis n. sp.
Baropezia eakini Gilmore
Dolichopodus tetradactylus Gilmore
Laoporus noblei Lull
Laoporus schucherti Lull
Laoporus coloradoensis (Henderson)
Nanopus merriami Gilmore
Nanopus maximus n. sp.
Paleopus regularis Gilmore

INVERTEBRATES

Mesichnium benjamini Gilmore
Octopodichnus didactylus n. gen. and sp.
Paleohelcura tridactyla Gilmore
Triavestigia niningeri n. gen. and sp.
Unisulcus sinuosus n. sp.

In the Coconino formation, fossil tracks are now known to occur at three distinct localities. On the Hermit Trail some little distance below the "White Zig Zags," where the upper part of the track-bearing horizon is marked by large cleared slabs by the side of the trail showing the footprints *in situ,* an out-of-doors exhibit was prepared on a former visit to the locality. Exploration of the slope to the north and south of this point disclosed track-covered surfaces wherever the local conditions permitted search for them. A second locality at "Dripping Springs" at the head of Hermit Gorge was not visited, although I was informed that tracks were to be found there. Dr. David White, accompanied by G. E. Sturdevant, visited this locality during the summer of 1926, and in a personal letter says: "On the Dripping Springs trail the tracks are very numerous and large ones in particular are abundant." The third locality is on the new Yaki Trail where it crosses the lower 150 feet of the Coconino sandstones some three and one-half miles east of Grand Canyon. Conditions here were not so favorable for examination of the sandstone surfaces, but numerous tracks and trails were seen; these were so poorly preserved, however, that no attempt was made to collect them. In so far as one may rely on field identifications the tracks seemed to pertain to the same species as those found in Hermit Basin, some seven or eight miles distant in an air line. Several tracks of the common *Laoporus noblei* were recognized.

That other localities yielding fossil footprints will be found in this formation there seems no question, but the precipitous face of the formation does not allow searching for them except at a few favored localities.

Hermit shale.—Schuchert, who was the first to discover fossil tracks in the Hermit shale, makes the following comments on their occurrence:[1]

Just below the sign "Red Top" in the lower turn of the Hermit Trail and immediately above the thick upper sandstones [of the Supai] are seen thin-bedded red shaly sandstones alternating with deep-red zones of shale. The surfaces of the glistening and smooth platy sandstones are replete with fillings of the small prisms of interbedded suncracked shales, often rain-pitted, and further marked by the foot impressions of freshwater amphibians described elsewhere in this number of the Journal by Professor Lull,[2] as *Megapezia ? coloradensis* and *Exocampe ? delicatula.* Some of the tracks are distinct impressions of the feet, and others are mere strokes of the toes. In these same beds also occur plant remains in very fragmentary condition which were badly macerated and coated with a slime of red mud during their entombment.

No further collection of tracks was made from the Hermit shale up to the time of the present expedition and consequently the known

[1]Amer. Journ. Sci., Ser. 4, Vol. 45, 1918, pp. 353-354.
[2] Lull, R. S., *Ibid.,* pp. 337-346.

ichnite fauna was confined to the two species mentioned above. Under the guidance of G. E. Sturdevant, who had previously made one or more prospecting trips over the Hermit shale at the head of Hermit Gorge (see pl. 1, figs. 1 and 2), we were led without loss of time to the locality from which many of the specimens described in this paper were collected. This locality may be roughly stated as being about one-quarter of a mile west of the sign "Red Top" on the slopes facing north or toward the entrance of Hermit Gorge into the main Canyon of the Colorado, and from 30 to 40 feet above the Hermit-Supai contact. The red shales that carry the tracks and plant remains lie in troughs eroded in the upper part of the Supai sandstone (see fig. 2). In some instances the knolls of sandstone rise 50 feet above the base of the hollow, and all of the tracks found

FIG. 2.—Diagram to illustrate erosional contact between the Hermit shale and Supai sandstone, and to indicate the position of the track and plant bearing horizon at *X*. (Modified from Schuchert.)

in situ came from two levels, one about 30 feet and a second 40 feet above the base of one of these troughs. Both track and plant remains were found also on the loose slabs covering these slopes even well around toward the head of Hermit Gorge opposite "Dripping Springs," but, as previously mentioned, only two thin layers were found in place. Noble,[1] however, reports finding plant remains "from beds at the base of the Hermit shale resting in depressions in the unconformity near 'Red Top' in Hermit Basin."

The Hermit shale, so named by Noble in 1922, was formerly included in the Supai formation and has a thickness in the Hermit Trail section of 317 feet measured from the base of the deepest depression in the disconformity in the top of the Supai, and 267 feet measured from the top of the highest knoll.

The Hermit shale is described by Noble as follows:[2]

The beds differ little from one another in composition and consist essentially of sandy mud colored red by ferritic pigment. The beds that I have desig-

[1] Prof. Paper No. 131, U. S. Geol. Surv., 1922, p. 66.

[2] *Op. cit.*, pp. 64-65.

nated sandstone in the section are massive and relatively compact as contrasted with the beds that I have designated shale, which are thinly laminated, but the distinction between sandstone and shale is unimportant. All the strata are friable. Many beds exhibit sun-cracks and rain-prints, some are ripple-marked. * * * Everywhere the formation makes a slope which is in strong topographic contrast with the sheer cliff of the overlying Coconino sandstone and with the steplike cliffs and ledges of the underlying Supai.

The beds containing the tracks in place are horizontal, and, where exposed to the weather, split into thinly laminated sheets; but as work was continued back into the hillside the layers became more massive.

In removing these layers it was found that one surface might be covered with tracks and plant remains and the very next one beneath devoid of all fossil evidence. Often a trackway could be clearly traced for a short distance only to become more and more indistinct and finally to entirely disappear, probably due to the varying degrees of softness of the surface at the time the animal passed over it. Some few of the trails have the imprints beautifully distinct but in many the details are destroyed by the inflowing mud after the withdrawal of the foot, which would suggest that they may have been made beneath a slight depth of water. No doubt tracks could be found in the Hermit shale at many other localities were search made for them, but such prospecting as was done where the Yaki Trail crosses the formation failed to disclose any, although plant remains were found in some abundance.

The recognition of many forms of the same genera as those described from other Carboniferous areas is of interest, especially those from Joggins and Paraboro, Nova Scotia. The conditions under which these tracks were made in such widely separated localities, seem to have been very similar as evidenced by the many resemblances not only in fauna but in the structural and lithologic features of the track-bearing rocks.

The fauna of the Hermit shale as known at this time consists of the following forms:

VERTEBRATES

Batrachichnus delicatula (Lull)
B. obscurus n. sp.
Collettosaurus pentadactylus n. sp.
Crusipes sp.
Dromillopus parvus n. sp.
Hyloidichnus bifurcatus n. gen., n. sp.
Hylopus hermitus n. sp.
Parabaropus coloradensis (Lull)

INVERTEBRATES

Dragonfly-like insect

This ichnite fauna is quite distinct from that of the Coconino which came after, or the Supai which preceded it.

Supai formation.—The Supai formation in the Hermit Trail section, as estimated by Noble,[1] has a total thickness of 950 feet. The first evidence of footprints occurring in this formation was noted by Schuchert in 1915.[2] Apparently no one gave the discovery further attention until 1925 when well defined tracks were found by G. E. Sturdevant on loose blocks of sandstone lying below the new Yaki Trail on the north end of O'Neill Butte, at a point slightly more than two miles down from the top. This information was, together with other discoveries made in the same locality, given to me by Superintendent J. R. Eakin. In all of the early discoveries the tracks were on detached blocks found lying on the hillside, and it was not until the late winter of 1926 that Dr. John C. Merriam of the Carnegie Institution of Washington, accompanied by Mr. Sturdevant, found tracks *in situ* (see pl. 2, fig. 2). These were in a sandstone layer estimated to lie in about the middle of the formation.

Unaware, at the time, of Schuchert's previous discovery of tracks in the Supai, I made this locality the first object of search in the spring of 1926, accompanied by Mr. Sturdevant. Our prospecting disclosed many additional tracks and we located a second track-bearing horizon in a light colored sandstone some 30 feet above those found by Merriam and Sturdevant.

Numerous tracks and trackways were found on blocks of stone in the débris which had been thrown below the trail in the course of excavating. No further attention was given the Supai tracks until near the close of operations when an attempt was made to locate these same track-bearing horizons in the Hermit Trail section in order that they might be considered with the other track-bearing formations in a single geological section. In this we were successful, finding the first recognizable footprints in a whitish friable sandstone to the left and below the Hermit Trail at a point about one-half mile below "Santa Maria Spring." Rather poorly preserved tracks of at least three kinds of animals were seen. The most distinct series collected is shown in plate 21. This is probably the same horizon in the formation in which Schuchert made the original discovery. The following day search was made for the lower horizon and passing backward underneath the cliff after descending the first short zig-zags above "Breezy Point," tracks were found, thus establishing their position in the section as identical with those previously found in the Yaki

[1] *Op. cit.*, pl. 19.

[2] Amer. Journ. Sci., Ser. 4, Vol. 45, p. 357.

Trail section.[1] That there is a distinct ichnite fauna in this formation is clearly evident though unfortunately the extreme hardness of the sandstone—and hence its failure to cleave in most instances—makes the collecting of tracks a problem requiring special tools and trained personnel.

Schuchert's[2] description of the Supai as exposed on the Hermit Trail is as follows:

The lower Supai formation [Supai of modern nomenclature] begins with a thick-bedded and cross-bedded cliff-making sandstone of about 150 feet in thickness. Beneath it are red sandy shales with two bands of sandstones that together have an estimated thickness of 200 feet. At the base of this zone is another horizon of thin flaggy beds with some sun-crack fillings and an abundance of rain-prints of the mammillary kind, interpreted as having been made by long continued rain. Midribs of either ferns or cycadofilices were seen and probably also indistinct feet imprints of amphibians. The trail runs along this zone for about two miles and one has a fine opportunity to study the sediments and to note the abundance of rainprints and a few rill markings.

The next lower zone is a cliff-making sandstone about 50 feet in height. Then follows one of shales 100 feet thick, that near the top has beds of septaria-like limy concretions embedded in a dark purple sandy mud. * * * associated are also thin zones of intraformational conglomerates with flat and somewhat rounded small pebbles; the shale pieces have blackened surfaces.

In the field it was estimated that the tracks occurred about 1,800 feet below the rim, but upon checking up with Noble's measurements of this section the conclusion is reached that the lowermost horizon would be about 1,767 feet down and the highest track-bearing layer about 1,717 feet below the top.

As redefined by Noble in 1922 the Supai formation is of Pennsylvanian and ? Permian age and rests with possible unconformity on the underlying Mississippian Redwall limestone. The sandstone has its grains bound together by calcareous cement as contrasted with the siliceous binding materials of the Coconino. Noble points out that the thick layers are conspicuously cross-bedded and that the prevailing dip is south as in the Coconino, and further it was noticed that in the majority of instances the trackways were ascending the slopes of the cross-bedding as in the Coconino.

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[1] As this paper was going to press, the National Museum received a slab of footprints, presented by Mr. G. E. Sturdevant, which was found by him in the Supai formation at one side of the Bright Angel Trail. In addition to its being an undescribed genus and species, it also records a new locality for tracks in the Grand Canyon.

It is also worthy of mention that Mrs. G. E. Sturdevant found a small section of the trail of some invertebrate animal in the Bright Angel shale, Cambrian, a specimen that was also donated to the National collections.

[2] *Op. cit.*, p. 357.

The tracks occur in Noble's subdivision *B* of this formation, and he is inclined to regard the entire Supai as of Pennsylvanian age. The fossil tracks so far collected are all new genera and species and offer no evidence bearing on this question.

The ichnite fauna of the Supai sandstone as known at this time consists of the following described genera and species:

VERTEBRATES

Anomalopus sturdevanti n. gen., n. sp.
Stenichnus yakiensis n. gen., n. sp.
Tridentichnus supaiensis n. gen., n. sp.

LIST OF DESCRIBED TRACKS FROM THE CARBONIFEROUS OF NORTH AMERICA

The following list of Carboniferous footprints is a complete roster of all tracks described up to the present time. This list, consisting of 34 genera and 60 species, is badly in need of revision, a task that would doubtless decrease rather than increase the totals given. In order to add to its value as a reference list, the geological horizon and general locality of each is recorded. The geological occurrence of many of the earlier described species was given as Coal Measures, but in the present list, in so far as I have been able, I have made more precise assignment of these, following the more recent age determinations.

Name	Horizon	Locality
Agostopus matheri Gilmore	Permian (Coconino)	Grand Canyon, Ariz.
Allopus ? arizonae Gilmore	Permian (Coconino)	Grand Canyon, Ariz.
Allopus ? littoralis Marsh	Pennsylvanian	Osage Co., Kans.
Anomoepus ? culbertsonii (King)	Coal Measures	Westmoreland Co., Pa.
Anomoepus ? gallinuloides (King)	Coal Measures	Westmoreland Co., Pa.
Anthracopus ellangowensis Leidy	Pennsylvanian	Mahanoy Coal Field, Pa.
Asperipes avipes Matthew	Coal Measures	Joggins, Nova Scotia.
Asperipes caudifer (Dawson)	Coal Measures	Joggins, Nova Scotia.
Asperipes flexilis Matthew	Coal Measures	Joggins, Nova Scotia.
Barillopus arctus Matthew	Coal Measures	Joggins, Nova Scotia.
Barillopus confusus Matthew	Coal Measures	Joggins, Nova Scotia.
Barillopus unguifer Matthew	Coal Measures	Joggins, Nova Scotia.
Baropezia abcissa Matthew	Coal Measures	Joggins, Nova Scotia.
Baropezia eakini Gilmore	Permian (Coconino)	Grand Canyon, Ariz.
Baropezia sydnensis (Dawson)	Coal Measures	Sydney, Nova Scotia.
Baropus lentus Marsh	Pennsylvanian	Osage Co., Kans.
Barypodus palmatus Gilmore	Permian (Coconino)	Grand Canyon, Ariz.

Name	Horizon	Locality
Batrachichnus plainvillensis Woodworth.	Carboniferous	Plainville, Mass.
Chirotherium ? heterodactylum King.	Coal Measures	Westmoreland Co., Pa.
Chirotherium ? reiteri Moore	Coal Measures	Alleghany Co., Pa.
Collettosaurus indianaensis Cox	Pennsylvanian	Warren Co., Ind.
Crucipes parvus Butts	Coal Measures	Missouri.
Cursipes dawsoni Matthew	Coal Measures	Joggins, Nova Scotia.
Cursipes levis Matthew	Coal Measures	Joggins, Nova Scotia.
Dolichopodus tetradactylus Gilmore.	Permian (Coconino)	Grand Canyon, Ariz.
Dromillopus quadrifidus Matthew	Coal Measures	Joggins, Nova Scotia.
Dromopus aduncus Branson	Mississippian	Giles Co., Va.
Dromopus agilis Marsh	Pennsylvanian	Osage Co., Kans.
Dromopus velox Matthew	Coal Measures	Joggins, Nova Scotia.
Dromopus ? woodworthi Lull	Alleghanian	Massachusetts.
Duovestigia scala Butts	Pennsylvanian	Kansas City, Mo.
Exocampe ? delicatula Lull	Permian (Hermit)	Grand Canyon, Ariz.
Hylopus hardingi Dawson	Coal Measures	Parrboro, Nova Scotia.
Hylopus logani Dawson	Coal Measures	Horton, Nova Scotia.
Hylopus minor Dawson	Coal Measures	Joggins, Nova Scotia.
Laoporus coloradoensis (Henderson).	Permian (Lyons)	Lyons, Colo.
Laoporus noblei Lull	Permian (Coconino)	Grand Canyon, Ariz.
Laoporus schucherti Lull	Permian (Coconino)	Grand Canyon, Ariz.
Limnopus vagus Marsh	Pennsylvanian	Osage Co., Kans.
Megapezia ? coloradensis Lull	Permian (Hermit)	Grand Canyon, Ariz.
Megapezia ? pineoi Matthew	Coal Measures	Parrboro, Nova Scotia.
Nanopus caudatus Marsh	Pennsylvanian	Osage Co., Kans.
Nanopus merriami Gilmore	Permian (Coconino)	Grand Canyon, Ariz.
Nanopus obtusis Matthew	Coal Measures	Joggins, Nova Scotia.
Nanopus quadratus Matthew	Coal Measures	Joggins, Nova Scotia.
Notalacerta jacksonensis Butts	Pennsylvanian	Kansas City, Mo.
Notalacerta missouriensis Butts	Pennsylvanian	Kansas City, Mo.
Notamphibia magma Butts	Pennsylvanian	Kansas City, Mo.
Onychopus gigas Martin	Upper Coal Measures	Lawrence, Kans.
Ornithoides ? adamsi Matthew	Coal Measures	Joggins, Nova Scotia.
Ornithoides ? trifidus (Dawson)	Coal Measures	Joggins, Nova Scotia.
Palaeosauropus antiquior (Dawson).	Coal Measures	Nova Scotia.
Palaeosauropus primaevus (Lea)	Coal Measures	Pennsylvania.
Paleohelcura tridactyla Gilmore	Permian (Coconino)	Grand Canyon, Ariz.
Paleopus regularis Gilmore	Permian (Coconino)	Grand Canyon, Ariz.
Pseudobradypus unguifer (Dawson).	Coal Measures	Joggins, Nova Scotia.

Name	Horizon	Locality
Punctatumvestigium circuliformis Butts.	Pennsylvanian	Kansas City, Mo.
Thenaropus leptodactylus King	Coal Measures	Westmoreland Co., Pa.
Thenaropus macnaughtoni (Matthew).	Coal Measures	Nova Scotia.
Thenaropus ovoidactylus King	Coal Measures	Westmoreland Co., Pa.
Thenaropus pachydactylus King	Coal Measures	Westmoreland Co., Pa.
Thenaropus sphaerodactylus King.	Coal Measures	Westmoreland Co., Pa.

SYSTEMATIC DESCRIPTION OF GENERA AND SPECIES

In the systematic description the genera and species are divided into distinct faunas beginning with that of the Coconino formation, those of the Hermit and Supai following successively. Since none of the genera passes over from one formation into the other, it was thought this manner of treatment would be more convenient for reference than any attempt to group related forms.

Following the policy inaugurated in my first study of Grand Canyon footprints, only the best preserved and most characteristic specimens were selected for description. In most instances the type specimens consist of trackways showing several steps and usually both the right and left sides of the trail. Had it seemed wise to describe all of the various kinds of imprints found, the faunal lists would have been considerably augmented, but after noting the variations found in the imprints in a trackway of a single individual, the more conservative method was adopted. This study has resulted in nearly doubling the known ichnite fauna of the Coconino, has established an adequate fauna for the Hermit, and has made a beginning in the development of a fauna for the Supai. One of the interesting facts established is that these three faunas are distinct, one from the other. A few of the tracks may be assigned with some assurance to the class in which they belong, but many more remain in doubt, and with our present information, there is little hope of clearing up these enigmas.

FAUNA OF THE COCONINO SANDSTONE

Genus DOLICHOPODUS Gilmore

Dolichopodus Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, p. 6.

Newly discovered material makes possible some slight emendation of the generic characters of this genus, particularly in verifying some points previously in doubt.

Generic characters.—Quadrupedal. Pes long and narrow with four digits; fourth long, slender and curved outward. Manus smaller than pes, three digits. Toes of both fore- and hindfeet acuminate. Feet turned strongly inward toward line of movement.

Genotype.—Dolichopodus tetradactylus Gilmore.

DOLICHOPODUS TETRADACTYLUS Gilmore

Dolichopodus tetradactylus Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, p. 6, pl. 4, fig. 1.

A second series of tracks (No. 11,503, U. S. N. M.) referable to *Dolichopodus tetradactylus* was found by the 1926 expedition at the Hermit Trail locality and in the same horizon in the Coconino sandstone in which the type occurred. It is of interest as furnishing confirmatory evidence of the original description and illustration, in addition to throwing further light on the structure of the forefeet, of which the type specimen showed little more than the presence of three sharply pointed digits. The present specimen shows the sole to be narrow and the foot, as a whole, smaller than the hindfoot. In the type the hindfoot was placed in advance of the fore, but in this specimen the forefoot impression is usually slightly in advance or at one side of the hindfoot. This placing of the feet, however, may be due to the irregularity of the stride as no two steps measure the same, varying from 160 to 250 mm. in length. None of the tracks of the forefoot gives evidence of more than three toes, although some are deeply impressed. The forefoot, measured from the back of the heel to the tip of the longest toe, has a length of 16.5 mm. and a width in the opposite diameter of 19 mm. The hindfoot has essentially the same proportions as the type. A third slab (No. 11,495 U. S. N. M.) also has a few impressions attributable to this species, but these are scattered tracks made by the hindfeet and add nothing to our previous understanding of them.

Genus NANOPUS Marsh

Nanopus Marsh, O. C., Amer. Journ. Sci., Ser. 3, Vol. 48, 1894, p. 82.

Marsh's conception of this genus as set forth in his description of the type species can now, with the discovery of two new species, be greatly emended as follows:

Generic characters.—Quadrupedal, semiplantigrade. Four digits in pes, three in manus. Manus usually smaller than pes. Toes acuminate or bluntly rounded. Lateral toes of pes either shorter or subequal in length with median toes. Forefoot placed in front of hind. Feet turned slightly inward toward line of movement. With or without tail drag.

Genotype.—*Nanopus caudatus* Marsh.

KEY TO SPECIES

Small size. Toes stout with obtusely rounded ends. Lateral toes of pes shorter than median toes.

N. caudatus Marsh

Small size. Toes slender, with acutely pointed ends. Lateral toes of pes shorter than median toes.

N. merriami Gilmore

Large size. Toes slender, acutely pointed. Lateral toes of pes subequal in length with median toes.

N. maximus n. sp.

FIG. 3.—Tracks of *Nanopus obtusis* Matthew. *1a,* hindfoot; *1b,* forefoot. Natural size. (After Matthew.)

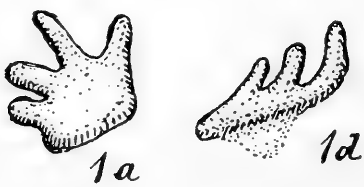

FIG. 4.—Tracks of *Nanopus quadratus* Matthew. *1a,* hindfoot; *1d,* forefoot. Natural size. (After Matthew.)

The two species *N. obtusis* and *N. quadratus* from the Coal Measures of Nova Scotia referred to this genus by Matthew show such a radically different foot plan as to indicate that their affinities lie elsewhere than in the genus *Nanopus.* Reference is made to the divergent fifth or outer toe, the progressive shortening of the digits inward, and the placing of the hindfoot in advance of the forefoot impression.

N. quadratus Matthew [1] quite certainly belongs in the genus *Dromillopus* with which its small size, digital formula of 4 and 4, and general arrangement and relative length of toes are in full accord. For these reasons it is unhesitatingly transferred to this genus to be known hereafter as *Dromillopus quadratus* (Matthew).

Unfortunately the case of *N. obtusis* cannot be so satisfactorily settled. The impression of the hindfoot offers no difficulties to its assignment to *Dromillopus* but the forefoot shows only three toes and the foot as a whole (see fig. 4) is quite out of accord with any described Carboniferous ichnite. This is probably due to distortion, as pointed out by Matthew,[2] so that the number of digits and the form of the foot as shown in figure 4 is probably not to be depended upon as expressing the true characters of the normal manus imprint. For that reason and as a temporary expedient this species is provisionally assigned to the genus *Dromillopus* to be known as *D ? obtusis* (Matthew) until such time as the discovery of better preserved specimens shall disclose its true generic affinities.

NANOPUS MERRIAMI Gilmore

Plate 4, fig. 1

Nanopus merriami Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, pp. 9-12, pl. 4, fig. 2, text fig. 5.

A specimen of *Nanopus merriami* (No. 11,516, U. S. N. M.) is of interest as recording a second occurrence of this species in the lowest track-bearing level of the Coconino formation a considerable distance north of where the type specimen was collected. It was found *in situ* about 30 feet above the Coconino-Hermit contact, immediately above the spring which supplies water for the trail caretaker's house in Hermit Basin. It would now seem that this species is confined to the lowermost horizon of the Coconino as no tracks attributable to it have been observed in the upper levels.

NANOPUS MAXIMUS, new species

Plate 3

Type.—Catalogue number 11,506, U. S. N. M. A large slab of light-colored fine-grained sandstone on which is an irregular trackway showing impressions of all four feet.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

[1] Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, p. 98.
[2] *Op. cit.*, p. 98.

Geological occurrence.—Coconino sandstones (about 150 feet above base), Permian.

Description.—Stride (average) about 277 mm., width of trackway (estimated) about 300 mm. Both of these measurements are subject to revision with the discovery of better material for it is quite apparent that the type specimen does not represent a continuous normal trackway. This is indicated by the irregularity of the stride and the great variation in the relative position of the tracks of the fore- and hindfeet, although the manus is always placed in front of the pes. The longest stride measures 320 mm., while the shortest of that same

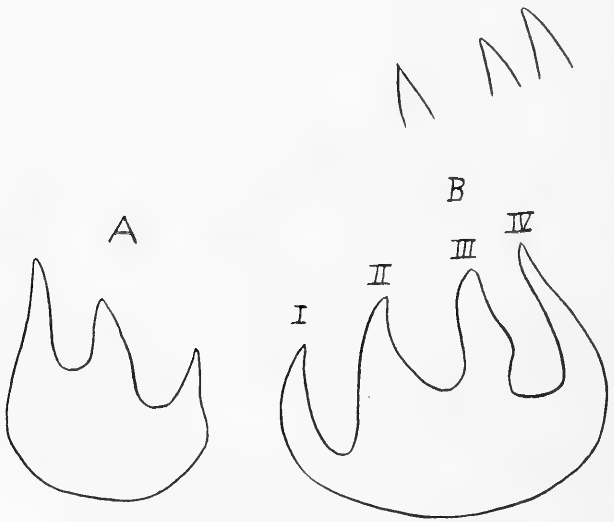

FIG. 5.—*Nanopus maximus.* Type. No. 11,506, U. S. N. M. *A*, imprint of right forefoot; *B*, showing relations of fore- and hindfeet of right side. About ½ natural size.

side is only 225 mm. *Hindfoot:* Greatest length 65 mm., greatest width 85 mm. Four toes acuminate and subequal in length. First and fourth more slender than median pair, both curving inward from their respective sides of the foot. Second and third having their tips directed slightly outward. Sole equal to length of toes, suboval, broadly rounded behind. That there were sharp well developed claws on all four toes is shown by the long deep scratches where the foot had slipped as may be seen on the left side of the trackway in plate 3. Length of digit I, 34 mm., digit II, 34 mm., digit III, 34 mm., digit IV, 36 mm. *Forefoot:* Length (estimated) about 43 mm., width about 52 mm. Three toes, acuminate, clawed, and probably subequal in length. The sole in most of the imprints is obscure but in the best preserved one (see *A,* fig. 5) it is relatively short fore and aft. The outer toe is somewhat set off from the median one. Sole broadly rounded behind. Judging from the depth of the imprints the weight of the animal was largely carried by the hind limbs. The length of digits in the manus varies so much in the different imprints that it seems useless to record their measurements. The outline of the manus as given in figure 5, *A,* is made from the best preserved imprint on the slab, but the relative length of toes is subject to revision when better specimens are found.

The presence of three and four digits in the manus and pes, parallel arrangement of the two middle toes of the hindfoot, short, broadly rounded sole, and forefoot placed in front of hindfoot, are characters found in the genus *Nanopus.*

The large size of *Nanopus maximus* at once distinguishes it from the other species of the genus, all of which are small. From *N. merriami* from this same formation, but apparently restricted to the lower part of the track-bearing horizon, it may be distinguished not only by its much greater size, but also by having the two lateral toes of the pes subequal in length with the two median toes, whereas in both *N. caudatus* Marsh and *N. merriami* Gilmore the two lateral digits are shorter than the median. From *N. caudatus* it is further distinguished by the more slender and acuminate form of the digits as contrasted with the heavy rounded toes of that species. The specific name is suggested by its great size as contrasted with the smaller footprints of the other species of the genus.

Genus LAOPORUS Lull[1]

Laoporus Lull, R. S., Amer. Journ. Sci., Vol. 45, 1918, p. 339.

Generic characters (emended).—Quadrupedal, semiplantigrade, with four digits in manus and five in the pes; fifth toe often not impressing. Lateral digits always shorter than median pairs. Sole broad, digits usually short. Feet usually grouped in pairs with front foot always placed in front of hind.

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[1]After the manuscript of the present paper had been accepted for publication an article on British Permian Footprints by George Hickling (Manchester Lit. and Philos. Soc., Memoirs, Vol. 53, 1909, Art. 22, pp. 1-24, pls. I to IV) came to my attention for the first time. Although too late to be discussed in the present article, I wish in this note to call attention to the fact that many of the British tracks show striking resemblances to those of the Coconino and that the genus *Laoporus* is quite certainly represented in the Pernith Red sandstone; see figs. 10 and 11, pl. II, of the article cited.

This brief note will bring to the attention of those interested the above mentioned fauna, and a more complete discussion of it will be included in my next publication dealing with footprints of the Grand Canyon.

Genotype.—*Laoporus schucherti* Lull.

Two species, *L. schucherti* and *L. noblei,* were described by Lull from the Coconino formation, but only a single specimen of the former species has been recognized in my collections although the other occurs in great abundance.

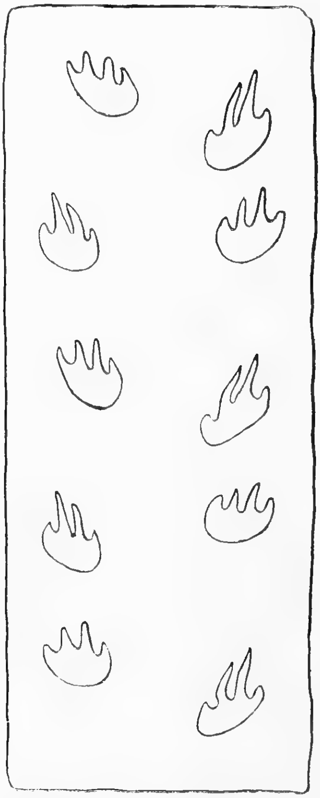

FIG. 6.—*Laoporus noblei.* No. 11,494, U. S. N. M. Diagram of a portion of the trackway to show the relatively long median toes of the manus. No indication of the fifth toe of the pes in this trackway. About $\frac{1}{3}$ natural size.

LAOPORUS NOBLEI Lull

Plate 4, fig. 2

Laoporus noblei Lull, R. S., Amer. Journ. Sci., Vol. 45, 1918, pp. 339-341, pl. 2, text fig. 2.

Footprints of *Laoporus noblei* Lull are by far the most abundant of all the animal tracks found in the Coconino sandstone. Usually the trackway of this species can be recognized at once by the uniformity of the stride and by the pairing of the impressions made by the fore- and hindfeet, the former always being placed in front of the latter. One trackway (No. 11,494 U. S. N. M.) among a considerable number collected in 1926 deserves special mention because of the unusual length of the median toes of the forefeet. These toes considerably exceed in length the longest toes of the hindfoot (see fig. 6) whereas the opposite condition usually prevails. Furthermore, in this specimen the fore and hind tracks are subequal in size whereas the forefoot impression is usually smaller. None of the pes tracks gives indication of the presence of a fifth digit. The rather meager evidence of its presence in the hindfoot may, however, now be considered as absolutely established by two specimens (Nos. 11,491 and 11,512 U. S. N. M.) both of which show several pes tracks with five toes clearly registered.

Genus BARYPODUS Gilmore

Barypodus Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, p. 27.

The genus *Barypodus* was originally characterized on rather scanty materials so that with the discovery of other species referable to this genus, it now becomes necessary to emend the original definition as follows:

Generic characters.—Quadrupedal, plantigrade with three parallel digits in both manus and pes. Digits long, either slender or stout, well separated, and with or without webbing between the toes. Sole of pes subtriangular in outline with heel hooking outward. Sole as long as or longer than digits. Forefoot placed in front of hind.

Genotype.—*Barypodus palmatus* Gilmore.

KEY TO SPECIES

Large size. Toes long, slender, joined by web. Outer toe of manus one-half length of inner. Palm of manus longer than digits with outward hook of heel.

B. palmatus

Medium size. Toes long, slender, without webbing. Outer toe of manus longer than inner. Palm of manus longer than digits with decided outward hook of heel.

B. tridactylus

Medium size. Toes, moderate length, stout without webbing. Outer toe subequal in length with inner. Palm of manus apparently shorter than digits, without outward hook.

B. metszeri

BARYPODUS TRIDACTYLUS, new species

Plate 5

Type.—Catalogue number 11,502, U. S. N. M. Consists of the positive and negative slabs on which is a beautifully preserved trackway.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

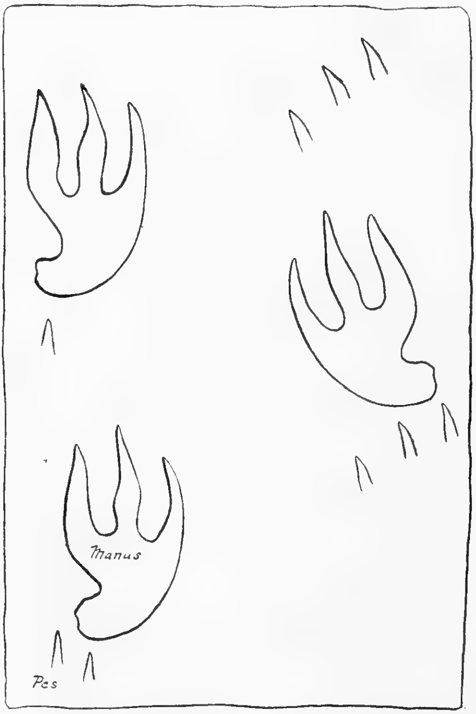

FIG. 7.—*Barypodus tridactylus.* Type. No. 11,502, U. S. N. M. Diagram of trackway. Toes indicate position of the hindfeet. About $\frac{1}{3}$ natural size.

Geological occurrence.—Coconino sandstone (about 150 feet above base), Permian.

Description.—Stride about 140 mm., width of trackway about 175 mm. *Hindfoot:* None of the impressions made by the pes is sufficiently clear to provide measurements. The presence of three digits is distinctly indicated by several tracks (see pl. 5). Measured across the toes the foot has a width of 44 mm. Digits shorter than those of manus. Length of first digit about 15.5 mm., second about 23 mm., third 26 mm. It will be seen from these measurements that the toes grow progressively longer toward the outside of the foot. The smaller size of the digits and the indistinctness of the impressions raises the question of these imprints having been made by the pes, but when critically examined, the fact that some of the impressions were made upon the slightly raised flow of sand forced out by the sole of the preceding foot, seems to leave no alternative conclusion than that they were made by the pes. If this interpretation be correct, then we have the very unusual condition of having the hindfoot apparently bearing less of the weight of the animal, as evidenced by the shallowness of the imprints. The sole is not distinctly impressed (see fig. 7) in any of the tracks and on that account no idea of its shape, extent, or peculiarities is to be gained from this specimen. *Forefoot:* Length 81 mm., width 46 mm. Three digits, long, parallel and sharply acuminate. Toes directed straight forward in relation to axis of trackway. Digit I is 37 mm. long, digit II, 43 mm., digit III, 42 mm. Sole subrectangular with a blunt, hook-like protuberance on the outer posterior angle as in *B. palmatus.* There is no deviation of the lateral toes as in so many three toed tracks, notably those of the Connecticut-Triassic, but in both fore- and hindfeet the toes are placed nearly parallel. All of the toes are equally well impressed. The resemblance in form of the palm of the manus to *B. palmatus* seems to indicate that the original interpretation of the position of the hook-like protuberance as being on the inside of the foot was in error. In the specimen now before me it is clearly shown to be on the outer side. This indicates that the type of *B. palmatus* belongs to the right side, a fact that was indeterminable at the time of description, due to the paucity of the type materials.

Although there are many resemblances to be found in a comparison of the two species here discussed, they may be at once distinguished by the smaller size of *B. tridactylus,* the absence of webbing between the toes, and the smaller relative size of the hindfoot as contrasted with the fore. Differences found in the relative length of digit III of the forefoot also furnish another distinguishing character.

BARYPODUS METSZERI, new species

Plate 6

Type.—Catalogue number 11,505, U. S. N. M. Consists of a trackway about 560 mm. in length showing impressions of all four feet.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 150 feet above base), Permian.

Description.—Stride about 235 mm., width of trackway (estimated) about 210 mm. *Hindfoot:* Length about 88 mm., width about 65 mm. Three stout sharply pointed toes of moderate length, well separated. Two outer toes having their outer borders curved

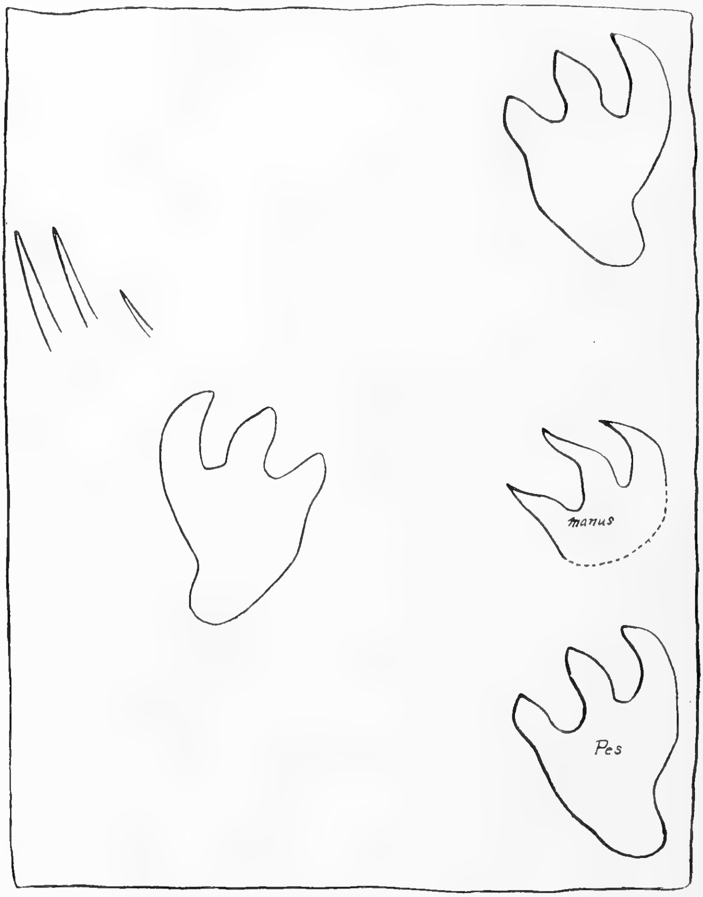

FIG. 8.—*Barypodus metszeri.* Type. No. 11,505, U. S. N. M. Diagram of trackway. Long scratches on the left show the slipping of the forefoot. About 1/3 natural size.

inward, which gives these digits the appearance of turning inward toward the median one, when in reality they are nearly parallel. Length of digits, I = 22 mm.; II = 28 mm.; III = 30 mm. Sole deeply impressed; elongate, narrowed, obtusely pointed heel that hooks slightly outward. Sole nearly twice as long as the digits. Toes turned strongly inward. *Forefoot:* Length (estimated) 54 mm., width about 58 mm. Three toes more slender and more acutely pointed than toes of hindfeet. Inner toe more widely set off from middle toe than is the outer one. Toes all strongly bent inward, the second and third especially so. The palm is so lightly impressed in all of the imprints that its outline is not clearly indicated, so that much doubt exists as to the correctness of the illustration of this portion of the foot in figure 8. It has therefore been shown in a broken line. The forefoot is placed in advance of the hindfoot and slightly outside. That the claws were acuminate is not only clearly indicated by the shape of the digits, but also by the long, deep scratches in the rock as shown on the left side of the trackway (see fig. 8). In both fore- and hindfeet, distinct cross ridges indicate the presence of deep creases on the bottom of the foot, at the base of the toes. The footprints are deeply and clearly registered and there is little probability of additional toes ever having been present since they did not register here.

This species is referred to the genus *Barypodus* largely on the ground of there being three digits on both fore- and hindfeet, and the presence of an elongate sole. From *B. palmatus* it is at once distinguished by the shorter, stouter, curved toes and the absence of webbing between the digits. Likewise it may be distinguished from *B. tridactylus* by the short toes with curved claws and a shorter palmar impression lacking pronounced outer hook.

The specific name is in honor of Mr. Arthur Metszer who collected the type specimen and whose efficient services contributed so largely in bringing together this fine collection of footprints.

Genus BAROPUS Marsh

Baropus, Marsh, O. C., Amer. Journ. Sci., Vol. 43, 1894, p. 83.

The genus *Baropus* was founded by Marsh on a series of tracks from the Coal Measures of Kansas. With the additional material collected in the Grand Canyon, it may be characterized as follows:

Generic characters.—Large size. Quadrupedal, plantigrade. Four toes on both manus and pes. Toes short, thick with rounded extremities, clawless. Forefoot subequal in size or smaller than hindfoot. Soles of feet large.

Genotype.—*Baropus lentus* Marsh.

KEY TO SPECIES

Imprints of fore and hindfeet subequal in size, with hindfoot placed in rear of forefoot. Sole of pes elongate, subtriangular in outline, with heavy protuberance on inner side.

B. lentus

Imprint of forefoot smaller than that of hindfoot, with hindfoot placed in front of forefoot. Sole of pes truncate, subquadrangular in outline, without protuberance on inner side.
B. coconinoensis

BAROPUS COCONINOENSIS, new species

Plate 7

Type.—Catalogue number 11,514, U. S. N. M. Consists of a slab on which are four tracks made by the fore- and hindfeet of the left side.

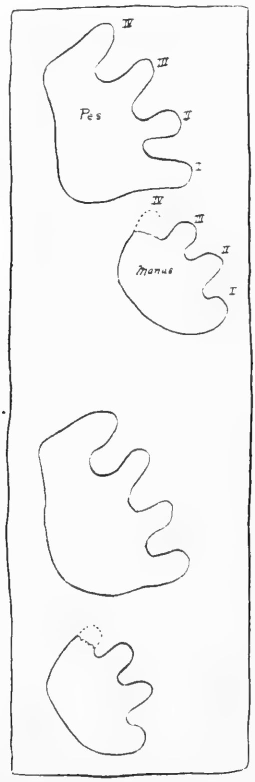

FIG. 9.—*Baropus coconinoensis.* Type. No. 11,514, U. S. N. M. Diagram of left side of trackway. About $\frac{1}{6}$ natural size.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 125 feet above base), Permian.

Description.—Stride about 300 mm., width of trackway unknown. *Hindfoot:* Length about 108 mm., width about 138 mm. Four toes of moderate subequal length, thick, with broadly rounded extremities, apparently without claws. First and second toes slightly diverted from the outer two which are more or less parallel. Foot turned strongly inward. Sole broad, subrectangular in outline. Approximate length of toes: I, 30 mm., II, 30 mm., III, 35 mm., IV, 35 mm. *Forefoot:* Length 75 mm., width (estimated) about 100 mm. There are probably four toes although only three can be observed. Both of the imprints have had at least one toe obliterated by the hindfoot

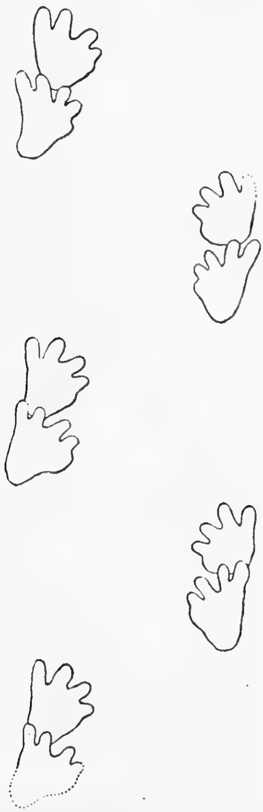

FIG. 10.—*Baropus lentus* Marsh. Diagram of trackway. About $\frac{1}{12}$ natural size. (After Marsh.)

stepping upon them so that their entire number is in doubt. The toes are stout, of moderate length, and, as in the pes, have rounded ends without claws. First digit slightly set off from the others. Sole wider than long and broadly rounded behind. Foot turned strongly inward and placed inside the line of the hindfoot impressions. Palm about twice the length of the longest toe, subquadrate in outline and broadly rounded behind. The missing toe has been tentatively restored as shown in figure 9.

The specimen selected as the type is the trackway of a large quadrupedal animal and consists of four imprints from the left side. The tracks are deeply impressed and the softness of the sand at the time they were made is indicated by the flows behind the impressions displaced by the impact of the feet.

The hindfoot with four toes, in size, shape and arrangement of digits has its closest resemblance to *Baropus lentus* Marsh from the Coal Measures of Kansas. It differs in having the forefoot smaller than the hind, sole of pes relatively broader, less elongate, and without inner protuberance (compare figs. 9 and 10). In this specimen the hindfoot is placed in front and outside of the forefoot impression, whereas in *B. lentus* the hindfoot is behind the forefoot. It seems quite probable, however, that the trackway now before me does not represent the normal walking stride of the animal. That the creature was climbing a slope is evidenced by the position of the slab *in situ* and also by the mounds of sand behind the imprints, displaced by the pressure of the feet. The weight seems to have been equally distributed between fore and hind limbs, as indicated by the subequal depth of the tracks.

This form may be distinguished at once from *Allopus ? arizonae* occurring in these same beds by its much larger size, and the lesser number of digits in the pes.

Genus AGOSTOPUS Gilmore

Agostopus Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, p. 23.

The genus *Agostopus* was established on well preserved specimens from the Coconino sandstone as exposed on the Hermit Trail section. A slightly emended characterization of the genus follows:

Generic characters.—Quadrupedal, semiplantigrade, with five digits in manus and four in the pes; broad soled with either two or three clawed digits in the pes. Feet directed inward, hindfoot placed in front of forefoot impressions. Short limbed, wide bodied.

Genotype.—*Agostopus matheri* Gilmore.

KEY TO SPECIES

Hindfoot with three long acutely pointed digits, all directed forward.
A. matheri

Hindfoot with two long acutely pointed digits, both bent strongly outward.
A. medius

AGOSTOPUS MEDIUS, new species

Plate 8

Type.—Catalogue number 11,509, U. S. N. M. Consists of a trail 870 mm. in length, showing consecutive impressions of all four feet.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 150 feet above the base), Permian.

Description.—Average length of stride about 170 mm., width of trackway about 230 mm. *Hindfoot:* Length about 75 mm., hindfoot placed in front of forefoot, the sole usually obliterating toes of the manus. Sole wider than long, palmate, broadly rounded behind. Sole longer than digits. Four, possibly five, toes, the two middle ones sharply pointed and strongly curved outward. First and fourth short and heavy, with bluntly rounded terminations apparently without claw; first often not impressing. Length of digits, I = 4 mm.; II = 23 mm.; III = 30 mm.; IV = 16 mm. While the trackway as a whole gives the impression of being clearly defined, when it comes to considering the details of the foot plan the specimen leaves much to be desired. On the type slab there are ten imprints made by the two hindfeet, but only two of these in the lower left hand side (see pl. 8) show the undoubted presence of a short, obtuse first digit. It is either missing entirely from the other tracks or else there is only the slightest trace of its existence. Where the imprint is missing, the inward extension of the sole is always sufficient to have carried it. In a few of these tracks on both sides a projecting protuberance on the outer posterior angle of the sole (see fig. 11) may represent the presence of a fifth digit, but additional specimens are necessary before this point can be definitely decided. *Forefoot:* Length (estimated) about 40 mm., width about 72 mm. Sole suboval in outline. Smaller than pes. Number of digits uncertain, probably five, apparently reducing inward. All short, stout, with broadly rounded terminations and apparently without claws. Fifth set off from the others. The uncertainty regarding the digits of the manus is largely brought about by their partial obliteration by the flow of sand crowded back upon them by the impact of the heel of the hindfoot.

A portion (negative) of this same trackway was collected in 1924 and presented to the Grand Canyon National Park Museum, while the positive portion (No. 11,136, U. S. N. M.) was brought to Washington under the impression that the tracks were duplicated in other specimens in the collection. Critical study demonstrated its distinctness from all others, but in the expectation of again visiting the locality, its description was deferred until another section of the trail could be secured. In addition there is a second specimen (No. 11,500, U. S. N. M.) in the 1926 collection that may also be referred to this

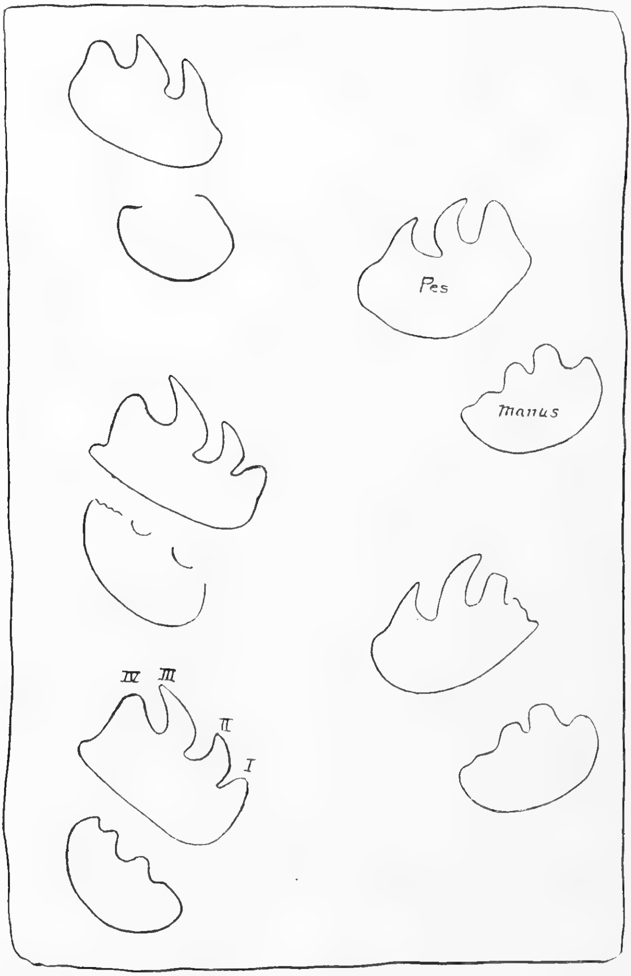

Fig. 11.—*Agostopus medius*. Type. No. 11,509, U. S. N. M. Diagram of trackway. About ¼ natural size.

genus and species, but the preservation is such that it throws no additional light on the detailed foot structure, and needs no further mention here.

The characteristic foot structure of this short-legged, wide-bodied animal shows it to be clearly referable to the genus *Agostopus*. From the single known species, *A. matheri,* it is to be distinguished by its larger size, the relatively wider soles, and the short, stout form of digit IV.

Genus AMBLYOPUS, new genus

Generic characters.—Quadrupedal, plantigrade. Toes of both manus and pes not differentiated but inclosed in the foot mass. Impressions of feet reniform in outline, being longer than wide. Pes tracks placed partly upon those of manus, and forming rows inside them.

Genotype.—*Amblyopus pachypodus,* new species.

AMBLYOPUS PACHYPODUS. new species

Plate 9

Type.—Catalogue number 11,511, U. S. N. M. Consists of a slab 830 mm. long, having a trackway running the entire length.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 130 feet above base), Permian.

Description.—Stride about 210 mm.; width of trackway about 330 mm. Hindfoot placed partly upon the imprint made by the forefoot. *Hindfoot:* Length about 100 mm. None of the footprints, and most of them are well impressed, gives any indication of the presence of separate toes, but in the deepest part of the pes tracks two longitudinal parallel tapering depressions (see fig. 12) evidently indicate the presence of at least two digits, but these were wholly inclosed within the mass of the foot. It is this peculiarity that has suggested the specific name *pachypodus.* The anterior portion of the imprints gives the impression of their having been made by a single broad toe, which had a broadly rounded ungual. This end measures 53 mm. in transverse diameter. On the inner side and a little posterior to its midlength a pronounced indentation may represent the division between toes and sole. The outline of the hindfoot impression as a whole may be said to be reniform. The sole is subquadrate in outline and well impressed in nearly all of the tracks, especially the series of the right side. *Forefoot:* The placing of the hindfoot wholly or in part upon the impression made by the forefoot has obliterated most of the details of its structure. It is quite evident that the feet were of about equal size, and from what little can be seen of them, that there was a similarity of structure. These resemblances are clearly shown in plate 9, the outer right-hand row being those made by the forefoot, the second inner row being those of the hindfeet of that side.

The depth of the tracks, wide trackway, short stride, and large size of the imprints indicates they were made by a heavy, squat animal, with a relatively short body, for otherwise it would be quite impossible for the hindfoot to have been set upon the imprints of

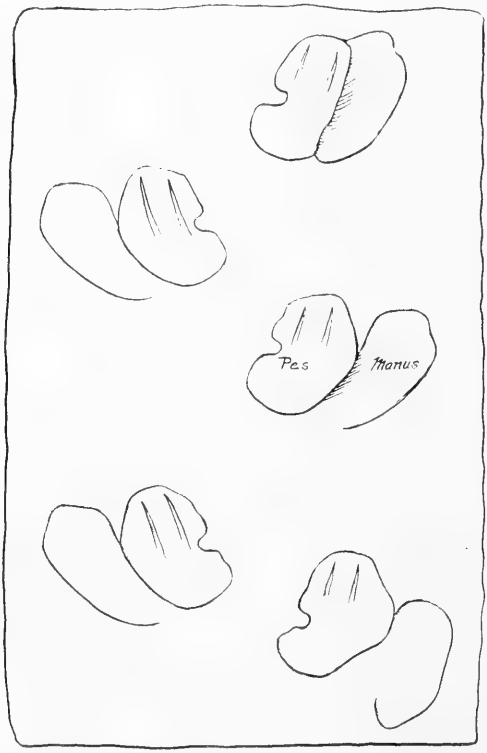

FIG. 12.—*Amblyopus pachypodus*. Type. No. 11,511, U. S. N. M. Diagram of part of the trackway. Outer row of tracks made by the forefoot; inner row, made by the hindfoot, and placed partly upon the tracks of manus. About $\frac{1}{6}$ natural size.

the forefeet. No evidence of a tail drag was found. This specimen occurred at a slightly lower level in the horizon than the one from which the major part of the Coconino tracks were collected.

Genus OCTOPODICHNUS, new genus

Generic characters.—Apparently eight footed with tracks arranged in groups of four, alternating, two anterior impressions didactyle, two posterior unidactyle.

Genotype.—*Octopodichnus didactylus*, n. sp.

OCTOPODICHNUS DIDACTYLUS, new species

Plate 10, fig. 2

Type.—Catalogue number 11,501, U. S. N. M. Consists of a slab 440 mm. long, having a trail traversing the entire length. A small portion of the obverse slab is also present.

Type locality.—Hermit Trail (500 feet to left of trail going down), Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 150 feet above the base), Permian.

Description.—The trail here described consists of two lines of imprints arranged in groups of four, the groups of the two sides alternating. These groups are arranged in a row of three regularly spaced tracks with the fourth offset inward and slightly behind the most posterior imprint of the line of three. A line passed through the three tracks has its axis everted 45° to the line of direction of movement (see fig. 13), this inclination of course being reversed in the groups of tracks on the opposite side. The direction of movement is clearly indicated by the displaced sand caused by the impact of the heel (see pl. 10). The tracks are subequal in size, the two anterior imprints being bifurcated, with the outer toe or claw slightly longer and more robust than the inner; the two posterior imprints seem to be unidactyle. The outer toe of the third imprint of each group, enumerated from the front, especially of the right side, has a heavy inward projecting heel. The toes have the same direction as the line of tracks. The stride, if the movement may be so designated, is 106 mm. The greatest width of trackway is about 94 mm., space between single imprints usually 21 mm., there being a slight variation; the fourth or offset impression is about 15 mm. inside the third. The three tracks in line occupy a linear space of 58 to 63 mm. Single tracks have a length of 13 mm., a width of 7 mm.

Much uncertainty exists as to the nature of the animal that made this trail. Some of the living crustaceans have didactyle extremities and that is the chief reason for the suggestion about to be made that the trail may be the tracks of a member of that group. While there seems to be no living crustacean that would make such a trail, in Permian times there may have been such an animal. The trackway is distinct from all others found at this locality and in all of the hundreds of square feet of sandstone surface examined only one other such trail was discovered. A second poorly preserved specimen (No. 7,846, U. S. N. M.) was collected in this same general locality in 1924, but the preservation was such that its principal characteristics were not recognized at that time.

The stride as compared with the width of trackway would seem to indicate an animal with considerable length of leg, and it is inconceivable that the imprints are other than those made by feet on separate legs, a conclusion substantiated by the direction of the claws or toes. While the tracks give the impression that all four were

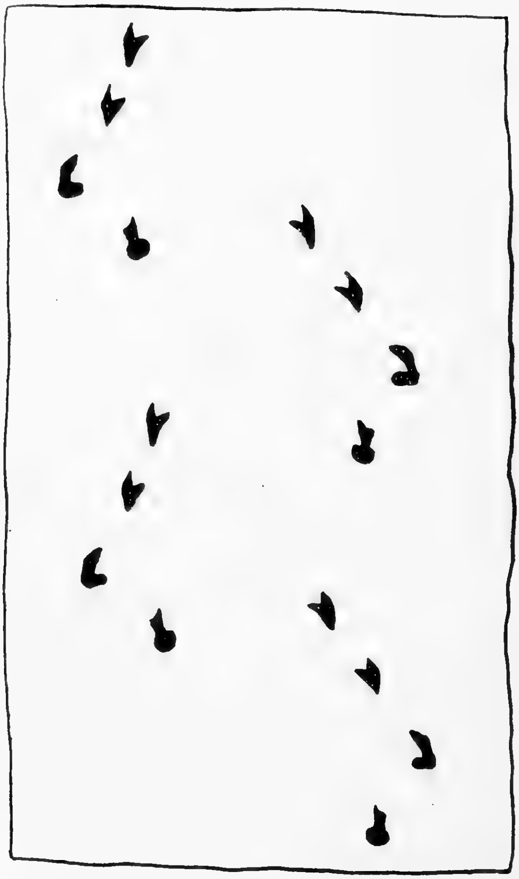

FIG. 13.—*Octopodichnus didactylus.* Type. No. 11,501, U. S. N. M. Diagram of trackway. About ½ natural size.

moved forward simultaneously, it may be that one leg was moved forward at a time after the manner of progression of many existing invertebrates.

GENUS TRIAVESTIGIA, new genus

Generic characters.—A continuous trail of three parallel sets of markings, between two of which there is a faintly impressed tail drag. Longer axes of feet impressions placed slightly diagonal to direction of movement, alternating. Feet apparently unidactyl.

Genotype.—*Triavestigia niningeri* n. sp.

TRIAVESTIGIA NININGERI, new species

Plate 10, fig. 1

Type.—Catalogue number 11,510, U. S. N. M. Consists of a slab about 260 mm. long, having a trail traversing about two-thirds of its length.

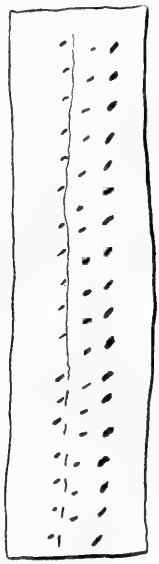

FIG. 14.—*Triavestigia niningeri.* Type. No. 11,510, U. S. N. M. Diagram of trackway. About ⅓ natural size.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (a loose slab from hillside about 100 feet above the base), Permian.

Description.—The trail here described consists of three parallel rows of impressions, between two of which the intermittent drag of a tail is faintly but clearly recorded. Width of the trackway 14 mm., width of the paired rows 8.5 mm. Length of step is about 7.5 mm. The feet seem to have been unidactylus, and made single mark-like depressions that stand diagonal to the axis of the line of movement. Curiously enough all of the markings forming the three rows have the same diagonal angle as shown in figure 14. The impressions forming the two rows on either side of the tail drag are regularly alternating. The outer or third row is composed of the largest and most distinct markings, but their spacing is the same as those of the other two rows. The impressions found on either side of the tail drag are quite certainly made by the feet, but as to the origin of the third row, one cannot be certain whether it was made by a foot or by some other appendage. However, the regularity of spacing and close conformity to the other rows leaves no other conclusion than that all were made by the same animal. Whether the normal trail would consist of four rows of tracks, as in *Bifurculapes*,[1] which in some specimens shows only three, there is no way of determining at this time. Only by the discovery of additional specimens can we hope to clear up this point. While I have been unable to definitely classify these tracks they give every indication of having been made by some invertebrate animal and for the present at least they will be so regarded.

The specific name is in honor of Prof. H. H. Nininger of McPherson, Kansas, who found the type specimen and generously donated it to the national collections.

PALEOHELCURA TRIDACTYLA Gilmore

Paleohelcura tridactyla Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 77, No. 9, 1926, pp. 31-34, pl. 12, fig. 1, text fig. 20.

The discovery of a second specimen (No. 11,499, U. S. N. M.) of *Paleohelcura tridactyla* is of interest because the tracks were found *in situ* in the Coconino sandstone, at about 150 feet above the base of the formation and not far distant from where the type was discovered. The type was a loose slab found lying on the hillside below the Hermit Trail about 125 feet above the base.

The second specimen adds nothing new to our knowledge of the species, as it exhibits the same tridactyle impressions with a tail drag in the center of the trackway.

Genus UNISULCUS Hitchcock

Unisulcus Hitchcock, Edward, Ichnology of New England, 1858, p. 160.

The genus *Unisulcus* was established by Hitchcock for a group of simple trails which he regarded as having been made by naked

[1] Hitchcock, Edward, Ichnology of New England, 1858, pp. 153, 154, pl. 30.

worms or annelids. The genus was characterized as "trackway a single continuous groove."

Genotype.—Unisulcus marshi Hitchcock.

A specimen found in the Coconino sandstone bears a trail which appears to have been made by some crawling, legless animal whose affinities seem to fall in this genus.

UNISULCUS SINUOSUS, new species

Plate 11

Type.—Catalogue number 11,498, U. S. N. M. Consists of a small slab of sandstone carrying three trackways.

Type locality.—Hermit Trail, Hermit Basin, Grand Canyon National Park, Arizona.

Geological occurrence.—Coconino sandstone (about 150 feet above base), Permian.

Description.—Trackway a continuous groove having an average width of 3 mm. and usually slightly sinuous. Sand on one side of trail slightly raised forming a slight ridge; the opposite side lower and somewhat rounded. On the ridged side the wall of the groove is nearly perpendicular, while the opposite side is beveled. At bottom the trail gives the impression of being grooved rather than rounded. The abrupt ending of one trail in the center of the slab as shown in plate 11 suggests that it was made by an animal that was able to move backward as well as forward. However, there is no accumulation of sand at this end such as has been observed by Hitchcock in trails of a somewhat similar nature. Slightly beyond the intersection of two of these trails, both are flattened and widened out and the bottom is sculptured by three distinct shallow, longitudinal grooves.

Of the Mesozoic ichnites assigned to this genus, the present species most closely resembles *Unisulcus marshi* in size and especially in width of groove, but is at once distinguished from that form by the more sinuous nature of the trackway, and by the grooved character of the furrow. The reference of this specimen to the genus *Unisulcus* by no means implies that it is regarded as having been made by a crawling worm, though such may have been the case. It seems more probable that it is the track of a mollusk, for the dragging shell would better account for the grooved appearance of the trail as well as the ridge of sand on one side, although in living mollusks the trail is usually ridged on both sides of the groove.

The type is the only specimen of this species observed in all of the hundreds of square feet of sandstone surface examined.

FAUNA OF THE HERMIT SHALE

Genus BATRACHICHNUS Woodworth

Batrachichnus Woodworth, J. B., Bull. Geol. Soc. Amer., Vol. 11, 1900, p. 542, pl. 40, text fig. 2.

This genus may be characterized as follows:

Generic characters.—Small forms, quadrupedal, with four and five toes on manus and pes respectively. With or without median groove. Toes slender, radially arranged.

Genotype.—*Batrachichnus plainvillensis* Woodworth.

This genus contains two species from widely separated localities, *B. plainvillensis* Woodworth from the Carboniferous of Massachusetts, and *B. celer* (Matthew) from the Carboniferous of Nova Scotia. The species *Exocampe ? delicatula* Lull, a form of small size with similar digital formula is provisionally referred to this genus to be known hereafter as *B. delicatula* (Lull). The digital formula of *Notalacerta jacksonensis* Butts[1] suggests its affinities also to be with this genus to which it is now referred. Its 4 and 5 short, bluntly rounded toes as contrasted with the five long and acuminate toes on both manus and pes in the type species of *Notalacerta* (*N. missouriensis*) certainly justify its removal from that genus. It is, however, quite possible that a comparison of the type specimens might show that *B. jacksonensis* and *B. plainvillensis* are cospecific, in which event the latter would become a synonym of the former on the ground of priority. This matter could only be settled satisfactorily by a restudy and comparison of the type specimens, which is outside the scope of the present study.

BATRACHICHNUS DELICATULA (Lull)

Plate 12

Exocampe ? delicatula Lull, R. S., Amer. Journ. Sci., Vol. 45, 1918, pp. 544-546, fig. 4, pl. 3, fig. 1.

Lull's original description, based on rather scanty materials from these same deposits, follows:

> The smallest of the forms collected by Professor Schuchert consists of a very delicately impressed fore- and hindfoot in relief on mud-cracked red shale. The hindfoot is the larger and shows four slightly radiating digits, but no trace of sole. The manus is also apparently four-toed with distinct impressions of terminal claws. The digits radiate more widely, but here again there is no palmar impression. The form may therefore be described as digitigrade. Faint indications which may represent phalangeal limitations may be

[1] The Kansas City Scientist, Vol. 5, 1891, p. 18, text fig.

seen on the second digit of the manus. This form resembles most closely the genus *Exocampe* of the Connecticut Trias, but is a generalized track which almost any small amphibian, such as a modern salamander for instance, might make and while it may for convenience be placed within the mentioned genus, genetic relationship with the creatures that made the tracks so designated is not of necessity implied.

Specific characters.—Manus somewhat smaller than the pes, with three well-defined, radiating digits, the middle one of which is directed forward. An

FIG. 15.—*Batrachichnus delicatula* (Lull). No. 11,519, U. S. N. M. *A*, diagram of trackway showing normal track. *B*, showing trackway made by the hindfeet only. Note that the stride has lengthened and the trackway is narrower than in *A*. Dotted lines connect impressions made by the hindfeet. Both figures ½ natural size.

obscure impression of an additional digit lying on the inner side of and more nearly parallel to the second is indicated. There is also at the base of the second digit what may represent a palmar pad. It may, however, be accidental, as there are other such on the slab.

Pes.—The four phalangeal impressions are more or less ovoid without indications of claws or phalanges and, except for the first, curve slightly outward. There is a faint mark which may indicate a fifth digit. The pes impression lies immediately behind that of the manus and a little apart from it as the figure indicates. There lies in advance and to the left of the impressions we have discussed a series of five minute rounded marks, whose relative position is precisely the same as the termini of the pedal toes in the track described. These marks seem therefore to indicate the impression of the right pes. If so they give a trackway width of 33 mm. and an estimated stride of the same foot of 42 mm., thus indicating a rather wide-bodied, short-legged form. This form is provisionally included in the genus *Exocampe* Hitchcock, the species being designated as *delicatula* in allusion to its delicate proportions.

A series of footprints, one of several trackways impressed on the undulating surface of a large slab of Hermit shale (No. 11,519, U. S. N. M.), seems to be referable to this species. The specimen was found one-quarter of a mile west of the sign " Red Top " on the Hermit Trail, at the head of Hermit Gorge by Mr. G. E. Sturdevant, of the Park Service, who discovered it lying loose on a slope about 30 feet above the Hermit-Supai contact where it had been exposed to weathering, which to some extent accounts for the distinctness of the minute tracks impressed upon the upper surface.

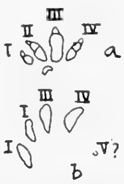

FIG. 16.—*Batrachichnus delicatula* (Lull). Type. No. 2,146, Yale Museum; right manus (*a*) and pes (*b*) natural size. (After Lull.)

The trackway, 300 mm. in extent, crosses the lower right hand portion of the slab shown in plate 12. The hindfoot has a length of 10.5 mm. and width of 13 mm. There are five digits, and a tracing of the foot plan, when placed upon Lull's figure of the pes, though slightly larger, agrees precisely in the placement and arrangement of the toes. The digits are slender, radiating, progressively lengthening toward the outside. The fifth, much reduced in length and widely set off from the others, has its origin far back on the sole and is directed strongly outward. As in the type, the sole is indistinct, though a few imprints seem to indicate that it was broadly rounded behind. The hindfoot, as shown by Lull, is placed directly behind the forefoot.

The forefoot has a length of 7 mm., a greatest width from tip to tip of first and fourth digits of 10 mm. There are four widely radiating digits apparently without claws, although Lull thought he detected " distinct impressions of terminal claws." Manus turned strongly inward toward the axis of the direction of movement. First and fourth toes usually in line across the palm of the foot, the former pointing inward and backward, the latter outward and forward as shown in figure 16. As in the pes the palmar impressions are hardly more than a suggestion. Forefeet usually inside the line formed by the hindfeet.

Such differences as may be noted between the forefeet of this and Lull's type may be more apparent than real for it must be remembered that Lull had but a single impression of the manus (see fig. 16) in the type, and as we well know the same trackway often exhibits differences in the toe plan in successive imprints made by the same foot (see fig. 15). It is, therefore, important to have trackways of some length in order to be sure of the precise arrangement of the digits.

Comparative Measurements

	Type No. 2146 Y.M.	No. 11,519 U. S. N. M.
	mm.	*mm.*
Length of stride	42.0	57.0
Width of trackway	33.0	45.0
Length of manus	5.5	7.0
Width of manus	7.0	10.0
Length of pes	7.0	10.5
Width of pes	7.0	13.0

A second series of small five-toed tracks on this same slab (see *B*, fig. 15) but crossing the trackway just described at right angles, is of interest as showing the apparent capability of this animal to walk entirely on the hind legs. This series, which may be clearly traced for a length of 290 mm., gives nowhere any evidence of the front feet. Furthermore the lengthened stride, 82 mm., and narrowed trackway, 34 mm., give corroborative evidence in support of this conclusion. In proportions of foot and relative arrangement of the digits the impressions of the hindfeet in the two trails are essentially identical and while both may not have been made by the same individual, they were quite certainly made by the same kind of an animal. That small, crawling quadrupedal animals often assume the bipedal mode of progression for short distances has often been observed among the small lizards of the southwestern United States, as has been convincingly portrayed by Sayville Kent in excellent photographs. However, it is rather surprising to find an amphibian doing likewise since our living amphibians are usually slow and sluggish of movement.

A salamandroid feature of the feet is seen in the inward toeing of the forefeet and the more outward direction of the toes in the hind-feet. The widely radiating toes of the forefoot and the digital formulas of 4 and 5 are particularly characteristic of the salamander group and it would seem quite probable that the affinities of these tracks fall into that group.

The assignment of this species to the genus *Batrachichnus* Woodworth, founded on a specimen from the Carboniferous shales of Massachusetts, is chiefly on the basis of a similar digital formula supplemented by its small size, with slender toes radially arranged. Its original reference to the Mesozoic genus *Exocampe*, as mentioned by Lull, was a temporary expedient and not intended to imply genetic relationship. The different digital formula as now definitely known shows at once that its affinities lie outside the genus *Exocampe* which has four digits in the pes and five in the manus.

The type species *Batrachichnus plainvillensis* shows a decided median groove (see fig. 18) of which there is no indication in *B. delicatula*, but in common with Matthew in referring *Dromopus celer* to this genus, this feature is not here regarded as of great classificatory importance.

B. delicatula is distinguished from *B. plainvillensis* and *B. celer* by its much larger size, more widely radiating toes, especially of the forefoot, and lack of sole impressions. Its distinction from the Joggins species is rendered difficult because of inadequate illustration and description.

BATRACHICHNUS OBSCURUS, new species

Plate 13

Type.—Catalogue number 11,529, U. S. N. M. Consists of a trail about 500 mm. in length; on this same slab are plant impressions and a few tracks of *Hylopus* sp.

Type locality.—About one-fourth mile west of the sign "Red Top" on Hermit Trail, at head of Hermit Gorge, Grand Canyon National Park, Arizona.

Geological occurrence.—Hermit Shale (about 30 feet above Hermit-Supai contact), Permian.

Description.—Stride 23 mm., width of trackway 23 mm., width of median groove 8 mm. *Hindfoot:* Length 9 mm., width 6 mm. There appear to be five short digits; third and fourth subequal in length and directed straight forward; fifth much shortened but not especially set off from other toes; second and first progressively shortened inward (see fig. 17). Although the trail is of considerable length only a few of the impressions show toe marks, and of the hindfoot none shows the full complement, all but one imprint lacking the fifth toe. The sole is relatively narrow, elongate and obtusely rounded

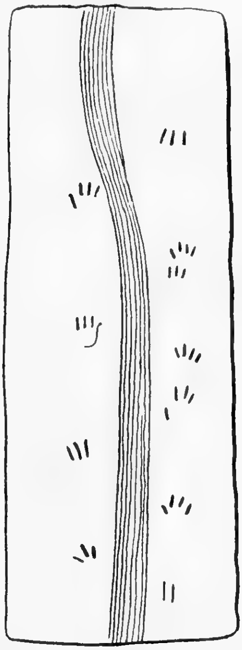

FIG. 17.—*Batrachichnus obscurus.* Type. No. 11,529, U. S. N. M. Diagram of part of trackway. About ¾ natural size.

behind. *Forefoot:* Length about 5 mm., width 4.5 mm. Four digits. First slightly set off from the others and directed forward and inward, others extending almost straight forward. The forefeet im-

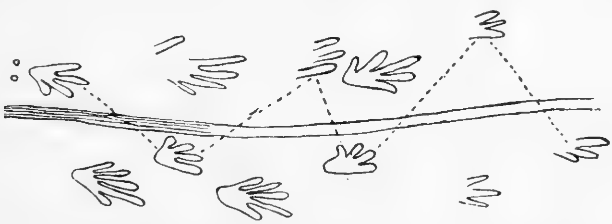

FIG. 18.—*Batrachichnus plainvillensis* Woodworth. Genotype. Diagram of trackway. Natural size. (After Woodworth.)

pressions are even more obscure than the hind, evidently due to the fact that the tracks were made in very soft mud which, in most instances, ran into the track as soon as the foot was withdrawn, leaving only a slight depression. The contour of the palm is not fully indicated in any of the tracks.

In the length of stride, which is equal to width of trackway, in size of tracks, number of digits, and presence of a median groove, these tracks bear a strikingly close resemblance to those of *Batrachichnus plainvillensis* from the Carboniferous shales of Massachusetts. The great width and depth of the median groove seem to indicate that it was made by the dragging belly. The course is irregularly sinuous and at one end the animal turned sharply to the left and with a more moderate bend to the right, and where these bends were made the median groove is much widened and smoothed out. (See pl. 18.)

It is quite evident that the tracks were made by a salamandroid, shortlegged crawling animal, which in moving about dragged the belly. The foot structure also suggests its amphibian origin. No other trails or tracks exactly comparable to it have been found at this locality.

From *B. plainvillensis* this species may be distinguished by the shorter toes, their more forward direction, and the wider and deeper median groove. It is distinguished at once from *Dromillopus,* also a small form in these same deposits, by the greater number of toes on the hindfoot. The specific name is suggested by the obscure condition of most of the tracks.

Genus DROMILLOPUS Matthew

Dromillopus Matthew, G. F., Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, p. 91.

Matthew characterizes the genus as follows:

Generic characters.—Small digitigrade batrachians. Toes slender, directed forward in a radial manner; imprint showing only four toes to each foot.

Genotype.—*Dromillopus quadrifidus* Matthew.

This genus was established by Matthew on a series of small tracks from the Carboniferous Coal Measures of Joggins, Nova Scotia.

DROMILLOPUS PARVUS, new species

Plate 14

Type.—Catalogue number 11,537, U. S. N. M. Consists of a small slab of shale showing the trackway and tail drag of a small animal.

Type locality.—About one-fourth mile west of the sign "Red Top" on Hermit Trail near the head of Hermit Gorge, Grand Canyon National Park, Arizona.

Geological occurrence.—Hermit shale (about 40 feet above Hermit-Supai contact), Permian.

Description.—Stride about 36 mm.; width of trackway about 33 mm. This small slab of reddish colored shale has impressed on its surface some few beautifully preserved tracks (see pl. 14), although the trackway as a whole is obscure in several important details.

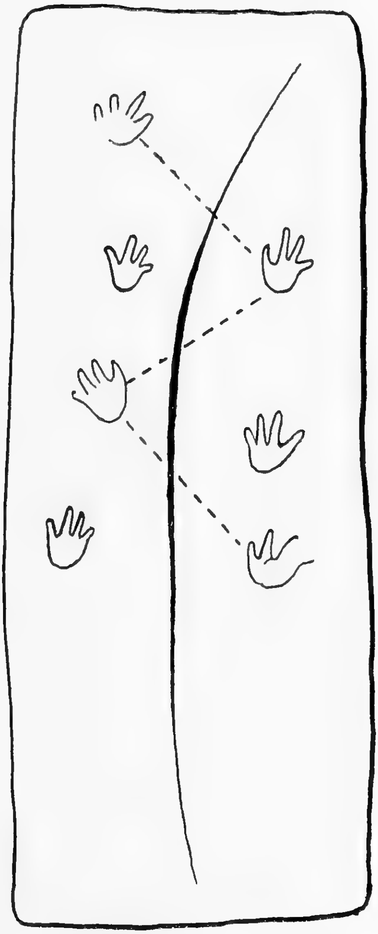

Fig. 19.—*Dromillopus parvus.* Type. No. 11,537, U. S. N. M. Diagram of trackway showing tail drag. Broken lines connect the supposed pes impressions of opposite sides. About natural size.

This obscurity is due to two conditions, first, the intermingling on the left-hand side of the tracks of two small animals; and second, the failure of one pair of feet to impress clearly. The feet most clearly registered correspond almost precisely in size and in number and arrangement of the digits with the so-called hindfoot described by

Matthew[1] as *Dromillopus quadrifidus* from the Coal Measures of Joggins, Nova Scotia. The presence of a distinct tail drag, and its absence in the Joggins trackway (compare figs. 19 and 20), differences found in the structure of the forefeet, longer stride, and greater width of trackway all point to its specific distinctness from the Nova Scotian species; hence the specific name *parvus* is proposed for its reception. *Hindfoot:* Length 9 mm., width 8 mm. Four digits of which the outer is set off from the other three. These are long and slender, regularly increasing in length toward the outside of the foot, the third being the longest, the fourth considerably shorter.

FIG. 20.—*Dromillopus quadrifidus* Matthew. Type. Diagram of trackway. About natural size. (After Matthew.)

The sole is well impressed and the full rounded outline of the heel is shown in figure 19, whereas in the Joggins species the sole is scarcely distinguishable. The foot is shown to have been semiplantigrade, not digitigrade as originally characterized by Matthew. *Forefoot:* Length about 8 mm., width 8 mm. While none of the so-called hindfoot impressions show the detailed structure plainly, it is clearly evident there were only four toes on the manus. The sole seems to be more broadly rounded than in the pes. A description of the other details of the foot must await the discovery of better preserved specimens.

The imprints connected by dotted line in figure 20 were regarded by Matthew as having been made by the hindfeet. No reasons were

[1] Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, p. 91.

given for this conclusion, though their slightly larger size may have influenced his decision. The relative position of these tracks suggests that their identity may be the reverse of Matthew's conception. The same condition prevails in the trackway now before me, but no positive evidence in solution of this suggestion is offered and for the present Matthew's identification will be followed. Between the rows of tracks is a distinct, well defined groove probably made by a dragging tail, which registers the movement of the animal as indicated by the undulating character of the impression.

A second series of tracks of this species is found on the upper side of the slab carrying the basi-relief tracks of *Hyloidichnus bifurcatus* (No. 11,598, U. S. N. M.). It is a short trackway that is in

COMPARATIVE MEASUREMENTS

	No. 11,537 U. S. N. M.	Type of *Dromillopus quadrifidus*
	mm.	*mm.*
Length of stride	36	26
Width of trackway	33	18
Length of pes track	9	9
Width of pes track	8	8
Length of manus track	8	7
Width of manus track	8	7

accord in all particulars with the type specimen. The tail drag is not continuous as in the type but left its trace only on the crests of the ripple marked surface across which the trail runs.

Genus HYLOPUS Dawson

Hylopus Dawson, J. W., Proc. Trans. Roy. Soc. Canada, Vol. 12, 1895, p. 77.

The genus *Hylopus* was briefly characterized by Dawson as follows: "Smaller footprints [than *Sauropus* Lea], digitigrade, and made by animals having a long stride and hind and forefeet nearly equal. Five toes. Probably footprints of Microsauria and possibly of Dendrerpeton." In all Dawson described five species. These named in chronological order are: *Hylopus logani, H. hardingi, H. caudifer, H. minor* and *H. trifidus*. All are from the Coal Measures of Nova Scotia.

Subsequently Matthew[1] reviewed the genus and reached the conclusion "that there is so much variation in the form of these foot-

[1] Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, pp. 82-85.

prints that they cannot all be contained in the genus *Hylopus.*" He then shows that *H. hardingi, H. minor,* and *H. logani* should be retained in the genus and at the same time selects *H. hardingi* as the genotype. He also concludes (p. 85) "that five toe-marks of the hindfoot and four in the fore is the typical number for *Hylopus.*" It is this conclusion that leads him to question the propriety of retaining *H. minor* which has a digital formula of 5-5. *H. caudifer* is removed to the genus *Asperipes,* and *H. trifidus* to the genus *Ornithoides.*

Dawson in his characterization and also in his first published figures[1] before the species was named, shows five digits on the forefoot. In the light of the many other resemblances to these tracks found in specimens from the Grand Canyon, in which there are five distinct toe impressions on the forefoot, it would seem that Dawson was probably correct, and that Matthew was in error in thinking there were only four toes on the manus. Because of the close resemblances found in these footprints from the Hermit shale to those of *H. hardingi* Dawson, especially in relative length of digits, stride and width of trackway, I refer the following new species to *Hylopus,* which may now be characterized as follows:

Generic characters (emended).—Quadrupedal, semidigitigrade. Manus subequal or smaller than pes. Five toes in both manus and pes; toes in both thick with bluntly pointed extremities; fourth longest, progressively decreasing in length inward; fifth in both fore- and hindfeet much shortened and strongly set off from others. Stride long, hindfoot placed behind forefoot.

Genotype.—*Hylopus hardingi* Dawson.

Matthew also points out that all of the species except *H. logani* have the print of the sole preserved, and on that account infers that Dawson was in error in regarding the feet as being digitigrade. This conclusion is fully sustained by the semi-plantigrade character of the impressions of the specimen about to be described.

HYLOPUS HERMITANUS, new species

Plate 15

Type.—Catalogue number 11,517, U. S. N. M. Consists of a slab on which is a trail showing many of the tracks of both fore- and hindfeet beautifully impressed.

Type locality.—One-fourth mile west of sign post "Red Top" on Hermit Trail, head of Hermit Gorge, Grand Canyon National Park, Arizona.

[1] Air-Breathers of the Coal Period, Montreal, 1863, pl. 1, figs. 2, 2a.

Geological occurrence.—Hermit shale (30 feet above base), Permian.

Description.—Stride about 144 mm.; width of trackway about 114 mm. *Hindfoot:* Length about 38 mm.; width 40.5 mm. Five

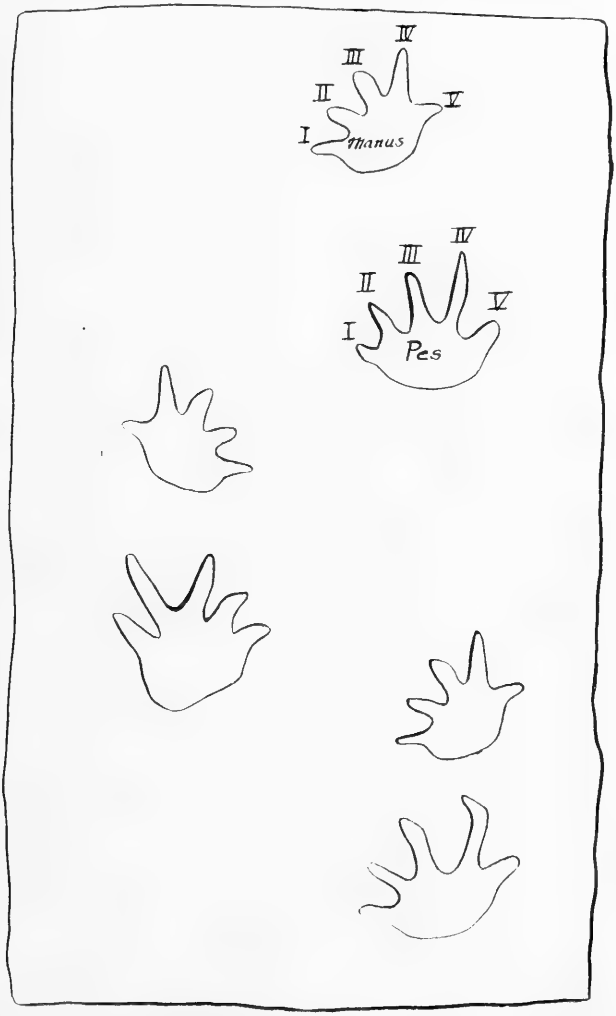

FIG. 21.—*Hylopus hermitanus.* Type. No. 11,517, U. S. N. M. Diagram of trackway. About ½ natural size.

toes. The fourth toe is longest, the others progressively shorter inward. The fifth is shortened, divergent, and with a tendency to turn backward. There seem to have been sharp claws on the second, third, and fourth digits as in *H. minor* Dawson, but the fifth had a bluntly rounded end and was apparently without claw. If a claw was present on the first digit it must have been obtusely pointed. In all of the tracks, the sole is rather faintly impressed in so far as its exact posterior outline is concerned. As determined it is relatively short, but broad, and apparently without prominent palmar pads. *Forefoot:* Smaller than hindfoot. Length 32 mm.; width from tip to tip of first and fifth toes is 36 mm. Five toes, arranged much as in the hindfoot. Fourth is longest, progressively shortening inward.

FIG. 22.—*Hylopus hardingi* Dawson. Trackway. (After Matthew.)

Fifth more widely divergent from fourth than in the pes, with an inclination to turn backward, and apparently without claw. The palm is short, and rounded behind.

A second series of tracks (No. 11,524, U. S. N. M.) from this same locality, occurring on the weathered surface of a small slab of shale found on the hillside below the ledge where the type was found in place, is identified as belonging to this same genus and species. It is smaller than the type (see table of measurements) but otherwise is in close agreement as to the proportions and arrangement of the digits. Other scattering imprints of *Hylopus* are present on several slabs of shale from this same locality.

Examination of the type (see pl. 15) shows that the animal was in the habit of placing the hindfoot directly in line with but a variable distance behind the forefoot, never overlapping. That the digits were flexible is indicated by the strongly bent ends of digits three and four in the lower impression of the pes as shown in figure 21, whereas the very next impression forward shows them perfectly straight. Since the straight form of digits predominates they are regarded as representing the normal shape of these toes.

COMPARATIVE MEASUREMENTS

	No. 11,524 U. S. N. M.	No. 11,517 U. S. N. M. Type	*Hylopus hardingi* *
	mm.	*mm.*	*mm.*
Stride	105	144	136.5
Width of trackway	84	114	90.0
Length of hindfoot	31	38.0	36.0
Width of hindfoot	...	40.5	33.0
Length of digit I	5.0	5.0	4.5
Length of digit II	8.5	9.0	9.0
Length of digit III	11.5	14.0	15.0
Length of digit IV	14	18.5	20.5
Length of digit V	...	7.0	6.0
Length of forefoot	21	32.0	...
Width of forefoot	26	36.0	...
Length of digit I	6	7.5	...
Length of digit II	7	8.0	9.0
Length of digit III	10	10.5	13.5
Length of digit IV	12	15.0	16.5
Length of digit V	4.5	6.0	5.7
Forefoot in front of hindfoot	...	12 to 30	...

* Measurements of *Hylopus hardingi* taken from Matthew's illustration.

Matthew[1] depicts a fore- and hindfoot of *Hylopus hardingi* which in the explanation of figures he attributes to the right side. By comparison with the tracks of *Hylopus hermitanus* now before me, and especially with Matthew's figure 2, plate 6, it becomes at once apparent that they pertain to the left side. It will be noted that in Matthew's illustration of the hand, the side from which the first digit would spring is left unfinished (see fig. 23), implying that the evidence for its absence was inconclusive. In view of the close resemblance to the specimen here described and in their close agreement

[1] Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, figs. 1*a* and 1*b*.

of relative proportions as shown in the table of comparative measurements, and especially by Dawson's original determination, it would seem there can be but little doubt that the creature making the tracks called *Hylopus hardingi* had five digits on the forefoot. The liability of toes not to impress is clearly shown in the specimen now before me for although in most of the tracks forming this short trail all toes are indicated, one hindfoot impression shows only the dimmest record of digit four and no trace at all of the outer toe.

Hylopus hermitanus most closely approaches *H. hardingi* in size and arrangement of the digits of the feet, but may be distinguished

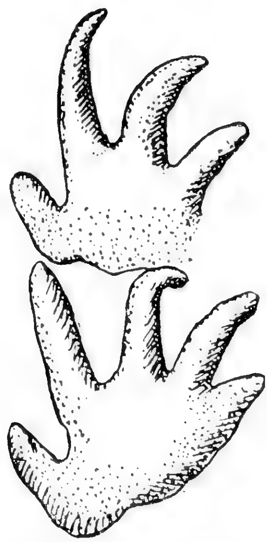

FIG. 23.—*Hylopus hardingi* Dawson. Fore- and hindfoot of left side. Natural size. (After Matthew.)

from that species by the more widely separated and more divergent toes, and especially by the more forward position of the fifth toe. In both *H. hardingi* and *H. minor,* the fifth toe is given off far back on the side of the sole. In the forefeet of both of these species the lateral toes are much less divergent than in the specimen here described (compare figs. 21 and 22).

In offering conjectures about the known animals which might have been responsible for the Nova Scotian tracks, Sir William Dawson suggests they may have been made by some microsaurian-like *Hylerpeton* or *Hylonomus.* In any event, all of the tracks here discussed seem to conform more nearly to those made by amphibians than to those of any known reptile.

In figure 24 is shown a diagram of the foot plan of *Anthracopus ellangowensis* Leidy from the Coal Measures of Pennsylvania, which displays such striking resemblances to the forefoot of *Hylopus hermitanus* as to allow the suggestion that with the recovery of better preserved specimens of the Pennsylvanian species they will be found to be congeneric. Through the courtesy of Dr. Witmer Stone, director of the Philadelphia Academy of Sciences, I have had the opportunity of examining the type of *Anthracopus ellangowensis* and find on one imprint a faint suggestion of the presence of a fifth digit, although none of the other five tracks preserved gives any hint of its existence. The evidence is, therefore, inconclusive. The absence of the fifth digit in *A. ellangowensis* is the only important difference found in a comparison of these two species, and its absence may be due to its not impressing, a condition observed in at least one track of the type of *H. hermitanus*. In general form, relative length and

FIG. 24.—*Anthracopus ellangowensis* Leidy. Imprint of the right side. Less than natural size. (After Leidy.)

divergence of the digits, and shape of palmar impression there is great similarity between the two. Attention should also be called to certain resemblances found between *H. hermitanus* and *Ichnium sphaerodactylum* described by Pabst[1] from the Permian (Tauback) of Thüringen. In the general plan of the feet there is a striking similarity, though the absence of the first digit in the manus and the heavier toes with bluntly rounded extremities in *I. sphaerodactylum* effectually distinguishes it from the Arizona form.

Genus HYLOIDICHNUS, new genus

Generic characters.—Quadrupedal, semidigitigrade. Both manus and pes have five digits. Manus smaller than pes and placed in front of hindfoot. Toes terminated either with pellets or having bifurcated ends.

Genotype.—*Hyloidichnus bifurcatus.*

[1] Pabst, W., Deutsche geol. Gesell., Vol. 48, 1896, pp. 638 and 808, text fig. 2.

HYLOIDICHNUS BIFURCATUS, new species

Plate 16

Type.—Catalogue number 11,518, U. S. N. M. Consists of the obverse slab on which is a trackway about 500 mm. in extent.

Type locality.—Hermit Trail, one-fourth mile west of sign "Red Top" head of Hermit Gorge, Grand Canyon National Park, Arizona.

Geological occurrence.—Hermit shale, 30 feet above Hermit-Supai contact, Permian.

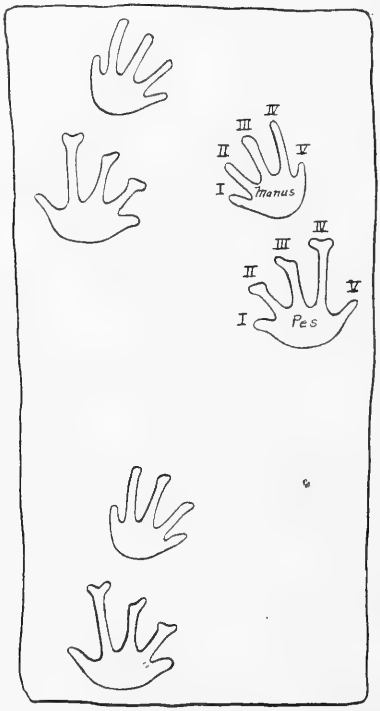

FIG. 25.—*Hyloidichnus bifurcatus.* Type. No. 11,598, U. S. N. M. Diagram of trackway. About ⅓ natural size.

Description.—Stride about 180 mm.; width of trackway about 125 mm. Forefoot somewhat smaller than hind and is placed in front of it. *Hindfoot:* Length 42 mm., width 40.5 mm. There are five toes, progressively longer toward the outside, the fourth being the longest. The fifth digit is much shortened, and somewhat set off from the others. Fourth digit is more than twice the length of the sole and extending directly forward as in *Hylopus.* First and fifth toes terminated by pellets, second, third and fourth usually having bifurcated ends with inner branch longer than outer (see fig. 25). These have suggested resemblance to the bifurcated digits of the living *Rhacophorus maximus,* a tree frog of Sumatra, which has the unguals split to give better support to the terminal disks. This reference should not convey the idea of relationship but simply calls attention to an interesting similarity of structure. Sole narrow antero-posteriorly but wide transversely. Digits have the following lengths. I = 7.3 mm., II = 17 mm., III = 23 mm., IV = 30 mm., V = 13 mm. *Forefoot:* Length about 32 mm., width 31.2 mm. Five digits as in the pes, which grow progressively longer toward the outside, the fourth being the longest. The fifth shorter than the first and especially set off from the other toes as in the hindfoot. All of the toes seem to be terminated by pellets. None of the imprints show bifurcated toes. First toe more widely separated from the others than in the hindfoot. The digits have the following lengths: I = 10 mm., II = 14.5 mm., III = 17.5 mm., IV = 20 mm., V = 9 mm. These tracks may be classed as digitigrade, as shown by the extreme shortness of the sole impression. They were evidently made by a quadrupedal batrachian, evidently of the walking type as indicated by the alternating position of the steps of opposite sides.

In such features as the digital formula, and their radiating arrangement, these tracks bear a close resemblance to *Hylopus* found in these same beds, but the longer and more slender toes terminated either by pellets or bifurcated ends at once distinguish them from that genus as well as all others coming under my observation. It is therefore regarded as new, the specific name *bifurcatus* being in reference to the divided ends of a few of the toes on the hindfeet.

Only one specimen referable to this species was found in the collection of 1926.

Genus PARABAROPUS, new genus

The discovery of additional specimens that appear to be referable to Lull's species *Megapezia ? coloradensis*[1] indicates the necessity of establishing a new genus for its reception. Its original assignment to the Nova Scotian genus *Megapezia* was regarded by Lull as provisional, largely on account of the paucity of the materials at his command. Certain resemblances to the genus *Baropus* suggest the name *Parabaropus,* which may be characterized as follows:

Generic characters.—Quadrupedal, plantigrade, with five digits in both manus and pes. Forefoot smaller than hind; toes in both rela-

[1]Amer. Journ. Sci., Vol. 45, 1918, p. 341.

tively short with rounded extremities, without claws; sole of pes elongated, narrowed behind. Forefoot turning strongly inward and placed in front of hindfoot.

Genotype.—Parabaropus coloradensis (Lull)

PARABAROPUS COLORADENSIS (Lull)

Plate 15, fig. 7

Megapezia ? coloradensis Lull, R. S., Amer. Journ. Sci., Vol. 45, 1918, p. 341.

In establishing this species, Lull had as type materials " three small slabs of red impure sandstone, one apparently of the manus obscured by crushing and mud-cracking, another of the pes, and a third with two impressions each of hand and foot, which determine the width of trackway but not the length of stride." From a study of these composite materials he depicted the plan of the feet as shown in figure 26.

A series of tracks (No. 11,598, U. S. N. M.) of the left side from the Hermit shale and from the same general locality as the type specimens, shows such striking resemblances to the tracks figured by Lull, except for their slightly larger size, as to at once raise the question of the proper association of the imprints as illustrated by Lull. This series, which is in relief, has been cast and thus affords all of the evidence of the original imprints. The manus is shown to be smaller than the pes, and the digits of the former resemble those of the latter in being relatively short with rounded ends without claws. This fact is entirely in accord with the large number of trackways in the collection from this same region in that the toes of the manus are always similar to those of the pes in the character of their termination. In other words, if one has the toes acuminate, they will be pointed in the other; if rounded in the hindfoot, they will be rounded in the forefoot, etc., etc. In the large collection of trackways now available from this same region, not a single exception to this rule can be found. This reason alone appears to be sufficient to show that these imprints have been incorrectly associated.

That Lull recognized this incongruity of foot structure is shown by the following remarks:

> The difference in character of manus and pes is so great, except for an agreement in size, that one would not, perhaps, be justified in associating them together were it not for the third slab.

Examination of the type materials made possible through the kindness of Dr. R. S. Lull, who forwarded them to the National Museum, all goes to confirm my above conclusions. The third slab, on which reliance was placed for the original association of the detached imprints, was found to have on its surface the tracks of no less than four kinds of animals, all rather indistinctly recorded in so far as their exact details are concerned. None of these can be positively identified with either of the detached tracks. The footprint which has suggested resemblances to the pes track figured by Lull is much smaller, but disregarding this difference in size, the preservation is such as to render its positive identification with that track out of the question.

In front of this track are two smaller tracks, one slightly encroaching upon the other, which in the light of newly discovered specimens can quite certainly be identified as the manus and pes tracks of

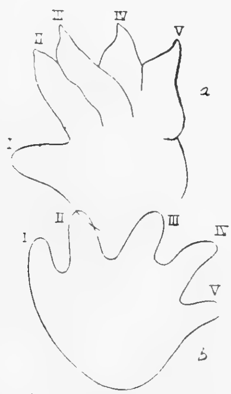

FIG. 26.—*Megapezia ? coloradensis* Lull. Type. No. 2,145, Yale Museum. *a*, right manus, *b*, right pes. ½ natural size. (Reduced from Lull.)

Hyloidichnus bifurcatus. The other tracks present on this slab are inferior in their preservation and deserve no further mention at this time.

After study of the type materials it is my conclusion that no evidence exists for the association of these detached footprints and on that account the track illustrated by Lull as the pes (see fig. 26) is selected as the type of the species *P. coloradensis.*

Comparison of the manus track of the newly discovered trackway (see fig. 27) with the type of *P. coloradensis* (Lull) (see fig. 28) shows such close resemblances between them as to leave no doubt that the type track pertains to the manus rather than the pes as originally determined. These tracks are practically of the same size, as may be seen in the table of comparative measurements and further resemblances are found in the short radiating digits, with rounded extremities, without claws, and short, broad sole rounded behind. The type shows the presence of only four digits but the faint impression of the sole which gradually fades out on the right hand side

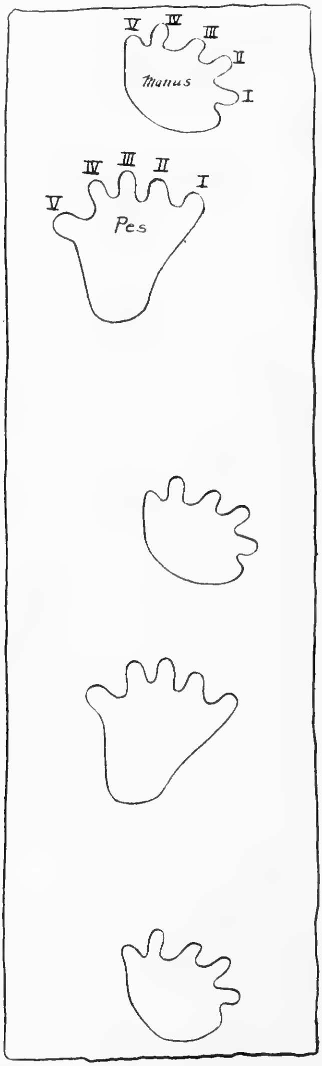

FIG. 27.—*Parabaropus coloradensis* (Lull) No. 11,598, U. S. N. M. Diagram of left hand side of trackway. About ⅕ natural size.

of the track indicates that is was sufficiently wide to carry a fifth toe. A tracing made from the type track without restoration is shown in figure 28.

Although the evidence is not entirely conclusive, in view of the many similarities pointed out specimen No. 11,598, U. S. N. M., is provisionally referred to the present species, and our knowledge of the species may now be elaborated by its description.

This specimen was found *in situ* in the Hermit shale about one-quarter mile west of the sign post " Red Top," on the Hermit Trail,

COMPARATIVE MEASUREMENTS OF FOREFEET

	No. 11,598 U. S. N. M.	Type No. 2,145 Yale Museum
	mm.	*mm.*
Length	48	48.5
Breadth	70	50.0
Length of digit I	12	12.6
Length of digit II	14	15.0
Length of digit III	14	17.0
Length of digit IV	13	?15.5
Length of digit V	11	....

in Grand Canyon National Park, Arizona, about 30 feet above the Hermit-Supai contact. The length of stride is about 240 mm., width of trackway unknown. Forefoot smaller than hind and placed in front of the hindfoot impression. *Hindfoot:* Plantigrade, length about 80 mm., greatest width 80 mm. Five relatively short digits having rounded terminations, without claws. Fifth toe set off from

FIG. 28.—*Parabaropus coloradensis* (Lull) Type. No. 2,145, Yale Museum. Outline of manus, unrestored. About ½ natural size.

the others and directed strongly outward. Sole elongate, more than three times as long as the longest toe. Digits have the following lengths: I = 14 mm., II = 21 mm., III = 23 mm., IV = 18 mm., V = 16 mm. *Forefoot:* Length about 48 mm., width about 70 mm. Five toes radially arranged. Toes as in the pes, short with rounded terminations without claws. Palm nearly twice as wide as long, and broadly rounded behind. The foot as a whole is turned inward whereas the hindfoot is directed straight forward (see fig. 26). The relative lengths of the digits are given in the table of comparative measurements (see p. 57). The form of the elongated hindfoot impression has a considerable resemblance to the pes track of *Baropus lentus* Marsh (see fig. 10), but is distinguished from that genus by the presence of five toes and in having the forefoot considerably smaller than the hind, and its much smaller size as a whole.

Genus COLLETTOSAURUS Cox

Collettosaurus Cox, E. T., Fifth Ann. Rep. Geol. Surv. Indiana, 1874, p. 247, one plate.

In reviewing the literature relating to Carboniferous footprints it became at once apparent that many of the authors gave but scant attention to the work done by their predecessors, a procedure that has resulted in the creation of a number of synonyms. While it is far beyond the scope of the present paper to attempt a revision of the entire subject, in order to secure a working basis for the proper classification of the specimens here considered it becomes necessary to make the nomenclatural changes herewith suggested.

In 1874 Cox proposed the genus *Collettosaurus* based on an adequate specimen from the Carboniferous of Warren County. Indiana. No attempt was made to characterize the genus, but from his rather meager description and illustration it may now be defined as follows:

Generic characters.—Quadrupedal. Five digits on both manus and pes. Toes relatively slender, acuminate, radiating, with fifth somewhat set off from the others; feet about equal in size; hindfoot placed behind forefoot.

Genotype.—*Collettosaurus indianaensis* Cox.

In February 1891, Butts[1] described the new genus and species *Notalacerta missouriensis* (see fig. 30) from the Upper Coal Measures of Kansas City, Missouri, and in March of the same year he established a second genus *Notamphibia magna* (see fig. 29), each having five slender sharply pointed toes on both fore- and hindfeet.

A critical comparison of these three genera fails to disclose differences of genetic importance, and on the grounds of priority *Notalacerta* and *Notamphibia* are considered synonyms of *Collettosaurus*, the species to be known hereafter as *Collettosaurus missouriensis* (Butts) and *C. magna* (Butts).

[1] Butts, Edward, The Kansas City Scientist, Vol. 5, 1891, p. 18.

FIG. 29.—*Collettosaurus magna* (Butts). Type. Imprint of right side. About natural size. (After Butts.)

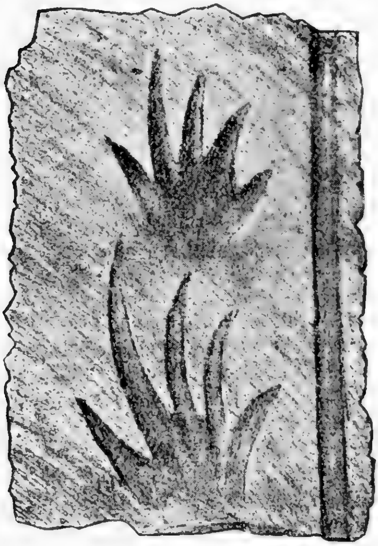

FIG. 30.—*Collettosaurus missouriensis* (Butts). Type. Imprints of fore- and hindfoot of left side. Natural size. (After Butts.)

Dromopus velox Matthew[1] from the Lower Carboniferous of Nova Scotia (see fig. 31), likewise appears to have its affinities within this genus, and were it not for the uncertainty of the digital formula of the forefoot, I should unhesitatingly refer it to the present genus. The hindfoot with five slender digits, digits three and four subequal in length, and the first slightly divergent, are all features in common with the pes impressions of the species to be described below.

Matthew was in doubt as to whether there were three or four toes in the manus of *Dromopus velox*, but in view of the close similarities noted above in the hindfeet, it would seem not unlikely that five may be found in this foot when better preserved specimens are known.

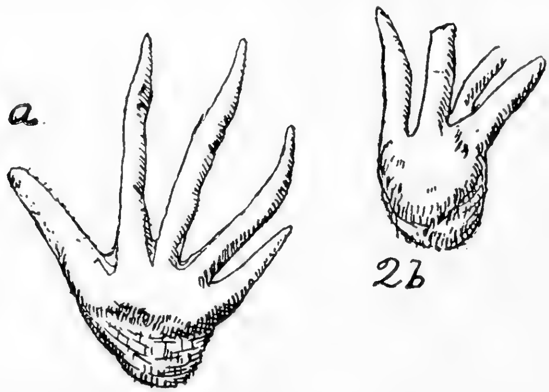

FIG. 31.—*Dromopus velox* Matthew. Type. *a*, right hindfoot impression; *2b*, right forefoot impression. From Joggins, Nova Scotia. Both natural size. (After Matthew.)

Footprints from the Hermit shale, having a similar digital formula, with slender sharp pointed toes are tentatively referred to *Collettosaurus*.

COLLETTOSAURUS PENTADACTYLUS, new species

Plate 19, fig. 1

Type.—Catalogue number 11,527, U. S. N. M. Consists of a slab of shale 390 mm. in length carrying a consecutive series of tracks evidently made in very soft mud.

Type locality.—One-fourth mile west of sign post "Red Top" on Hermit Trail, head of Hermit Gorge, Grand Canyon National Park, Arizona.

Geological occurrence.—Hermit shale (about 30 feet above base), Permian.

[1] Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, p. 86, pl. 2, figs. *2a*, *2b*.

Description.—Stride about 330 mm.; width of trackway 120 mm. *Hindfoot:* Five digits, third and fourth long, slender, subequal in length, and usually directed straight forward in the direction of

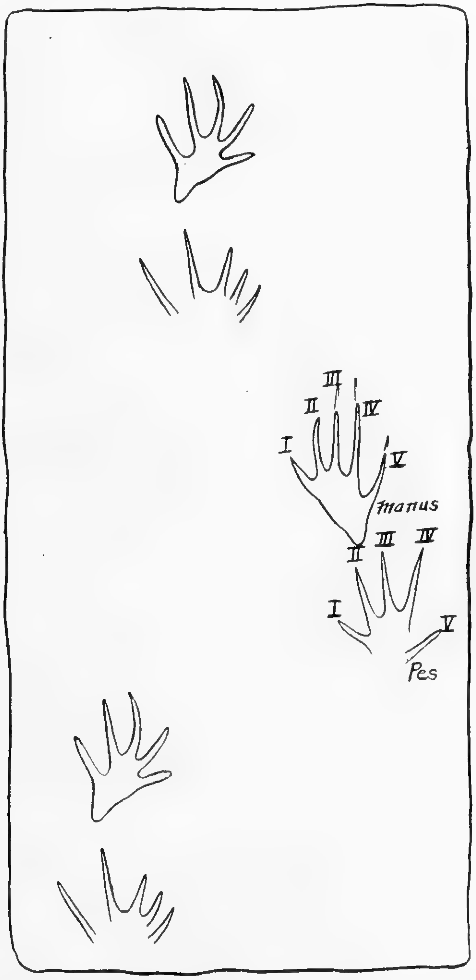

FIG. 32.—*Collettosaurus pentadactylus.* Type. No. 11,527, U.S.N.M. Diagram of trackway. About 1/3 natural size.

movement. The fifth digit originates well back on the side of the sole and is diverted strongly outward. The first is weak and about half the length of the median digits. Sole apparently long, but none of the hindfoot impressions is sufficiently clear to show the precise shape of the sole. Roughly estimated the pes may have a total length of about 50 mm. The length of the digits may tentatively be recorded as follows: digit I, 14 mm.; digit II, 24 mm.; digit III, 28 mm.; digit IV, 28 mm.; digit V, 22 mm. These figures are subject to revision since the impressions may have been lengthened by slipping in the mud. *Forefoot:* Length about 54 mm.; width measured from tip of digit I to the tip of digit V, 41 mm. Five digits, inner and outer, shorter than median toes, both somewhat divergent, and both originate well back on the opposite sides of the palm behind the bases

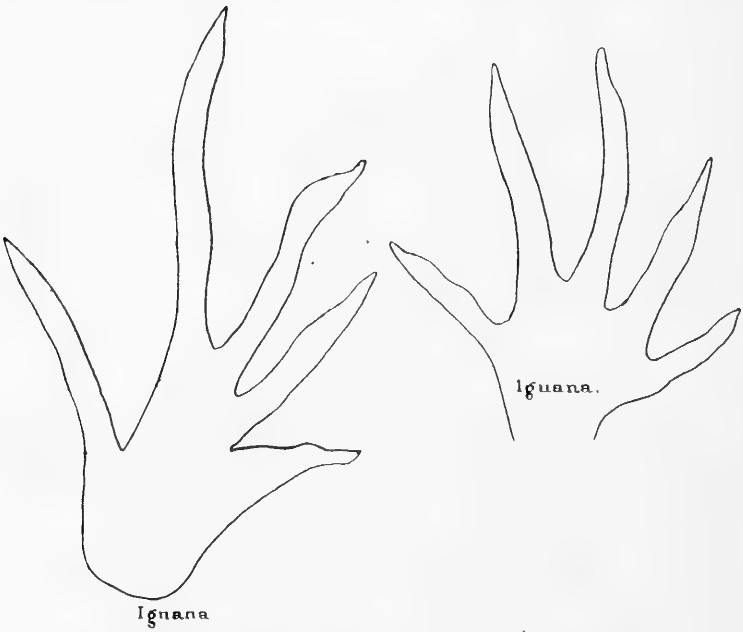

FIG. 33.—*Iguana* sp. Tracks. Right figure, manus; left figure, pes. Both of the left side. Natural size. (After Hitchcock.)

of the median digits. The first is weak, and, as in the hindfoot impressions, about one-half as long as the middle toes. Sole long, narrow, and obtusely pointed behind. Length of digit, I, 13 mm.; digit II, 26 mm.; digit III, 27 mm.; digit IV, 25 mm.; digit V, 20 mm. In walking the forefoot is placed forward and directly in front of the hindfoot. The weight of the animal, judging from the depth of the impressions of the feet, was about equally distributed between the fore and hind limbs. Forefoot but little smaller than hind.

From *Collettosaurus magna* (Butts) the present species may at once be distinguished by the much shorter digit I in both manus and pes and by the greater relative narrowness of the imprint as a whole.

Unfortunately Butts neglected to state whether the imprint figured by him was of the hand or the foot, nor did he designate whether right or left, but from comparison with the specimens under consideration it becomes quite apparent that the track was made by a foot of the right side of the animal, clearly indicated by the posterior position of the fifth digit.

The tracks here described seem to have been made by a long-legged quadruped walking rapidly through soft mud, for when the foot was withdrawn the ooze closed in from either side in many instances leaving only a narrow streak to indicate the imprint of the toe. There are no indications of a tail drag.

The foot plan, especially of the manus, shows some striking resemblances to that of the living Iguana (compare figs. 32 and 33). The long slender acuminate toes; two median digits of subequal length; divergent fifth toe and narrow pointed palmar impression, are all features in common between the fossil tracks and those of the Iguana, and at least permit the suggestion that in all probability these fossil tracks were reptilian if not Sauri in origin.

Genus CURSIPES Matthew

Cursipes Matthew, G. F., Canadian Rec. Sci., Vol. 9, 1903, p. 102.

The genus *Cursipes* was established by Matthew on specimens from the Carboniferous of Joggins, Nova Scotia. The chief characters distinguishing *Cursipes,* as extracted from Matthew's description would seem to be as follows:

Generic characters.—Quadrupedal. Five digits in pes, three in manus. Toes long and slender in both feet. Sole small in both manus and pes.

The presence of this genus in the Hermit formation seems to be indicated by the rather inferior specimen briefly described below.

CURSIPES, sp.

Plate 17, fig. 2

A series of footmarks (No. 11,521, U. S. N. M.) more or less obscured by the tracks of other animals stepping upon them, seems to be referable to the genus *Cursipes,* and if correctly identified marks the first recognized occurrence of this genus in the Hermit ichnite fauna. This specimen was found in the same locality as the other Hermit specimens described herein.

As shown best on the upper right hand side of the slab, the print of the three toed forefoot was distinct from the hind and placed some distance in front of it. The stride is about 115 mm., width of trackway about 125 mm. *Hindfoot:* Length about 30 mm., width about 33 mm. There are five digits. Toes widely spread as in *Hylopus*. Fifth toe strongly set off from the other. Second and third toes subequal in length, others progressively shorter toward the outside of the foot. Sole rather lightly impressed. Considerable variation in the length of toes is noted in the several impressions available; the length of toes as given below are measurements taken from the two most clearly impressed tracks. Length of toes: I = 9 mm.; II = 11 mm.; III = 10.5 mm.; IV = 10 mm.; V = 9 mm. *Forefoot:* Length about 28 mm., width about 20 mm. There are three long slender toes, the outer slightly spreading from the inner two. Toes subequal in length, none less than 18 mm. long. Sole indistinctly impressed.

The digital formula of five in the pes and three in the manus at once distinguishes this trackway from all others found in the Hermit fauna, but in the Joggins, Nova Scotia, fauna two genera, *Asperipes* and *Cursipes,* are found with a similar number of digits. The elongated nature of the toes, especially in the manus, and the relatively small soles seems to show that its affinities lie in the genus *Cursipes* to which it is provisionally referred.

The much larger size of the tracks, and differences noted in the plan of the feet, especially in the relatively shorter and stouter toes of the pes, are characters that might serve to distinguish it from the described species, *C. dawsoni* and *C. levis* Matthew, but on account of the unsatisfactory nature of the evidence to be obtained from this single specimen its designation as a distinct species is deferred for the present. It is sufficient at this time to call attention to the presence of *Cursipes* in this fauna in the expectation that better specimens may be found, which will permit its adequate characterization.

INCERTE SEDIS

Plate 17, fig. 2; plate 18

Under this heading, attention is called to certain ichnites occurring in the Hermit formation that are apparently new to the fauna, but due to the paucity of information to be obtained from specimens in hand it seems undesirable to name them.

Specimen No. 11,528, U. S. N. M. (see pl. 18), is notable as being the largest footprint yet discovered in the Hermit formation, and as such it appears worthy of this brief description.

This specimen was found by Mr. G. E. Sturdevant and was presented by him to the national collections. It was picked up on the hillside about one-fourth mile west of the sign "Red Top" on the Hermit Trail, in Hermit Basin, and from 30 to 40 feet above the Hermit-Supai contact. The single track is deeply impressed on the sun-baked surface of a slab of reddish sandy shale. There are five toes and a tapering heel of moderate length. If correct in regarding it as being the imprint of a right foot (probably the hind), the fifth toe is somewhat set off from the others and subequal in length with the fourth. The fourth is the longest digit, the others progressively reducing in length toward the inside of the foot. The toes give the impression of all being acuminate. The track has a greatest length of 128 mm.; a greatest spread of toes of 130 mm. Length of digits as follows: I = 20 ? mm.; II = 30 mm.; III = 40 mm.; IV = 52 mm.; V = 50 mm. On the lower left hand corner of this slab, about 165 mm. posterior to the above described tracks are three toe marks, but whether made by the same foot cannot be determined. In size, narrowing of the heel, presence of five digits, toes reducing in length inward with a divergent fifth digit, this track suggests affinities with *Chirotherium heterodactylum* (King)[1] from the Carboniferous of Pennsylvania. The much shorter digits with other minor differences would separate it from that species if more perfect specimens should show its affinities to lie within that genus.

A second specimen (No. 11,530, U. S. N. M.) from this same locality and geological horizon, and likewise consisting of a single track made by a much smaller animal, also seems to represent an undescribed member of this Ichnite fauna. Its principal characteristics are well shown in plate 17, figure 3. It has four long, tapering, acuminate toes, two of which are curved. A short spur extending outward from the base of the larger toe on the left hand side of the specimen may represent a very short fifth digit. The heel is largely missing. Greatest spread of toes 46 mm. Length of digits taken from left to right is as follows: I = 5 mm.; II = 15 mm.; III = 26 mm.; IV = 34 mm.; V = 31.5 mm.

FAUNA OF THE SUPAI FORMATION

Genus STENICHNUS, new genus

Generic characters.—Quadrupedal, plantigrade. Four toes on both fore- and hindfeet. Toes long, slender, and acuminate. Hindfoot placed upon the impression made by the forefoot.

Genotype.—*Stenichnus yakiensis,* new species.

[1] Amer. Journ. Sci., Vol. 48, 1845, pp. 349-351.

STENICHNUS YAKIENSIS, new species

Plate 19, fig. 2

Type.—Catalogue number 11,533, U. S. N. M. Consists of a slab on which is a trackway about 330 mm. in length.

Type locality.—Yaki Trail (about 2 miles down from top), east side of O'Neill Butte, Grand Canyon National Park, Arizona.

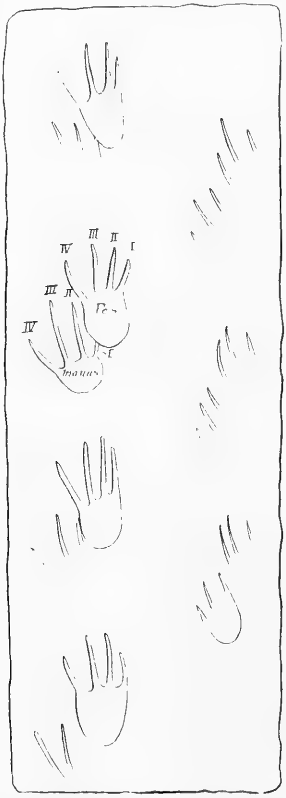

FIG. 34.—*Stenichnus yakiensis.* Type. No. 11,533, U. S. N. M. Diagram of trackway. About 1/3 natural size.

Geological occurrence.—Supai formation (about middle), Pennsylvanian.

Description.—Stride about 81 mm., width of trackway (estimated) 94 mm., hindfoot placed forward and partially upon forefoot. Forefoot nearly equal to hindfoot in size. *Hindfoot:* Length about 45 mm., width across the toes 23.5 mm., across sole 18 mm. There are four long, slender toes. Toes nearly equal to length of sole, and inner three directed straight forward, outer toe slightly divergent. Two median toes subequal in length, lateral toes slightly shorter. The sole longer than wide, practically the same length as the toes, obtusely rounded behind. *Forefoot:* Length about 40 mm., width across palm

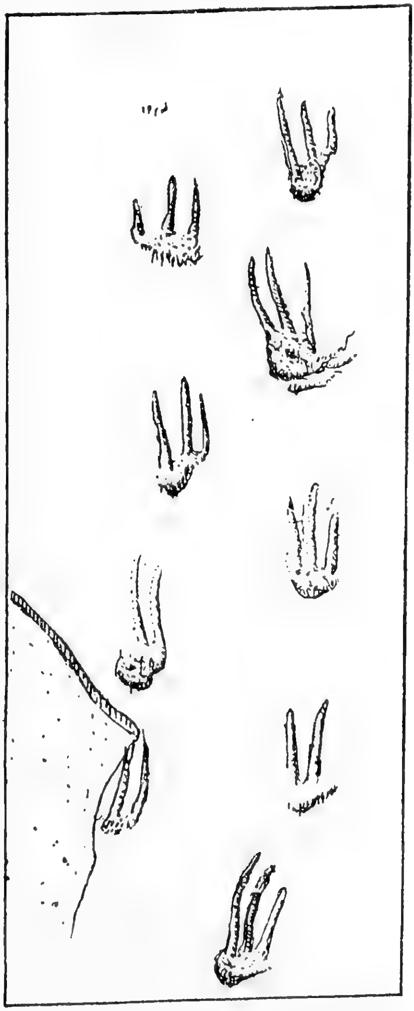

FIG. 35.—*Ornithoides ? adamsi* Matthew. Type. Diagram of trackway from Coal Measures, Joggins, Nova Scotia. Natural size. (After Matthew.)

about 18 mm. In most of the imprints three toes are registered, but the hindfoot, in the greater number of instances, was partially placed upon the fore and wiped out the imprint of the shortened inner toe. Although plainly present on the right side, in these tracks the outer toe failed to impress. Sole shorter than in pes, being wider than long. As in the hindfoot the two median toes are longest, the inner much shortened and the outer somewhat shorter than the second and third. All seem to be directed forward.

In slenderness of the toes and narrow sole, these tracks bear a striking resemblance to *Ornithoides ? adamsi* Matthew, from Nova Scotia, but the greater number of toes and larger size of the present specimen serves to distinguish the two genera. A comparison of the two, however, leads me to wonder whether the Nova Scotian species is not also four-toed, the outer toe failing to register as on the right side of the specimen now before me. In his original description of the species Matthew remarks: " It may be associated with *O. trifidus,* though the examples do not exhibit the characters of this genus fully."[1] Matthew's inability to distinguish fore- and hindfoot impressions adds a further resemblance to the specimen in hand. Its reference to the present genus would seem most appropriate.

Genus ANOMALOPUS, new genus

Generic characters.—Quadrupedal. Four digits in pes, three in manus. Forefoot smaller than hind, with hind placed in front of fore. Outer toe of both manus and pes stout with rounded clawless extremity directed outward and forward; other toes acuminate. Inner toe of pes short as in *Agostopus.*

Genotype.—*Anomalopus sturdevanti,* new species.

ANOMALOPUS STURDEVANTI, new species

Plate 20

Type.—Catalogue number 11,577, U. S. N. M. Consists of a slab of sandstone 475 mm. long having a trail of 13 imprints traversing its entire length.

Type locality.—Yaki Trail, Grand Canyon National Park, Arizona.

Geological occurrence.—Supai formation. Pennsylvanian.

Description.—Stride about 155 mm., width of trackway about 200 mm. *Hindfoot:* Length about 90 mm., width about 80 mm. Four digits. First toe very short, heavy, with rounded extremity; fourth toe stout with rounded end much diverted outward from the others. The fourth digit on the left hindfoot has a more pointed end and projects more directly outward than the fourth of the right side. It has the appearance of having suffered injury, which would fully account for the differences noted. The second and third toes are long, comparatively slender, with sharply pointed extremities. These me-

[1] Proc. Trans. Roy. Soc. Canada, Vol. 10, 1904, p. 97.

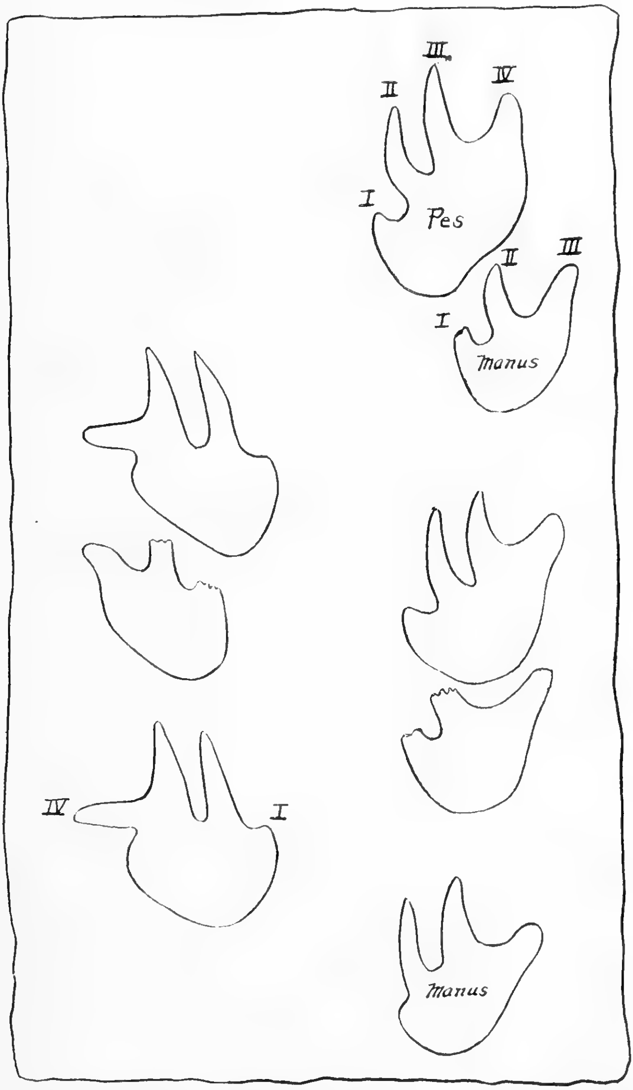

FIG. 36.—*Anomalopus sturdevanti.* Type. No. 11,577, U. S. N. M.
Diagram of a portion of trackway. About ⅓ natural size.

dian toes, although directed straight ahead in the direction of movement, have a tendency to turn outward. The sole of the foot is relatively narrow and supplied with palmar pads. The toes have the following lengths: I = 5 mm.; II = 35 mm.; III = 35 mm.; IV = 26 mm. Hindfoot placed in front of forefoot and the impression of the sole usually obliterating the toes of the forefoot. *Forefoot:* Length about 68 mm.; width measured from tip of digit I to tip of digit III, 53 mm. Three digits. Outer toe stout, with broadly rounded extremity and spreading outward from the others. Digit I and II as in the pes, long, comparatively slender, parallel acuminate and directed straight forward. Sole relatively narrow with broadly rounded heel. Length of toes as follows: I = 29 mm.; II = 27 mm.; III = 18 mm.

This series of footprints is impressed on a fine grained pinkish colored sandstone that is covered with worm trails. The footprints are deeply impressed and clearly defined except that portions of the forefoot track are destroyed by the hindfoot partially stepping upon it.

The species is named for Mr. Glen E. Sturdevant, ranger naturalist of the Grand Canyon National Park, who discovered and collected the specimen, and through whose efforts it was presented by the Park Service to the United States National Museum.

Genus **TRIDENTICHNUS**, new genus

Generic characters.—Quadrupedal, semiplantigrade. Five toes in pes, three ? in manus. Manus smaller than pes, with hindfoot placed behind forefoot.

Genotype.—*Tridentichnus supaiensis,* new species.

TRIDENTICHNUS SUPAIENSIS, new species

Plate 21

Type.—Catalogue number 11,534, U. S. N. M. Consists of a slab on which is a trackway of eight imprints divided equally between the feet of the two sides.

Type locality.—Hermit Gorge (to the left of Hermit Trail, descending, about one-half mile below Santa Maria Spring), Grand Canyon National Park, Arizona.

Geological occurrence.—Supai formation (upper track bearing horizon; about 350 feet below top), Pennsylvanian.

Description.—Stride about 185 mm., width of trackway about 187 mm. Forefoot placed about 18 mm. in front of hindfoot; in one pair of tracks slightly outside of it. Forefoot smaller than hindfoot. *Hindfoot:* Length about 68 mm., width about 70 mm., five toes, the three median ones subequal in length and directed forward; first much shortened and extending forward and inward, while the fifth is widely set off from the others and is directed almost straight

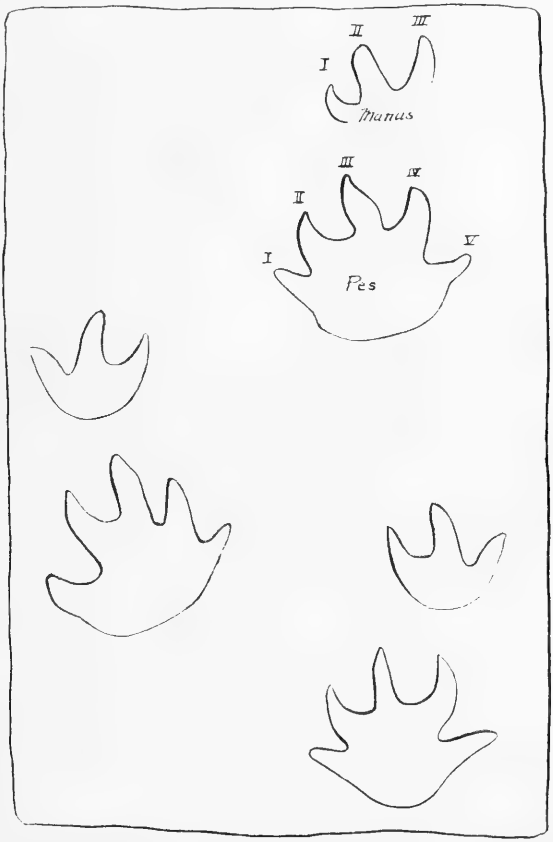

FIG. 37.—*Tridentichnus supaiensis.* Type. No. 11,534, U. S. N. M. Diagram of a portion of trackway. About 1/3 natural size.

outward. Three median toes bluntly acuminate, second and fourth having a tendency to turn in toward the third (see fig. 37). Sole broader than long and broadly rounded behind. Digits have the following lengths: I = 10 mm.; II = 23 mm.; III = 26 mm.; IV = 26 mm.; V = 13 mm. *Forefoot:* Length (estimated) about 40 mm., width of three toes 48 mm. Three toes impressed, but there may have been more in the complete complement. The three median toes bear a strikingly close resemblance to those of the hindfoot, in size, shape, and relative positions to one another. The presence of lateral toes is suggested by a toe scratch on the inner side of one impression, and on the outer side of this same print the sand shows disturbance as if a fifth toe was present, but one cannot be sure and the other forefoot tracks are not sufficiently well impressed to give any additional evidence on this point. The sole is imperfectly impressed and this fact may account for the faintness of the evidence relating to the lateral digits. Width of three digits 48 mm., same as those of the hindfoot. Lengths: II = 22.5 mm.; III = 26 mm.; IV = 26 mm.

The variation in the different tracks is clearly indicated in figure 37.

A second occurrence of this genus and species seems to be indicated by a comparison of figure 2, plate 2, with the trackway above described. In the illustration the three-toed frontfoot may be seen in its proper position in front of the hindfoot, which, except for the lack of a fifth digit, agrees in all essentials with the type of the present genus and species. If this long range identification is correct it shows the presence of this form at the Yaki locality some seven or eight miles distant in an air line from the type locality.

SUMMARY

The study of these fossil footprints has resulted in the establishment of adequate ichnite faunas for the Coconino and Hermit formations and the beginning of a fauna for the older Supai. The various forms described are, with few exceptions, based upon trackways showing impressions of all four feet, a procedure that should give the minimum trouble in the identification of specimens that may be subsequently discovered. The faunal lists could have been considerably augmented had it seemed expedient to describe inferior material, but a more conservative course was adhered to.

Comparison of these three faunas shows them to be absolutely distinct from one another as not a single genus has yet been found common to any two of the formations. In so far as the Hermit is concerned, this fact occasions no particular surprise, even though the difference in geological level be disregarded, for the environmental conditions were such as to lead one to expect an entirely different assemblage of animal life than would be found in either the Coconino or Supai. The muddy character of the sediments with sun-cracked surfaces, with associated ferns and other water-loving plants are all indicative of the low lying nature of the region at the time these animals inhabited it. The many amphibian-like footprints, and tracks left by crawling, short-legged creatures who dragged their tails and bellies in the mud appear typical of such an environment.

The Coconino fauna is nearly doubled in the number of known species but the facies of the fauna remains as stated in a previous paper—"Carboniferous in aspect, as shown by the relatively small size of the animals, all of which are quadrupedal, as contrasted with the considerable number of very large forms and many three-toed bipedal animals of the Triassic." Taken as a whole, this fauna now consists of 15 genera and 22 species and seems to have closer relationships to the ichnite fauna from the Middle Coal Measures of Kansas, described by Marsh than to the more extensive fauna from the Coal Measures of Nova Scotia made known by Dawson and Matthew.

On the other hand the Hermit fauna has its closest affinities with that from Nova Scotia, for of the eight genera now known, four are common to both and the facies of the two faunas taken as a whole shows striking resemblances. That similar environmental conditions prevailed in these two widely separated localities is indicated by the similarity in the character of the sediments in which the imprints occur.

The Supai fauna, known at present by three genera and as many species, shows no close relationships with tracks from other localities, although it may be said to be Carboniferous in aspect. It apparently represents an ichnite fauna new to North America and consequently has little correlative value at this time.

Aside from the trails of invertebrate animals found all others were made by quadrupedal creatures, but only a comparatively few give any certain clue as to whether they pertain to the Reptilia or Amphibia.

Animals having a digital formula of 5 and 5 predominate in the Hermit, while those having a lesser number are more abundant in the Coconino. Whether this fact has any significance remains to be determined. Search of the literature shows that all Permian animals in which the foot structure is known have five digits in both manus and pes and of the Coal Measures Amphibia none shows fewer than four digits in the manus and five in the pes. It would seem therefore either that none of the Permian animals known from their skeletons may be considered as the makers of the three and four toed tracks, or else certain digits consistently fail to leave their impressions.

In an attempt to identify some of the known Permian vertebrates as being responsible for certain of these tracks, tracings were made of all of the available fore- and hindfeet of animals of that period, in order that these tracings might be placed directly upon the tracks, in order to more accurately compare them. No information of importance resulted, as so many unknown factors enter into such a comparison as to render any likenesses found to be of little consequence. At present there appears but little likelihood of definitely correlating the footprints with fossil skeletons. The chief importance of these footprints, it now seems, is the establishment of adequate faunas for each of these three formations, which in the absence of other fossil criteria may be of future use in correlating these deposits with other track-bearing formations of distant localities.

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EXPLANATION OF PLATES

Plate 1

PAGE

Fig. 1. General view of fossil footprint locality at head of Hermit Gorge. Most of the specimens of fossil tracks and plants from the Hermit shale were collected from the slope above the massive sandstones in the middle foreground. The disconformable Hermit-Supai contact is plainly indicated on the left side of the photograph. The cross indicates the level where footprints, plants, and insect wing were found *in situ*.................... 6

2. Close up view of the fossiliferous ledge indicated by the cross in fig. 1. The projecting ledge extending to the right from the base of the cedar tree, which is estimated to be 30 feet above the Hermit-Supai contact, contained footprints, plants, and insect impressions.

Plate 2

Fig. 1. Looking up Yaki trail from a point two miles down from the top of the rim, where the trail cuts through a massive sandstone in the middle Supai formation on the east side of O'Neill Butte. Numerous tracks and trails occur in the upper light-colored sandstone seen in the right of the picture..................... 8

2. Casts of footprint impressions (probably *Tridentichnus* sp.) in Supai sandstone. These were the first tracks to be found *in situ* on the Yaki Trail. Found and photographed by Dr. J. C. Merriam. These occur at the base of the heavy, darker colored sandstone shown at the right but further down the trail than in fig. 1... 8

3. Undescribed trackway on a large block of sandstone from the débris blasted out of the upper light colored sandstone (shown in fig. 1) in building the Yaki Trail.......................... 8

Plate 3

Nanopus maximus, new species. Type. No. 11,506, U. S. N. M. Showing an irregular trackway. Note the scratches made by a slipping hindfoot on the lower left hand side. × 4.3.................. 15

Plate 4

Fig. 1. *Nanopus merriami* Gilmore. No. 11,516, U. S. N. M. Trackway from lower part of track-bearing horizon in the Coconino sandstone. × 1.77 15

2. *Laoporus noblei* Lull. No. 11,494, U. S. N. M. Showing the especially long second and third digits of the manus. × 3........... 18

PLATE 5

PLATE 6

PLATE 7

PLATE 8

PLATE 9

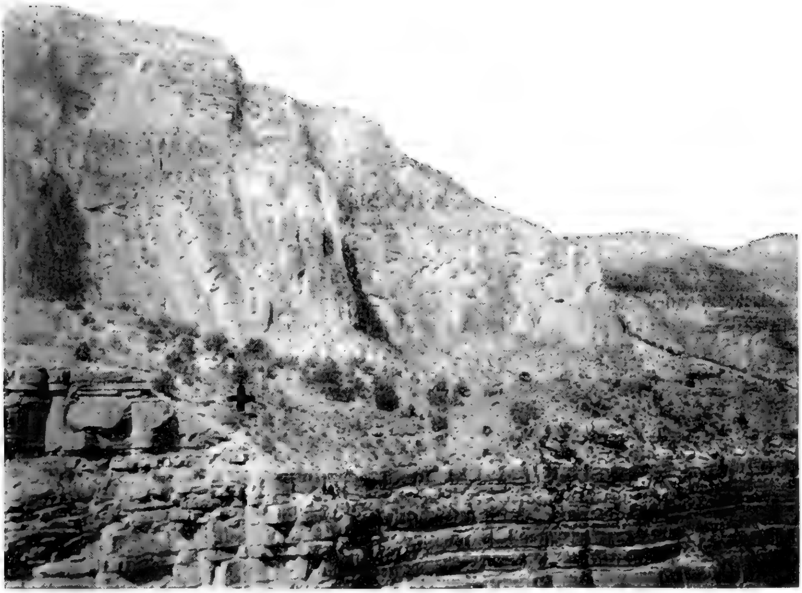
PLATE 10

PLATE 11

PLATE 12

PLATE 13

PLATE 14



1

2

Locality of fossil footprints, Grand Canyon.

(For explanation, see page 76)

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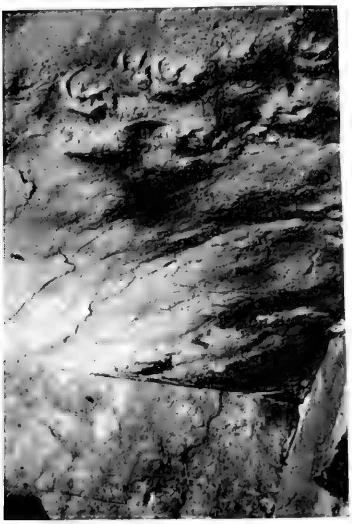

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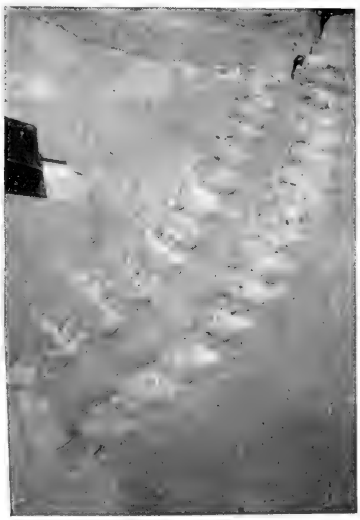

3

1. Looking up Yaki Trail.
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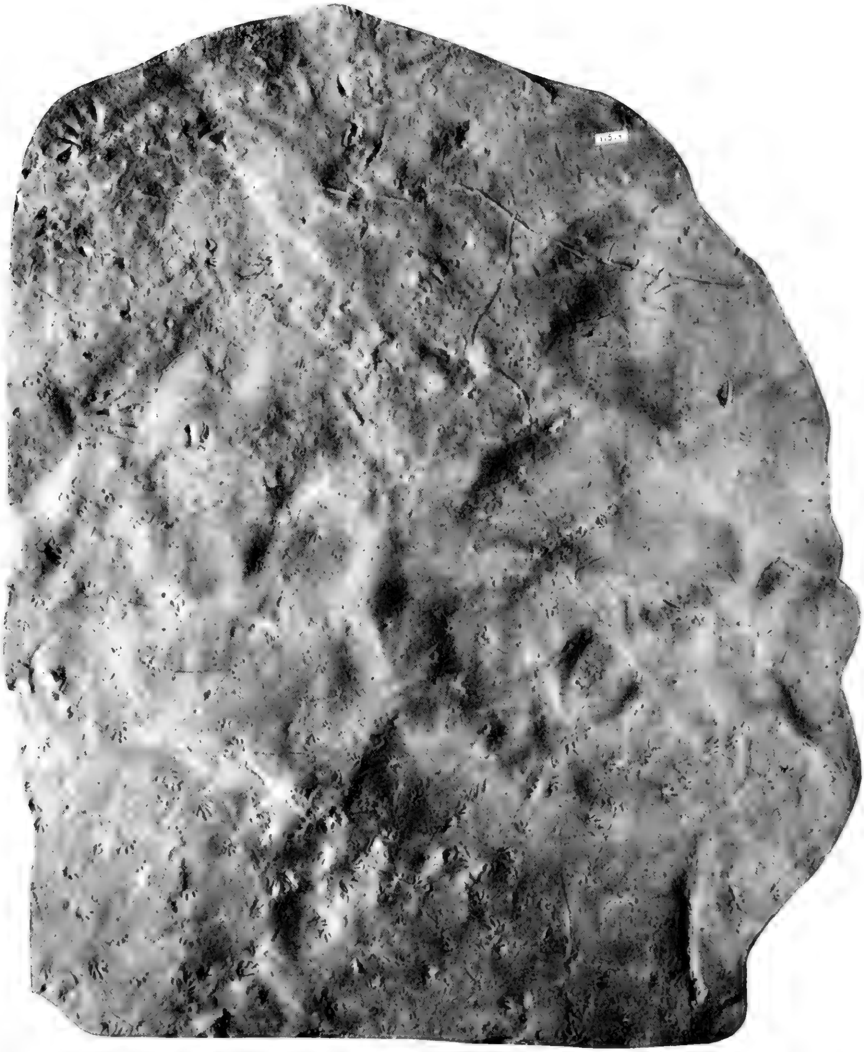

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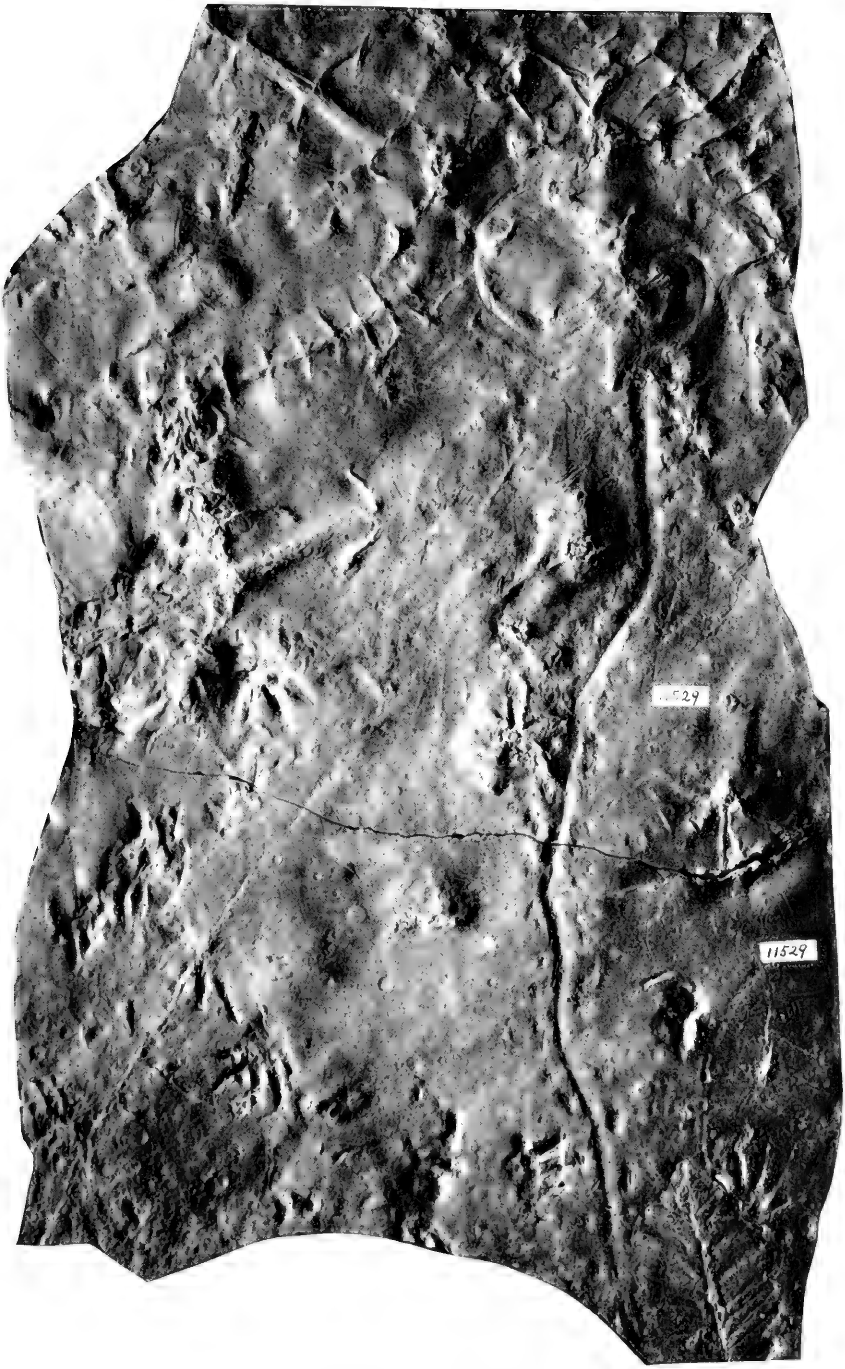

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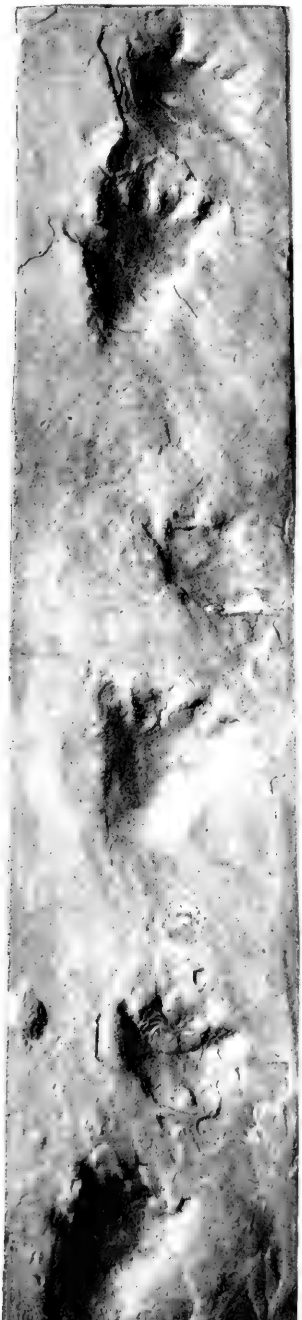

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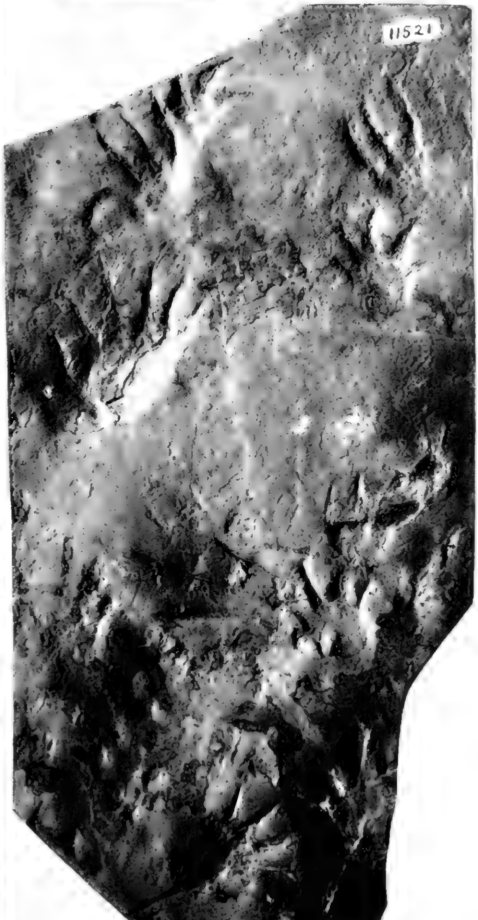

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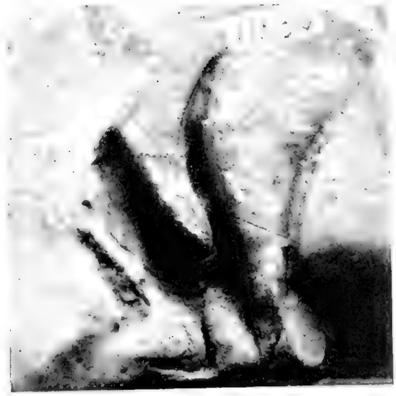

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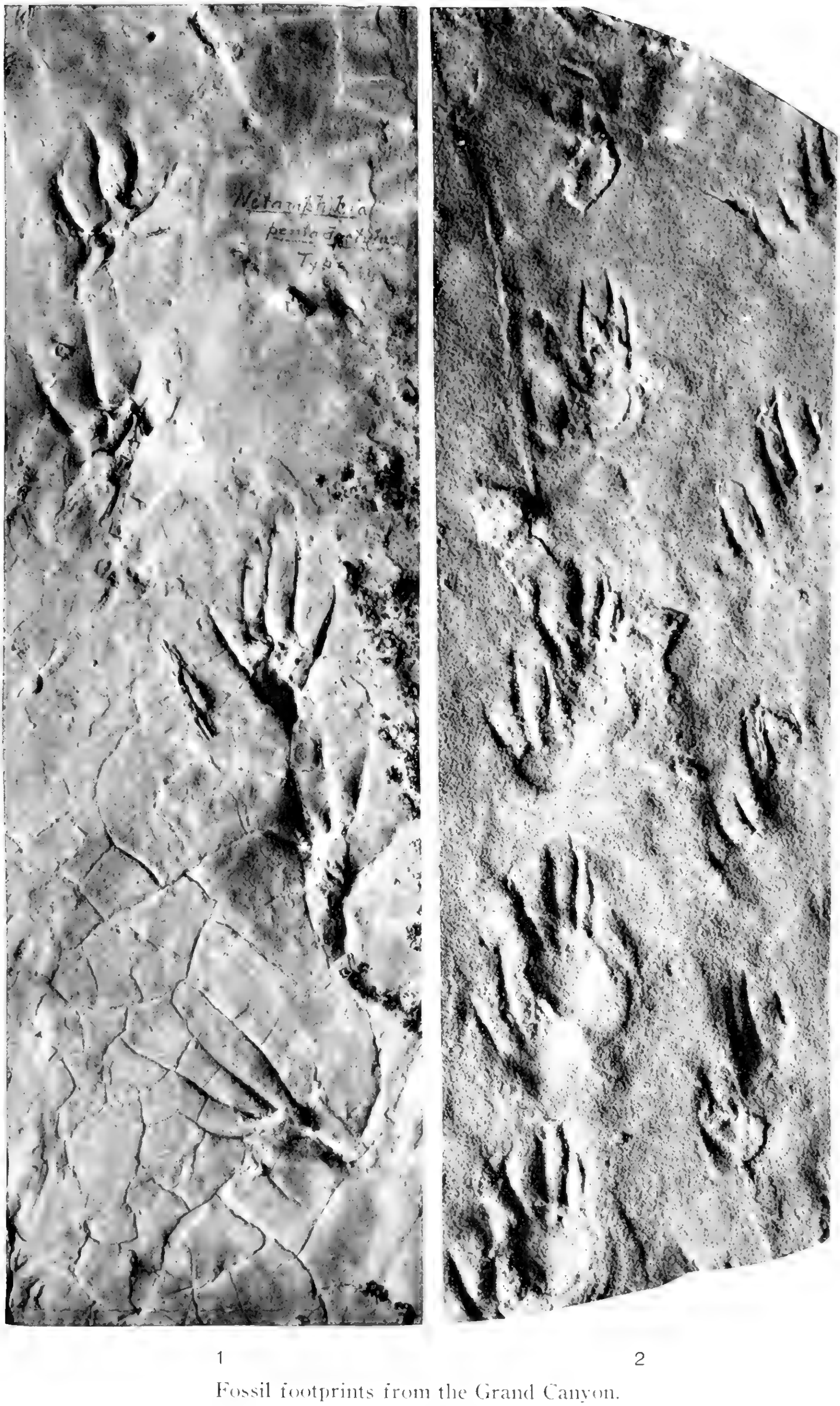

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
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RELIGION IN SZECHUAN PROVINCE, CHINA

(With Twenty-five Plates)

BY
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RELIGION IN SZECHUAN PROVINCE, CHINA

By DAVID CROCKETT GRAHAM

(With 25 Plates)

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Smithsonian Miscellaneous Collections, Vol. 80, No. 4

PREFACE

The materials for this paper were gathered at first hand in Szechuan Province during the years 1919 to 1926. The idea of collecting the data and of writing this paper was the result of a course in comparative religion under Prof. Albert Eustace Haydon of the University of Chicago in 1919. The writer gladly acknowledges his unusual indebtedness to Prof. Haydon for inspiration to undertake this study, and for supervising the writing of the manuscript. Thanks are also due to Dr. Berthold Laufer for helpful suggestions.

The fact that there are few written sources outside the Chinese language has made this study on the one hand more difficult and on the other hand more interesting. It is hoped that it will form a contribution towards a better understanding of the Chinese religion.

I. INTRODUCTION

1. THE GEOGRAPHY OF SZECHUAN PROVINCE

Szechuan lies on the extreme west of China. It is a whole nation in itself, having a population of over 60,000,000 and an area of over

218,000 square miles. In the center of the province is the great red-sandstone basin, in which the soil is exceedingly fertile. Here the altitude varies from 900 to 2,000 feet above sea level. Rainfall is abundant, and it almost never snows. Trees and vegetables are green throughout the year. The farms often yield four crops annually, and a family can support itself on three or four acres of land. A part of this basin is the Chengtu plain, where there is an extensive irrigation system, and which is one of the most thickly populated country districts in the world.

On the north and west of the province are high mountains, inhabited for the most part by aborigines. To the west of Szechuan lies Tibet, "the roof of the world," and to the south are the mountainous provinces of Kueichow and Yunnan. In Szechuan, Kueichow, Yunnan, and Tibet, more than 100 tribes of aborigines inhabit the high, mountainous districts, while the rich lowlands are in the possession of the Chinese.

Great salt deposits that seem to be inexhaustible occur in some parts of the province. Coal is found almost everywhere. It is known that there are deposits of gold, copper, and iron, but, because of the lack of machinery, mining is not a main occupation of the people. Silk-raising is an important industry.

The word Szechuan means four rivers. The province contains four great rivers and many tributaries that serve as arteries of trade. There are also many overland routes, one leading through Yachow and Tatsienlu to Tibet, one northward through Chengtu and Songpan to the high grasslands on the northwest of Szechuan, one southward from Suifu through Yunnan Province, and one overland to Peking. Because of these and other trade routes, commerce plays a large part in the lives of the people of Szechuan. The main occupation, however, is agriculture.

Even in the red-sandstone basin, nature has been at work for thousands of years, resulting in erosion and folding of the rock strata, so that many natural wonders occur in the province. In places, the rock strata have been twisted and folded almost beyond belief; in other localities the sandstone has been entirely eroded away, exposing rugged limestone cliffs often abounding with natural caves. Beautiful waterfalls are not uncommon. One often sees rocks that have been washed or eroded into strange or striking shapes, or mountains that tower majestically over surrounding valleys. On the borders of Tibet are mountains capped with perennial snow. West China has some of the most beautiful, most picturesque, and strangest scenery in the world. " Szechuan is a spooky place " is a proverb among the common people.

2. THE HISTORY OF THE PROVINCE

In the past centuries there have been many floods and occasional droughts. More than 1,000 years ago Suifu was destroyed by flood. The city was then rebuilt on higher ground on the opposite side of the Min River. This calamity has never recurred, and the city is now again in the more favorable location at the junction of the Yangtse and the Min Rivers. In the summertime there are terrific thunderstorms. Pestilences sweep across the land, striking terror into the hearts of the people, and killing hundreds and sometimes thousands.

Into this fertile province the Chinese came about 300 years before Christ. They soon took possession of the lowlands, although the history of Suifu says that Chu Ko Liang finally drove the aborigines out of that city after the time of Christ.

One outstanding event in the history of the province is its almost complete depopulation, during the years 1643 to 1648, by Tsang Shien Tsong, one of the most cruel rulers that ever lived. Killing off every man, woman, or child who refused to join his ranks and many of his own followers, he almost made that fair province a wilderness. After the death of Tsang Shien Tsong, settlers came from other provinces, so that Szechuan was soon again the scene of a thriving population.

3. CONTACTS WITH THE REST OF CHINA AND WITH OTHER RACES

There is a common conception that until very recent times China has been isolated from the rest of the world. The great wall, the Pacific Ocean, the plateau of Tibet, and the high mountains between China and India are assumed to have been efficient barriers to inter-racial contacts.

Among anthropologists, the fact that few if any groups of people have long been isolated is gaining general acceptance. Diffusion of culture, although it cannot explain all social phenomena, is receiving a larger emphasis than before. Able sinologues have dwelt on the isolation of the Middle Kingdom during the past milleniums,[1] but there is increasing evidence that this isolation has been more or less fictitious.

[1] Pott, F. L. Hawks, A Sketch of Chinese History, 1915, pp. 1, 3.

In the year 65 A. D. the Emperor of China sent envoys to India to learn about the teachings of Buddha.[1] It is safe to assume that he would not have done so had not China had previous contacts with India. In A. D. 621 Zoroastrianism was introduced into China, Muhammedanism in 628, and Nestorianism in 631.[2] There is evidence of a Jewish community in China which disappeared in comparatively recent times.

According to Gowen many foreigners were resident in China in the ninth century.[3] Marco Polo arrived in A. D. 1271, remaining for 17 years and visiting many parts of the Empire.[4] Wars have been fought with Burmah, with the Turks, and with the Russians, and at one time Chinese dominion extended to the shores of the Black and the Caspian seas.[5]

The works of Dr. Berthold Laufer, the great American sinologue, contain a large amount of evidence of diffusions of culture between China and Japan, the Philippines, India, Persia, and even Europe.[6]

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[1] Gowen, Herbert H., An Outline History of China, 1913, p. 102.
Pott, F. L. Hawks, A Sketch of Chinese History, 1915, p. 38.
Li Ung Bing, Outlines of Chinese History, 1914, pp. 53, 84.

[2] Gowen, H. H., An Outline History of China, 1913, p. 119.

[3] *Ibid.*, p. 132.

[4] Gowen, H. H., An Outline History of China, 1913, p. 156.
Williams, A History of China, 1897, p. 42.
Pott, F. L. Hawks, A Sketch of Chinese History, 1915, p. 80.
Li Ung Bing, Outlines of Chinese History, 1914, p. 220.

[5] Williams, A History of China, 1897, pp. 32-35.
Li Ung Bing, Outlines of Chinese History, 1914, p. 215.

[6] Laufer, Berthold, Ivory in China, 1925, pp. 14, 50, 56.
" " Tobacco and Its Use, 1924, pp. 2-3.
" " The Chinese Gateway, 1922, p. 1.
" " Sino-Iranica, 1919, pp. 1, 376.
" " Chinese Clay Figures, 1914, Part I, pp. 231-4, 243-4, 246, 249.
" " Jade, 1912, Int., pp. 2, 5; pp. 23, 25, 292.

NOTE.—Since the point we are making may be considered open to question, we are adding other references showing inter-racial contacts between China and other nations.

1. Cole, Fay-Cooper, The Tinguian, 1922, pp. 237, 241-2, 247, 260, 396, 413, 414.
2. Pott, F. L. Hawks, A Sketch of Chinese History, 1915, pp. 54, 58, 59, 73, 79, 80.
3. Williams, E. T., China Yesterday and Today, 1923, pp. 339-40, 341-44.
4. Parker, E. H., China Past and Present, 1903, pp. 6, 10, 13-14.

In *Sino-Iranica* he shows that a large number of cultivated plants have been brought from distant lands and made to enrich the agricultural life of China. To quote Dr. Laufer:

> We know that Iranian peoples once covered an immense territory, extending all over Chinese Turkistan, migrating into China, coming into contact with Chinese, and exerting a profound influence on nations of other stock, notably Turks and Chinese. The Iranians were the great mediators between the West and the East, conveying the heritage of Hellenistic ideas to central and eastern Asia and transmitting valuable plants and goods of China to the Mediterranean area. Their activity is of world-historical significance, but without the records of the Chinese we should be unable to grasp the situation thoroughly. The Chinese were positive utilitarians and always interested in matters of reality: they have bequeathed to us a great amount of useful information on Iranian plants, products, animals, minerals, customs, and institutions, which is bound to be of great service to science.[1]

Szechuan has been rich in racial contacts. Many wars have been fought between the Chinese and the aborigines, and these continue to the present day. The Chinese, being more numerous, better organized, and more highly civilized, have always in the end been victorious. There have also been wars between the inhabitants of Szechuan and those of other parts of China.[2]

Commerce, perhaps, has been of even greater importance. Quantities of hides, medicines, and other raw materials are shipped from Tibet and from the various aboriginal districts into the center of the province, and thence down the Yangtse River. Rice, tea, clothing, and other commodities are sent back in return. Before the completion of the railroad from Haiphong to Yunnanfu, Suifu was the shipping-place for most of the exports of Yunnan Province. When undisturbed by civil wars, the Yangtse River and its tributaries carry a tremendous amount of commerce.

The language spoken by the Chinese of Szechuan is the mandarin, which is used by about two hundred and fifty million Chinese people. The written language is the same throughout all China. Until very recent times the old system of examinations in the Chinese Classics, and the appointment of officials from Peking, further served to connect the lives of the Szechuanese with the rest of the nation. Chinese scholars went from Szechuan to Peking to continue their studies or to compete in the examinations. Officials from other parts of the empire came to help govern Szechuan. Through these contacts, through wars and pilgrimages, through commerce, and through the

[1] Laufer, Berthold, Sino-Iranica, 1919, p. 185.

[2] Pott, F. L. Hawks, A Sketch of Chinese History, 1915, p. 41.

interchange of literature, the people of Szechuan have been brought into contact with the rest of China and with other parts of the world.

4. SOCIAL CHARACTERISTICS OF THE PEOPLE

It is a well-known fact that in China the family and not the individual is the social unit. The rights of individuals are subordinated to those of the family group. Property generally belongs to the family. When a new couple is married, they do not live in a separate house, but in a part of the groom's family home, with his parents and the families of his brothers. This principle affects the entire social, ethical, and religious world of the Szechuanese. Religion is a family and a community affair. Ethics are social. Engagements and marriages are family affairs, contracted by representatives of the families rather than by the individuals concerned.[1]

Filial piety is the cardinal virtue. One of the worst things that can be said about anyone is that he is unfilial. Filial piety requires that a child show love and respect to his parents and elders and to his ancestors for three generations. This virtue has been the cement that has strengthened and held together Chinese society for millenniums. Many of the legends are such as will develop filial piety in the hearts of the young. The results are partially manifested in elaborate funerals and in the erection of expensive tombs for the ancestors.

The dualistic *yinyang* conception, which has been a part of the thought form of the Chinese for millenniums, vitally affects the social life. The *yin* is the female principle, and is lower, inferior to, and weaker than the *yang*, the male principle. Happiness and prosperity depend on the keeping of this female principle subordinate to the male. Women, therefore, have always been given a subordinate position. The husband is master, and is morally and religiously ruler over his wife. Women must accept the religion of their husbands.

5. THE UNIQUE OPPORTUNITY FOR THE STUDY OF RELIGION IN SZECHUAN PROVINCE

In the preface of Dore's monumental work, Researches Into Chinese Superstitions, the following statement is made:

> Real China exists little in the Open Ports. Civilization has there done its work, and raised the Chinaman to a higher level than his fellow countrymen. Whosoever, therefore, would study him in real life, must needs see him in

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[1] There are great changes taking place in China which will profoundly affect social life and customs, and in the end will affect religion.

the remote regions, the quaint old towns, and the secluded villages of some distant province.[1]

The second sentence of this statement may be seriously questioned. The fact that a Chinese wears foreign clothing, smokes foreign cigarettes, plays foreign *bogeh* (poker), and drinks foreign liquor, does not prove that he has been raised above his fellow countrymen in a distant village. The first and third sentences are true, and Szechuan, situated far from the seacoast, with only one treaty port and no foreign concessions, offers an unique opportunity to study the Chinese religion as it has been handed down through the past ages.

One day in Shanghai the writer heard a brass band in the street below. Looking out of the window, he saw a great Buddhist funeral procession. In front were two gigantic deities pushed along in carts constructed for the purpose. The deities were to clear the road of demons. Then followed six bands, three using Chinese musical instruments and three foreign. For tunes the latter were using Christian hymns. The mourners were riding in foreign cabs. Such a foreignized religious ceremony is at present never seen in West China. The student of religion has in Szechuan Province an excellent opportunity to study the religion of the Chinese people, not to mention the numerous tribes of aborigines about which comparatively little is known.

6. THE WRITER'S PREPARATION[2]

The religious and social life of the Chinese people in Szechuan is exceedingly complex, and one might well despair of becoming a master of the Chinese language or of the Chinese religion, even in a lifetime. The writer has had fair success with the Chinese language, and has had 13 years of contact with the Szechuanese people. Most of this contact has been very friendly, and has included all classes, from the child and the coolie to the high official, the scholar and the priest. He has spent weeks in Chinese villages where foreigners are seldom seen, and, as zoological collector for the Smithsonian Institution, has travelled beyond Tatsienlu in Tibet and as far north as Songpan. He has spent several summers on Mt. Omei, and has visited Washan. He has had contacts with the Lolo, the Chuan Miao and other aborigines, and has crossed overland from Suifu to Yunnanfu and

[1] Dore, Henry S. D., Researches Into Chinese Superstitions, Vol. I, 1915, Int., pp. i-ii.

[2] The written sources on the religion of Szechuan Province are so meager, and some of them are of such questionable value, that it has been necessary to secure most of the material for this paper at first hand in Szechuan Province.

thence to Haiphong in Indo-China. Among the Chinese whom he has met are many well-known Christian leaders, army officials, Chinese government officials of influence, one of the leading Buddhists of China, a Da Yung Fah Si, and many others.

The following pages are an attempt to present objectively the religious life of the Chinese of Szechuan.

7. THE RELATION OF RELIGION TO THE BASAL HUMAN NEEDS

The writer believes that the basal human needs are for food, protection or security, sex, and play or amusement. Although the soil is very fertile in Szechuan, the density of the population makes the procuring of food a great problem. If no rain falls for an unusual length of time, people become panic-stricken, the prices of rice and of other foods climb rapidly, and thousands of poor people are threatened with starvation. This is also apt to be true in time of war. In the summer of 1925 the price of rice was so high in Kiating and in a number of other cities that only the rich could secure enough to eat. Well-informed Chinese said that many became half-starved, and in this weakened condition contracted disease and died. "They were half starved and half killed by disease." In Suifu this happened to an old church member. In time of threatened drought or of civil war, the suffering on the part of the poor people is intense. All over China one of the most common ways of greeting is by asking, "Have you eaten your rice?"

Security is needed from the forces of nature, from wild animals, from enemies, and from disease. Men build houses as a protection from storm, from the heat and sunshine of summer, and from the winter cold. In Szechuan occur floods, terrific storms with rain, wind, and thunder, and droughts, and from these protection must be sought. In the mountains there is danger from rolling stones. Wild leopards and other animals roam in the woods.

The need of safety from disease is keenly felt by the Szechuanese A common pimple or boil easily becomes infected and may cause death. To this the writer can bear testimony, for he has had to be lanced by a physician three different times. Two of his best Chinese friends died of such infections. A physician who has spent many years in West China printed the following paragraph in the West China Missionary News:

> Long experience in China has taught me the danger of face infections, especially those of the lip. The purpose of this short article is not primarily to scare people. But there is such an element of danger in these infections that I

feel constrained to sound a warning about them. Not only are the Chinese afflicted with these infections, but foreigners as well. We should know how to care for ourselves and be able to give advice to the Chinese on this matter.[1]

Malaria spreads over communities, causing suffering to thousands. Smallpox, typhus, typhoid, pneumonia, measles, and many other diseases spread from district to district, filling the hearts of the people with terror, and causing untold suffering and death.

The following story illustrates the fear of sickness and death on the part of the Szechuanese. It was told by a Chinese preacher. In ancient times there was a great Chinese warrior named Tsang Fei. He was noted for his bravery. He was unafraid of most of the things that cause ordinary or even brave men to fear. All efforts to inspire fear in his heart were in vain. Finally, a friend wrote the word *bin,* meaning sickness, on the palm of his hand and showed it to Tsang Fei. The great warrior was speechless. Of that he was afraid. Sickness is accompanied by weakness and pain, and is often followed by death, and death is dreaded by all.

The fact that all diseases are supposed to be caused by demons does not lessen, but increases the dread of disease. The demons are thought to be frightful in appearance, and cruel and evil in purpose. The sick man imagines himself to be the victim of a demon. Sometimes the demon is inside him, and native doctors sometimes puncture the bodies of the patients with needles to let the demon out.

As a respite from worry and toil, the Chinese in Szechuan feels the need of, keenly desires, and enjoys amusements, play, and recreation. This is true of men and women of all ages. With the grownups it finds expression in the popularity of the theatricals, of gambling, and of feasts. Often this need is met by a social visit with a friend in the teashop. We shall see later that this is an important element in the religious festivals, and in the ordinary programs of Buddhist and Taoist temples.

One will not be long in Szechuan before he realizes that everybody is seeking happiness. In many important places he sees the word *fuh* which means happiness. If he questions one of the many pilgrims on the way to or from Mt. Omei, the conversation may run approximately as follows: "Where are you going?" "I am going to Mt. Omei." "Why do you go there and worship the idols?" "I am seeking happiness." "What do you mean by happiness?" "That our family may prosper, that we may be protected from diseases and calamities, that our crops may be good, that we may grow wealthier,

[1] West China Missionary News, May, 1925, p. 37.

and that we may have many children." In other words, happiness, as used in Szechuan, is an inclusive word, meaning the satisfying life. All are seeking it, and the religious rites and ceremonies are the techniques for its attainment.

One is impressed with the fact that in Szechuan religion is very closely and vitally related to human life and human needs. This is expressed in Dore's Chinese Superstitions, Vol. III, preface, page ix, in the following words:

> Religion in China is not an effort to apprehend the Infinite, love and enjoy it; it is not man's nature clamouring for food necessary for life and perfection; nor is it a duty to serve the deity directly. So far as these three volumes impress us, it yokes rather the spiritual world, the superhuman element in which man believes, to the needs and welfare of humanity.

II. THE ANCESTRAL CULT AND DEMONS

1. THE IDEA OF THE SOUL

We have seen that in China the family and not the individual is the social unit. Newly married couples generally do not establish separate homes of their own. They become a part of a large family group, of which the oldest members are the heads. The individual earnings are often shared with the family. If a member of the group acquires wealth, it may be necessary for him to assume the support of his parents and of poorer relatives.

The deceased ancestors are considered a part of the family group. They are the most honored members. There is a state of interdependence between the dead and the living. The living descendants provide food, clothing, money, and other necessities, and in return receive the help and the protection of the departed ancestors.

Sometimes a person is scared by a mad dog and takes a certain kind of medicine which destroys the kidneys and causes death. The popular explanation is that the dog has stolen his shadow and that this is the cause of his death. A variation of this explanation is that the dog has bitten his shadow. Here we have the conception that the shadow is a vital part, if not the soul or a soul, of the human being.

The Chinese have the idea of a multiple soul, three *hucn* and seven *peh*. This makes it possible for them to commemorate the dead person at the grave and also at the ancestral tablet, considering that the deceased is present in both places and also in hades. For all practical purposes, however, we may speak of one soul or spirit as representing that which is most vital and valuable in the individual.

In ancient China there was a custom, which probably exists in some parts of China to-day, of calling the soul, soon after death, to come back. In Szechuan there are ceremonies by which the soul is enticed into the ancestral tablet, which becomes its dwelling place. Afterwards the ancestral tablet is regarded as the ancestor himself, and is treated as such. The writer once offered a poor woman, who was having much difficulty in making ends meet, a good price for her ancestral tablet. She exclaimed in surprise, " Do you think I would sell my parents? " Several years ago an enquirer applied for baptism. The foreign pastor asked, " Have you discarded your housegods? " A Chinese Christian added, " Have you destroyed your ancestral tablets? " The man was really interested in Christianity. With tears in his eyes he said, " My dear old mother, do you think I would reject her? " He never united with the church.

The ancestral tablets are carefully preserved either in the homes or in ancestral temples. At the middle of the seventh moon, at the winter solstice, and on the anniversaries of the births and the deaths of both parents, the ancestors are " worshipped." That is, food is offered, money is provided, incense is burnt, and there are the usual prayers and prostrations.[1]

There is a tendency in Szechuan to connect snakes with ancestors. If a large snake appears in a Chinese home he is not killed, but incense is burnt to him, and the inmates prostrate themselves before him. They regard him as the ancestor who has returned to visit his descendants.

A visit to a Chinese graveyard will furnish a probable explanation. Many of the old tombs are open. Into them broken dishes, bones, stones, and other débris have been thrown, so that they become excellent hiding places for the snakes. Serpents of different sizes, and their skins and skeletons, are often seen in and around the tombs, so that it is easy and natural for the primitive mind to regard snakes as souls of the dead.

2. THE ANCESTRAL CULT

The Chinese word which is translated as worship is *gin*. It means to honor, respect, venerate, or worship. It is often used in conjunction with the word *bai*, which is similar in meaning. These words vary in meaning from common respect paid to a friend or to an object to the idea of worship paid to a deity. What the Chinese think about is reverencing their ancestors. What the typical occidental thinks of

[1] West China Missionary News, September 1917, pp. 22-23.

when speaking of ancestor worship is venerating the ancestors as deities. Instead of misunderstanding and mislabeling these rites as "ancestor worship," it might be better to speak of the ancestral cult. The Chinese regard the ancestors with loving reverence, of which the burning of incense, the prayers, the offering of food and spirit money, and the prostrations are the outward expressions.

The memorial ceremonies of the ancestral cult are performed by the oldest son. They cannot be performed by a girl or by a woman. It is exceedingly important that the ceremonies be performed at the proper seasons. For these reasons every family is very anxious to have sons, and, once they are secured, to protect them from harm. Failure to give birth to sons is a sufficient reason for divorce. Often the solution is found by the taking of a second wife, or a concubine. Sometimes sons are adopted into the family.

3. THE BELIEF IN DEMONS

If due reverence is offered to the ancestors, and the needed food, money, and other articles are provided, the ancestor is beneficent, and aids and protects his descendants. If he is neglected, he does harm to his descendants and others. He becomes a demon. In the course of time, there are naturally many without descendants who can conduct the funeral rites, and others who are neglected by their unfilial descendants. They then become demons, and demons are the causes of all diseases and calamities.

Dangerous rivers are supposed to be the abode of demons who try to drown other people. When drowned, the victims become demons dwelling in the water. The natives explain that the only way in which they can escape their demonic condition is to cause others to drown. When a person is drowning, it is thought that a water-demon is responsible, and is trying in this way to escape the demonic state. If one rescues the drowning person, he will incur the displeasure of the demon, and may himself be drowned instead of the original victim. For this reason it is sometimes hard to get a native of Szechuan to save a drowning person.[1]

The *tiao gin kuei* are those who have died by hanging, and can only escape their demon existence by causing others to be hanged. Women who die in childbirth are called *ts'an lan kuei,* and to escape their

[1] One day I was crossing a stream near Uen Chuan Shien. We had just passed a village of Wasi aborigines. The bridge gave way, and one of our coolies fell into the swollen stream and was soon drowned. We appealed to the villagers to assist us, but not one of them would move, fearing that if they tried to save the coolie the demon would drown them.

condition and to become reborn as human beings they must cause others to die in childbirth. *Mo gin kuei* have been killed by having their throats cut, and try to cause others to die in that way so that they can escape from their condition.

4. THE CH'IN MIN CEREMONY

On the fifteenth day of the seventh moon, there is what corresponds to the All Saints' day as it was originally observed in Europe.[1] Elaborate ceremonies are held. Amid the beating of gongs and the playing of musical instruments, much paper money is burnt. At night lights are set floating on streams or rivers. Having received the money and other offerings, the demons are expected to follow the lights away, leaving the community free from their danger.

5. DEMON POSSESSION

An insane person is thought to be possessed or controlled by a demon. That is why Europeans and Americans sometimes confidently assert that there is demon possession in China. Near Li Duan Ts'ang lived a girl who had spells of insanity. Her relatives believed that she was possessed by a demon, and were afraid of her. They began to talk of putting her to death. She heard them, and was wise enough to know what it meant. She said, "If you kill me, I will come back and harm you as long as you live." Thereafter they were afraid to harm her, and treated her with much consideration.

There was a robber who lived at Huen Kiang. He robbed and killed a rich acquaintance. Later the spirit of the victim haunted him in his dreams. He became ill and died, asserting that he was being done to death by the spirit of the victim. Then the son of the robber also began to have bad dreams, and saw the spirit of the victim coming to injure him. He felt that the spirit of the victim was near him all the time trying to harm him. He sought the aid of priests, but all to to no avail. Finally he secured the help of a local magistrate, a man of considerable influence. This man said to the spirit, "Come, now, you have done enough harm already. Go away and let this man alone." The spirit obeyed, and the son was saved.

In Suifu a merchant named Ch'en had two daughters and a son. Three years before the events we are about to relate, Mrs. Ch'en had died in Chungking. At the time of the death of his wife, Mr. Ch'en had opened a shop in Suifu, and on account of his business was unable

[1] Dore, Henry S. D., Researches Into Chinese Superstitions, 1915-22, Vol. I, p. 62.

to attend the funeral. He sent thirty dollars for the funeral expenses in care of a friend who was to make the proper arrangements and pay the bills. The friend did things very poorly, merely covering the coffin with a little dirt. The money he saved he used himself. The second daughter married, but her husband soon died. Later she married a man named Tsu. This man Tsu previously had a wife, but it is thought that he made away with her in order to marry the second daughter. The oldest daughter married a man named Tsao. Mr. Tsu died at Chungking and the second daughter came to Suifu. Her father was about to remarry when a curious thing happened.

The second daughter became black in the face and began to utter words incoherently. She then began to talk as though she were her mother. She said that the reason her mother had not complained before was that in hades when she first intended to complain the god told her that she should first suffer misery three years in hades, then make her complaints; that Mr. Tsu, on hearing that the second daughter was about to be married, seriously objected, and raised a row with the dead Mrs. Ch'en; that since Mrs. Tsao was unable to bear children, Mrs. Ch'en demanded that a second wife or a concubine be found for Mr. Tsao so that he should not be without descendants: and lastly, that the grave of Mrs. Ch'en must be put in first-class condition.

Mr. Ch'en proposed that much paper or spirit money should be burnt for Mrs. Ch'en so that she should have plenty of money to spend in hades. Mrs. Ch'en replied that this was not a matter of primary importance, but that she would permit Mr. Ch'en to spend much money in this way. She said that the king told her in hades that within three days she must compel Mr. Ch'en to agree to carry out all these matters. If Mr. Ch'en did not, the god would rob him of his soul so that he would die.

Mr. Ch'en agreed to all these conditions, and secured two middle men who were to guarantee the execution of all these demands. They were all carried out, so that Mr. Ch'en suffered no harm.

It was believed that Mrs. Ch'en had come from hades, and taken possession of the second daughter, Mrs. Tsu, and had used Mrs. Tsu's mouth so as to be able to speak. It was asserted that spirits cannot speak audibly because they have no bodies.

6. SUMMARY

So prominent is the belief in and fear of demons in Szechuan that one is tempted to say with Dore that the essence of the Chinese religion is the belief in and fear of demons, who are thought to be the cause of all diseases and calamities, and the attempt to ward them off and secure safety and happiness by means of marvellous, superhuman power that is made available through charms, amulets, incantations, priests, and gods.[1] This, however, would be an exaggeration. We merely note that protection against demons is a very important part of the religious technique in Szechuan.

III. BIRTH, MARRIAGE, DEATH, AND BURIAL

1. VARIETY OF CUSTOMS IN SZECHUAN PROVINCE

To most individuals, birth, marriage, and death are the outstanding events of human life. It is natural that many religious rites and ceremonies group themselves around these events.

While general resemblances between the birth, marriage, and burial customs are noticeable throughout all China, there are also many variations. These are evident even in different parts of Szechuan Province. Adam Grainger, in a little booklet entitled Studies in Chinese Life, describes in detail birth, marriage, and burial customs in Szechuan. Mr. J. Mortimore, in a series of short articles, has also described the burial customs. A book entitled Chinese Culture and Christianity, by J. L. Stewart, and based primarily on conditions in Szechuan, has recently appeared. In these descriptions one is impressed more by the differences than by the resemblances.

It is probable that the religious and social customs of Szechuan are a blend of the old Chinese culture with other elements that are aboriginal, or have been brought in from India, Tibet, or possibly other countries. It is not always possible to distinguish between them. The Miao and the Chinese of Szechuan both have the Pan Ku myth, monosyllabic languages with five tones, and many customs in common, but it cannot always be ascertained which has borrowed from the other. It seems wise and necessary to limit ourselves to those elements which are probably general in the province, and to pay special attention to certain burial customs which can be traced back into antiquity, and which throw light on the development of the Chinese religion.

2. THE DESIRE FOR AND THE METHODS OF SECURING CHILDREN

Like other branches of the human race, the Chinese desire a numerous posterity. This is intensified by the need of sons to conduct the ancestral ceremonies.

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[1] Dore, Henry S. D., Researches Into Chinese Superstitions, Vol. IV, p. 431; Vol. V, pp. ii-iii.

There are several ways by which people believe that they can secure sons. A common way is to pray to one of the goddesses who gives sons, either the Song Tsi Kuan Yin or the Song Tsi Niang Niang. The Goddess Of Mercy is sometimes entirely consecrated to this purpose, and holds a child in her lap. Sometimes the priests are hired to read the sacred scriptures in the homes.[1]

Sometimes a person will pray for a son, and if the prayer is answered he will present a wooden image of a child as a thank-offering to the deity. If a good number of these are at the feet of the god, it adds considerably to his prestige. If a barren woman steals one of these wooden images, she will surely give birth to a son, after which she is supposed to return the image. The stealing of other sacred articles will cause the mother to bear a son. Among these are the headcloth of an idol, sacrificial food, or eggs at a marriage feast.[2]

In some parts of the province one will occasionally see a round hole in the rock resembling the female sex-organ. It is believed that if a person succeeds in throwing a stone into certain of these holes his wife will give birth to a son. One of these holes is at Tao-si-kuan, on the Min River between Suifu and Kiating. Two others are near Suifu, one across the Min River near Tiao-huang-lo, and the other beyond Lankuang at Da Er O, or Strike Son Hole.

3. BIRTH CUSTOMS

Before a child is born, a priest or " sorcerer " is generally called to exorcise demons or other influences.[3] At birth, firecrackers or other means may be used to scare away evil spirits.[4] At a later time the goddess of progeny is worshipped, and a feast is held.[5]

Those who have the advantage of modern hospitals, with trained physicians and nurses, and anesthetics, can hardly appreciate the excruciating pains suffered by Chinese mothers. Sometimes delivery is impossible, resulting in the death of both mother and child. At other times the suffering is multiplied many fold by a slow and difficult delivery. The only duty of the female deity, the Tsua Sen Niang Niang, is to secure quick and safe delivery. The spirit tablet of

[1] When a Buddhist or a Taoist priest reads his scriptures ceremonially, it is customary for foreigners to say that he is praying. He is really reading his sacred scripture, which is considered an act of great virtue that will move the gods and bring good fortune.

[2] West China Missionary News, January, 1921, pp. 9-11.

[3] Grainger, Adam, Studies in Chinese Life, 1921, p. 5.

[4] *Ibid.*, p. 5.

[5] *Ibid.*, p. 6.

the Tsua Sen Niang Niang is brought to the home when necessary. There are many other methods. A charm may be written and pasted on the body of the mother. A priest may come to the house and read scriptures or perform ceremonial rites. If a mother dies in childbirth, she is not admitted into hades, but becomes a demon called a *ts'an lan kuei.*

After the child is born, there is something dangerous or unclean about the mother. For this reason she is not allowed to leave the room of her confinement for a month. Some of the ideas concerning childbirth are given in the Classic Of The Bloody Basin, the writer's translation of which is given below in full:

THE TRUE CLASSIC OF THE BLOODY BASIN

(Outside Title)

THE TRUE CLASSIC OF (OR FOR) THE SAVING OF MOTHERS BY DI TSANG P'USAH

(Inside Title)

Reprinted in the fourth moon of the fourth year of the Republic.

From Shansi Province, Shanuen Shien, published by the disciple of Li Yin Lin. The printing boards at the T'ong Yih shop in Suifu.

The True Classic Of The Saving Of Mothers From The Bloody Basin.

Correct words for purifying the mouth.
Shiu li shiu li mo ho shiu li shiu shiu li so p'o ho.
Correct words for cleansing the body of impurities.
Shiu do li shiu do li shiu mo li so p'o ho
Correct words for pacifying the Tu Di gods.
La mo shan man do mo t'o lan ngan du lu du lu tsae wei so p'o ho.
For respectfully calling the eight gods.
La mo Kuan Si Yin P'usah mo ho sah.
La mo Mi Leh Fuh P'usah mo ho sah.
La mo Shu K'ong Chang P'usah mo ho sah,
La mo P'ushien Fuh P'usah mo ho sah,
La mo Gin Kang Seo P'usah mo ho sah,
La mo Miao gih Shiang P'usah mo ho sah,
La mo Ch'u Tsai Chang P'usah mo ho sah,
La mo Di Tsang Wang P'usah mo ho sah.

Verse for beginning the Classic—

O marvellous way, so lofty and so deep,
A myriad ages one can hardly meet;
But now I see and hear, can grasp and keep;
With joy I'll tell the truth to others as is meet.

The True Classic For The Saving of Mothers By Di Tsang Wang P'usah.

Reverently calling the gods.
Shi T'ien Fuh P'usah,
Mi T'o Fuh P'usah,
Ru Lai Fuh P'usah,
Shih T'ien Nien Wang Da Di P'usah,
Ih Ch'ih Gieu Lan P'usah.

La mo Gieu K'u Gieu Lan P'usah who pronounces the following incantation: "*Do ch'ueh lan ngan do fah lu lai t'ang shuen i ho gieu lan uin t'o sen.*" I now will cultivate and preserve and always read and chant (this classic) in order that I may save my female relatives from that punishment which befalls them when after ten months of pregnancy they have given birth. I will constantly chant with my mouth this classic for the rescuing of mothers. When Nien Wang in his dwelling brings the women to him and reproves them for their sins, if one chants the True Classic it interferes with the star of calamity. I pray that my female relatives may early escape from the calamities, and I, the son, receive the punishment, which I should. I have already prayed and obtained the saving from calamities by the goddess Kuan Shi Yin who by the pure water from her vial washed away the body of evil sins from all people. The female relatives do not understand the meaning of this, but let all kinds of sin and evil be upon me. Every day I will chant this classic which frees from calamity. May my mother escape from all earthly evils, and our family cultivate themselves in mercy and righteousness.

A chant to be accompanied with the burning of incense.

Ti Tsang P'usah, the merciful gods of the ten courts, the gods of the three terraces, and of the eight thrones, the nine ministers, the rulers of hell and Tsen O. If you invite the Buddhist priests to proclaim abroad this classic, hell will change into heaven.

La mo Di Tsang Wang P'usah mo ho sah (repeat three times).

The Faith Of The Bloody Basin Classic Explained By The Great Tibetan Orthodox Religion Which Was Spoken By Buddha.

Once upon a time the god Muh Lien went to U Tseo Tsua Yang Shien, and saw the hell of the bloody basin pool eighty-four (probably li) wide, in which there were one hundred and twenty things, iron crossbeams, iron pillars, iron cangues, and iron locks, and saw a multitude of the non-Buddhist women of the earth with unkempt hair all dishevelled, and long cangues and bound hands being punished in hell. The keepers of hell and the king of demons three times daily took bloody water and ordered the women to drink it. The sinners did not dare to obey, therefore they were beaten with an iron club by the Lord of Hell until they screamed. Muh Lien had compassion and asked the Ruler of Hades saying, "I do not see the non-Buddhist women's husbands undergoing this punishment. I only see many women suffering this bitter pain." The Ruler of Hades replied to the Learned One, "This does not concern the husbands, but it is simply that women in giving birth allow the bloody dew to defile the gods in the earth. If the unclean garments are taken and washed in creeks or rivers, the water carries the defilement and injures all the righteous men and women of the faith who secure water and boil tea to offer to all the holy ones (gods, saints, etc.), causing it to be unclean. The Great General of Heaven writes down their names, records them in the book of good and evil, to await until, within a hundred years, life is ended, when they receive this bitter recompense." Muh Lien was very compassionate, and quickly asked the Ruler of Hades, "How can we reward the virtue of mothers in bearing children so that they can escape from the hell of the bloody basin pool?" The Ruler of Hades replied, "Only by carefully being filial, and men and women respectfully worshipping the Three Precious Ones and by observing the three years bloody basin fast, and assembling the festival for succeeding over the bloody basin, inviting Buddhist priests to chant this classic once, and when the time is fulfilled the repentance observances are completed, and then a boat of mercy will bear her over the River of Purgatory to the shore, and it will be seen that five lotus flowers appear in the bloody basin pool. The sinners will be glad, and will develop shame in their hearts, and they will be able to rise to the Buddhistic land. Then all the great gods and Muh Lien will inform and respectfully urge the unbelievers and the men and women who believe righteousness to quickly learn and cultivate virtue so as to remove the punishments and greatly alter the future course of events. Do not lose this teaching, for in ten thousand years you will not easily get it back." Buddha said, "If the people who believe in the classic of the bloody bowl write it and keep its instructions, it will cause them to secure the ascension to heaven of all their parents for three generations, and their enjoying all blessings—clothing and food of course, long life, wealth, and honor." Now, at this point (in the reading of this classic), the Heavenly Dragon, the eight grades of men, and the non-human beings are all filled with great joy and believe, receive, and obey this book, give a salute, and depart.

The Completion Of The Classic Of The Orthodox Tibetan Religion Explaining The Faith Of The Bloody Basin.

The Classic That Buddha Spoke Of The Great Grace Of Fathers And Mothers And Of Bones Of Unborn Babes.

I have heard thus, that once upon a time at Tsisou in the Kingdom of Shaewae, Buddha spoke to the gods of Kuh Duh Uen and to the 1,250 priests of Dae Pi Ch'iu, at which time the divine Ho Lan arose from his throne, with his hands offered obeisance to Buddha, and spoke these words: "What is greatest in the universe?" Buddha replied, "In the universe that which is weightiest and of most importance is the grace of fathers and mothers." Ho Lan asked Buddha, "Will Buddha mercifully and kindly explain?" Buddha said, "When the child is in the womb of the mother for the first month, it is like pearls of dew on blades of grass." Ho Lan asked Buddha, "Why do you say pearls of dew on blades of grass?" The Universally Honored One replied, "In the morning it collects, but at noon it evaporates. It is present only in the morning. It is not present in the afternoon. When the child is in the mother's womb for two months, it changes like snow crystals." Ho Lan asked Buddha, "Why do you say snow crystals?" The Universally Honored One replied, "Like snow crystals in the air falling down. When the child has been in the womb for three months, it changes into a lump of blood six and three-tenths inches long." Ho Lan asked Buddha, "Why do you say a lump of blood?" The Universally Honored One said, "In the first place, it may be called a lump of blood. In the second place it may be called a snow mountain. In the third place it may be called blood collected together. When the child has been in the mother's womb four months, it develops the four limbs." Ho Lan asked Buddha, "Why do you say four limbs?" The Universally Honored One replied, "First two hands appear like spring and summer. Later two feet appear like autumn and winter, and finally you call them four limbs. When the child has been in the mother's womb for five months, it develops the five lumps." Ho Lan asked Buddha, "Why do you call them five lumps?" The Universally Honored One replied, "First, the skull develops, then the fanbones develop, then the two kneecaps, so they are called five lumps. When the child has been in the mother's womb for six months, it develops the six senses." Ho Lan asked Buddha, "Why do you say the six senses?" The Universally Honored One replied, "Eyes can see color, ears can hear sound, the nose can smell all fragrances, the tongue can taste flavors, the body feels fineness and smoothness, and the mind can understand all things, so they are called the six senses, and are also called the six thieves. When the child has been in the womb of the mother seven months, it develops the seven kinds of bones." Ho Lan asked Buddha, "Why do you call them the seven kinds of bones?" The Universally Honored One replied, "My mother bore me having bones of diamond that would not decay. Kuanyin P'usah was born having red lotus bones. Shen Uen Lohan when born had bones that are sacred relics. Wan Shen Di Wang was born having bones like the womb of a dragon and the body of a phoenix. The imperial officers and the prime minister are born with *keo lien shiao* (meaning not clear) bones, and the generals of war are born with bones of tigers and wolves. We, whether we are men or women, are born with three hundred and sixty joints. The bones of men and women are different. Bones of men develop from the head down. Bones of women develop from the soles of the feet upward. The large intestines are twelve feet long, just as a year has twelve months. The small intestines are twenty-four feet long, as the year has twenty-four semi-lunar periods. When the child has been in the womb of the mother eight months, it daily suffers eight kinds of hellish torments." Ho Lan asked Buddha, "Why do you call them eight kinds of hellish torments?" The Universally Honored One replied, "When the mother eats hot food, it is called the hellish torments of (boiling) kettle soup. When the mother eats cold food, it is called the hell of cold ice, When the mother is full (that is, when her stomach is full), it is called the hell of crushing stone. When the mother is hungry, it is called the hell of hungry demons. When the mother eats hard things, it is called the hell of the sword mountain. When the mother travels or is weary of labor, it the called the hell of pounding and beating (with pestles, mallets, etc.). When the mother is sitting down, it is called the hell of the iron bed. When the mother nods her head, it is called the hell of hanging upside down (the idea is that the nodding of the head causes the child to be turned upside down). When the child has been in the womb of the mother for nine months, it will daily turn over three times, and with both hands take hold of its mother's heart and liver, and twice (daily) turn its body and tread on the mother's backbone and thighs so that it tires her four limbs painfully, and all her joints are tightly stiffened. When the child has been in the mother's womb for ten months, you can see that it is about to be born. Daily it comes and congeals the mother's abdomen, and nightly it comes and congeals the mother's womb. When the time of birth arrives, then you should fear four kinds of evil birth. The first to fear is the grasp-dry-wood birth, the second to fear is the birth of stepping on the lotus flower (feet appearing first), the third dreadful birth is being born crosswise, and the fourth to dread is that of begging salt (probably with the hands appearing first). The middle fingers of filial children are hot when they are born. When an unfilial child is born who in past existences has been your enemy, in two or three days of travail he will still be unborn, the whole family will be alarmed, and the mother's life will be lost because of the child. If men and women who believe wish to recompense their parents, they should copy this book, and with it exhort the people all around, spread abroad the teaching of filial piety, and contribute to the support of Buddhist priests, and they will secure the good health of their parents in this world, and cause them after death to rise to the land of Buddha. At this point the Heavenly Dragon, the Eight Divisions of Gods, and all men will greatly rejoice, believe, obey, perform a courtesy, and disperse. This is the end of the classic which is Buddha's words about the great grace of parents in regard to pregnancy.

The Words Of Buddha Which Are The Marvellous Classic Of Di Tsang P'usah For Salvation From Torments.

Once upon a time Di Tsang P'usah dwelt in the everbright land in the south, and used his pure, heavenly eyes, and saw in far away hades all human creatures who were undergoing torments—iron pestles and beaters, iron grinders, iron saws, kettle soup (boiling), fierce fire reaching to heaven, hungry people swallowing hot iron, thirsty people drinking melted brass, receiving all bitterness and vexations, having no rest. Di Tsang P'usah could not bear to see it, so he came from the south to the midst of hell, and was in the same apartment with Nien Wang, but slept in another bed. They discussed all the reasons: first, that possibly Nien Wang might not have judged justly; secondly, that possibly the documents of accusation were disposed of wrongly; thirdly, that possibly the god had wrongly caused individuals to die; and fourthly, that possibly sinners were allowed to suffer punishment beyond their due. Therefore, for these four reasons, if a good man or a believing woman has images made of Di Tsang Wang P'usah and causes the classic of Di Tsang P'usah to be read, calling out to Di Tsang P'usah, this person can certainly reach the western paradise before the face of O Mi T'o Fuh (Amitabha), and his body become pure like the lotus flower, which cannot be explained, and his six souls will become intelligent and can go anywhere, from Buddhaland to Buddhaland, and from one heaven to another. Any person who causes images of Di Tsang P'usah to be erected, and this classic to be read, and protects the name of Di Tsang P'usah, after he dies Di Tsang P'usah himself will come to welcome this person to be forever with Di Tsang P'usah. All divine creatures and men of the universe, and O Shiu Lo when they hear this classic which Buddha spoke, will rejoice, believe, obey, make an obeisance, and depart.[1]

After the month of confinement is over, the relatives and friends who have been given presents are invited to a feast.[2]

4. MARRIAGE

Up to very recent times it was customary in Szechuan for all marriages to be arranged by the parents through go-betweens. Even

[1] The above "classic" is evidently a translation into Chinese of a Tibetan book, and the incantations are transliterations of incantations used by the Tibetan lamas, having no meaning in the Chinese. This book, although it has sometimes been prohibited by progressive officials, is widely used and its ideas are generally accepted in West China.

[2] Grainger, Adam, Studies In Chinese Life, 1921, p. 6.

now the exceptions are few. The consent of the young couple was not asked, and they were not permitted to see each other until they met at the marriage ceremony. Social conditions are now in a process of change, and sometimes young people find a way of choosing their own life partners, but on the whole the old customs are still in vogue.

A family will generally resort to divination before approaching another family about the marriage of their son to a young woman. If results are assuring, a middle man is found. The middle man or woman takes presents when approaching the parents of the young lady. If the parents are willing to negotiate, they produce the girl's horoscope, with which the go-between returns to the boy's parents.[1] Again divination is resorted to. If the result is favorable, an authority on horoscopes is called, and the horoscopes of the two young people are compared.[2] If the results indicate that the marriage would be unlucky, the matter is dropped; if the opposite is true, there are further negotiations, and a lucky day is set for the exchange of horoscopes.[3] Presents, and sometimes money, are given to the parents of the young lady, who in turn provide a feast for all the guests.[4]

On the day of the wedding, which must be on a lucky day, there is a procession, and the bride is carried to the home of the groom in a *hua giao,* or flowery sedan chair, which is red in color and beautifully decorated.[5]

The bride says farewell to her parents, and departs with weeping.[6] The procession is led by musicians with gongs, drums, flutes, and other wind instruments.[7] Banners and other paraphernalia are carried.

On the back of the bridal chair one or two lighted lanterns are hung, although it is broad daylight, to keep the demons away. Old bronze mirrors, glass mirrors, and other charms are used. The bride is often clothed in special garments that are supposed to protect her from evil spirits.

On arriving at the home of the bridegroom, a cock is killed, and the blood is sprinkled in a circle around the flowery chair.[8] This is a

[1] Grainger, Adam, Studies In Chinese Life, 1921, pp. 8-9.
Stewart, James Livingstone, Chinese Culture and Christianity, 1926, pp. 144-5.
[2] Grainger, Adam, Studies In Chinese Life, 1921, p. 9.
[3] *Ibid.,* p. 9.
[4] *Ibid.,* p. 9.
[5] Ibid., p. 12.
Stewart, James Livingstone, Chinese Culture and Christianity, 1926, p. 102.
[6] Grainger, Adam, Studies In Chinese Life, 1921, p. 12.
[7] *Ibid.,* pp. 11-12.
[8] *Ibid.,* p. 13.

further protection against demons. Then the bride enters her new home.

The bride is led to her place beside the bridegroom. Their first act is often to face the front door and worship heaven and earth.[1] Then they worship the housegods and pay their respects to the bridegroom's parents and ancestors. Finally, they bow to each other.[2]

Most of the guests bring presents to the new couple, and the customary wedding feast is held.

A widow does not generally remarry. A man may take several wives if he wishes and is able to support them. There is little ceremony when a widow is remarried or when a man, while his wife is still living, takes a second wife or concubine.

5. DEATH AND THE FUNERAL PROCESSION

Soon after death cash paper is burnt to provide the spirit with travelling expenses for use on the way to hades. This is bound in small, square bundles. Mortimore has translated the inscription on the last bundles:

The recently deceased . . . . (name) . . . . whose earthly life began in (the reign of) . . . . such and such a year . . . . month . . . . day . . . . hour, in . . . . province . . . . prefecture . . . . county . . . . township . . . . section at the place called . . . . grew to manhood; enjoyed . . . . years of life; the great sphere (of earthly existence) closed in (the reign of) . . . . such and such a year . . . . month . . . . day . . . . hour . . . . while living at . . . . province . . . . prefecture . . . . etc., death took place due to illness. This is personally-prepared cash paper for use en route, packet number . . . . to defray expenses in the spirit world.

(To whom it may concern:) At each of the barriers by land and water and at fords, examine and take note and allow to pass without obstruction.

On the last package must also be written:

The year that the sky disappears;
The month when the fixed time is fulfilled;
The day that the end has come;
The hour when a standstill is reached.

Transform (that is, the paper is to be burnt and transmuted into paper currency).[3]

The first two paragraphs correspond very closely to what the Chuan Miao K'a Gi, who opens the way for the spirit of the dead person to hades, says as a part of the Chuan Miao funeral ceremonies. Mr. Mortimore also says that a careful watch is kept so that no one can

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[1] *Ibid.*, p. 13.

[2] *Ibid.*, p. 13.

[3] West China Missionary News, April, 1915, p. 26.

throw pieces of iron into the coffin for that would cause disaster to come to the descendants of the deceased. This also corresponds to one of the customs of Chuan Miao.

A priest or geomancer closes the coffin. He must also choose a lucky burying site where the *fengshui* is good. If it is not good, the descendants of the dead will have calamities and reverses and surely decline. If it is good, the descendants will prosper and be happy. A lucky day for burial must also be chosen.

It is believed that the soul goes to hades to be judged, and that there, in contrast to earthly conditions, judgment is just and in accordance with one's conduct on earth. In many Buddhist temples are scenes that portray judgment and punishment in hades. Sometimes hades is also represented in Taoist temples.

Before the funeral, Buddhist or Taoist priests are called to "open the way" for the soul to hades. This involves much ceremony, including the reading of scriptures and the worship of gods. The spirit is generally provided with a road-guide or passport to heaven.

Friends of the family send gifts in the form of *tua tsis,* or double scrolls, which have written on them sentiments that are complimentary to the deceased. In return they are invited to the funeral and to the funeral feast, and provided with a white cloth of mourning to wear on the head during the ceremonies.

In the funeral procession the oldest son of the deceased walks in front of the coffin, dressed in sackcloth and supported by friends. A live cock is generally perched on the coffin to keep away demons. Firecrackers are set off at the beginning of the funeral procession and at the grave.

6. THE BURIAL AND GRAVE CUSTOMS

At the grave the customary scenes of mourning take place, including weeping and prostrations. Paper cash, gold and silver ingots, a gold hill and a silver hill, and paper images of human beings, of houses, furniture, boxes, weapons, and even opium pipes are burnt. They are transformed by burning into cash, gold and silver ingots, a gold hill and a silver hill, living servants, sedan chairs, houses, etc., for the use of the departed spirits in the land of shades. Actual food is offered, incense and candles are burnt, there are prostrations and mourning, and the coffin is covered with dirt. Usually the hole is not dug very deep, and the dirt is heaped up in a mound over the coffin.

To explain the custom of burning paper money, paper images of human beings, houses, furniture, and other articles, we must go back thousands of years into ancient Chinese history. In the sixth section of the history of Si Ma Ch'ien, it is stated that 177 persons were killed and buried with the emperor. The following quotation is from the journal of the North-China Branch of the Royal Asiatic Society for 1910:

From the Chinese classics we know that, in remote antiquity, a straw figure of a man was placed in the grave with the dead. Confucius himself commended the act in preference to a later custom of substituting a wooden image with moveable joints. His counsel, however, went unheeded. It is not certain, but presumably he was aiming at stopping the immolation of human beings at the tombs of the great. The burying of wooden men was, in all likelihood, the bogus form of this savage reality. Later history contains many examples of it. To quote from Professor Kid: "When Woo—king of the state Tsin—died sixty-six persons were put to death and buried with him. One hundred and seventy-seven ordinary individuals, together with three persons of superior rank, were devoted by death to the service of Muh-kung in the other world; a monody still exists lamenting the fate of these three men. Tsin-shih-huang-ti, who flourished about two hundred years before the Christian era, commanded that his household females and domestics should be put to death and interred with him." The custom long survived this period, "and when persons offered themselves voluntarily to die, from attachment to their masters and friends, such sacrifices were esteemed most noble and disinterested." [1]

In the Encyclopaedia Sinica there is a similar statement:

SACRIFICES, HUMAN. This title should more properly be reserved for the killing of men as offerings to the Deity, as in the case of Abraham and Isaac, or the religious ceremonies of the Aztecs. In default of a more convenient term, it is used for the burial of living slaves, concubines, and others, with the rich or royal dead; though the idea of providing companionship and service in the other world is more prominent than that of appeasing anger or seeking favor.

The practice must have been established in China in very early times, but the first example recorded in Chinese history was at the burial of the Ch'in ruler Wu Kung, B. C. 678, when sixty-six persons were buried alive to keep him company in the other world. In Ch'in again, when Mu Kung died in B. C. 621, there were buried with him one hundred and seventy-four people. This caused the Ode called *Huang niao* to be made (Legge's She King, p. 198). The fact itself is recorded in the Ch'un Ch'iu. The practice had been forbidden by Hsien Kung on his succeeding to the Ch'in earldom in B. C. 384, but at the death of Ch'in Shih Huang Ti in B. C. 210, all his wives and concubines who had not borne him children were buried with him, and the workmen who had made his tomb were also walled up alive in it.[2]

In North China many old graves have been unearthed, and their contents are in the world's great museums. Some of them go as far

[1] Journal of the North-China Branch of the Royal Asiatic Society, Vol. XLI, 1910, pp. 63-4.

[2] Encyclopaedia Sinica, 1917, p. 493.

back as the Han Dynasty. A number of large cases of these relics are in the Field Museum in Chicago.

In Szechuan Province are thousands of caves that were chiseled out of the soft red-sandstone many centuries ago. Perhaps most of them are around Kiating and Chengtu, and all of them seem to be near rivers and streams. There are fewer around Suifu, possibly due to the facts that the sandstone is much harder and the Chinese secured possession of Suifu at a later date than Chengtu and Kiating. The larger of these caves are nearly a hundred feet deep and contain many relics. The most extensive collections that have been made are in the British Museum and in the Museum of the West China Union University. Many Chinese and foreigners assert that these caves were the homes of the aborigines who lived in these districts before the arrival of the Chinese. Rev. Thomas Torrance, F. R. G. S., was one of the first to assert that they were burial tombs of wealthy Chinese who probably lived from the Ts'in Dynasty B. C. to the time of the Three Kingdoms. Mr. Torrance has spent years in the study of these caves and their contents, and the collections in the British Museum and in the Museum of the West China Union University were made almost entirely by him. The following quotation is from a letter received from Mr. Torrance, written at Kuanshien, Szechuan, China, July 12, 1925:

> The cave tombs are found all the way from the Hupeh-Szechuan border westwards as far as Lifan. Ninety-nine per cent of them are in low altitudes. Their age is from the end of the Ts'in Dynasty B. C. to the time of the Three Kingdoms. The people were in the Pa, Shuh (Szechuan), and Chinese territories. My own opinion is that the people were Shuh-Chinese or Pa-Chinese, mixed blood. There are only a few inscriptions in seal and common Chinese character. There is no evidence at all that they were originally for anything else than tombs. Later they were used for different purposes, that is, some of them, notably near Kiating. The goods found in these caves correspond closely to goods found in tomb mounds of the same date and in underground graves all over China, that is, China north of the Yangtse. The carvings are distinctly of Han type and are all in close correspondence. The carvings often follow the appearance of Han houses, showing they were built of logs.

Volume I of the Supplementary Papers of the Royal Geographical Society, published in 1886, contains an article entitled "A Journey Of Exploration in Western Ssu-ch'uan," by E. Colborne Baber, Chinese Secretary of Legation, Peking. This article tells of a visit to West China in 1877, when a number of caves between Kiating and Suifu were inspected. Mr. Baber found what he decided were cisterns inside the caves, and so concluded that the caves were dwelling-places.[1]

[1] Supplementary Papers, Royal Geographical Society, 1886, Vol. I, pp. 131-2.

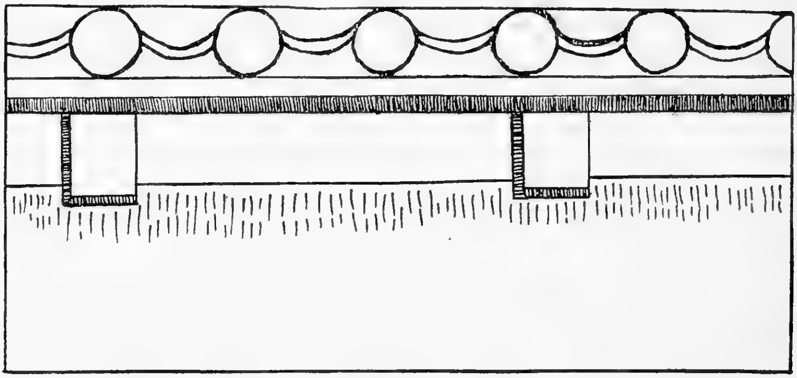

FIG. 1.—Diagram of a carving on the wall of a cave above Suifu on the Min River. Copied from a drawing by E. Colborne Baber.

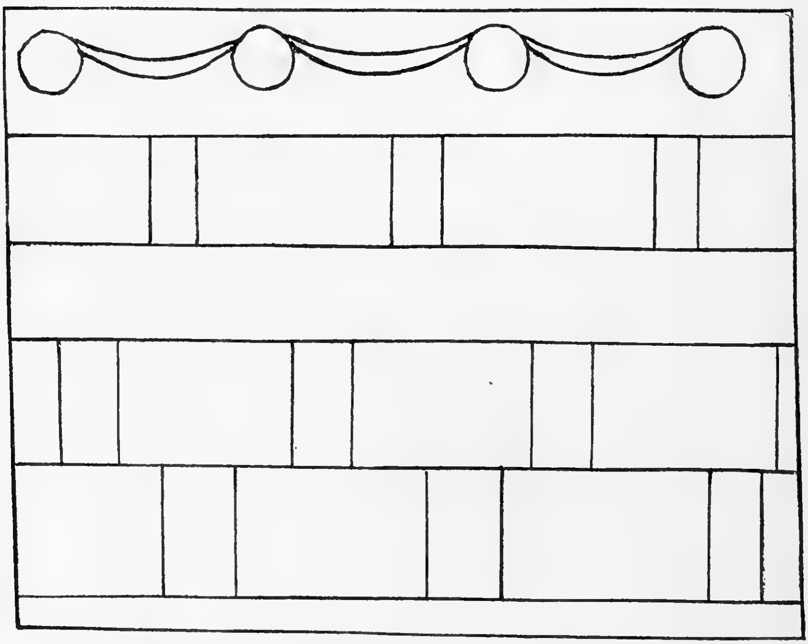

FIG. 2.—Diagram of a carving on a wall of a cave three miles west of Kiating, China.

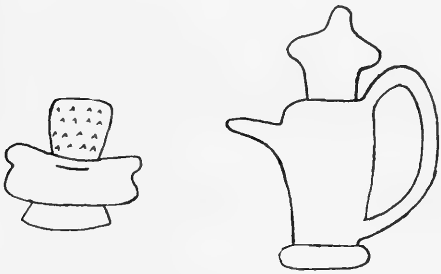

FIG. 3.—Copy of carvings of an ancient teapot and a teacup on the wall of an old burial tomb in a cave at Song Tsua, near Li Chuang, about fifteen miles east of Suifu.

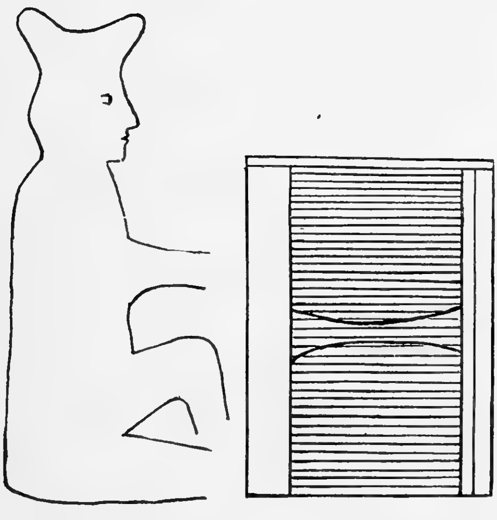

FIG. 4.—Copy of a carving on the wall of an ancient Chinese tomb in the sandstone at Song Tsua, near Li Chuang, about 15 miles east of Suifu. The instrument probably represents a loom. The tomb is a cave in a solid rock.

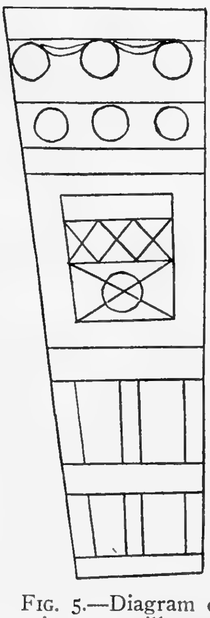

FIG. 5.—Diagram of a carving on a pillar at the entrance of an ancient Chinese burial cave near Kiating, Szechuan, China.

The writer has visited the caves about Kiating and Suifu a number of times, and is convinced that Mr. Torrance is right, and that these are burial tombs of the early Chinese. The reasons, briefly stated, are as follows:

First, the relics found in these caves very closely resemble those in the tombs of North China which belong in the Han and the Tang Dynasties. The watchdogs look so much alike that one could believe that they came from the same tomb. The articles found are very similar, from earthenware images of houses, human beings, and chickens to the coins and the jade cicadas that were placed on the tongues of the dead. Evidently, they were the work of the same civilization.

Secondly, the coins in the Szechuanese tombs are all Chinese coins. The dates of most of them can easily be determined.[1]

Thirdly, large numbers of these caves still have remnants of coffins in them. Some caves have places for several coffins, indicating that they were probably used by a family. Some of the coffins have been found with skeletons in them. Baber's "cisterns" are the places where the coffins are found.

Fourthly, the caves are so well made that they are evidently the work of a people who were in a high state of civilization.

Fifthly, we know of no tribe of aborigines in West China that is accustomed either to live or to bury its dead in artificial caves of this kind.

We believe that the weight of evidence is strongly in favor of the theory that the caves of Szechuan are Chinese burial tombs dating approximately two thousand years ago.

All the images yet found in these caves are of unglazed, burnt clay, of a gray color. Later the Chinese of Szechuan ceased the burying of their dead in caves, and buried them in tombs covered by mounds. Many of the images found in the later tombs are beautifully glazed.[2]

[1] Journal of the North-China Branch of the Royal Asiatic Society, Vol. XLI, 1910, p. 69.

[2] Some diagrams are appended that the writer has made of carvings on caves near Kiating, and also copies of some pictures that he found on the side of a cave at Song Tsui, near Li Chuang, east of Suifu. The hat worn by the man whose picture is carved in the cave near Song Tsui resembles those on clay images, unglazed.

Mr. Torrance gives the following list of the articles which he has gathered in the caves of Szechuan:

> Instead of straw or moveable wooden figures of men you will find them of burnt-clay, grey and terra-cotta in color, glazed and unglazed, from a few inches high to nearly full life-size. They represent persons of both sexes and various ranks and callings. There are besides models of houses, cooking-pots, boilers, rice-steamers, bowls, basins, vases, trays, jars, lamps, musical instruments, dogs, cats, horses, cows, sheep, fowls, ducks, etc. Standing with your reflector lamp in the midst of a large cave it seems verily an imitation of Noah's Ark.[1]

It is true that the Chinese believe that the caves of Szechuan were made and used by aborigines, and call them Mantsi caves. This is explained by the fact that the old Chinese population was practically exterminated by Tsang Shien Tsong, and the new immigrants would naturally know little about the past history of the province.

We therefore advance the following theory: In early Chinese history men provided food for the dead as the Chinese still do to-day, and also placed in the tombs weapons of war, money, and articles of everyday use. They killed human beings, including wives and servants, to put in the graves with the deceased leaders. The moral development of the people led to the substitution of burnt-clay images for human beings and the fowls, animals, and the articles of everyday life. The clay images were at first unglazed, but later were glazed. The placing of quantities of money in the graves took it out of circulation, and with other valuables tempted the robbers to loot the graves. In time people began to substitute paper money for real money. The paper was burnt, and was transformed by the flames into spirit money that could actually be used by the departed spirits in the land of shades. Now nearly all the articles are burnt, so that very little is placed in the tombs. Actual food is still offered at the graves and before the ancestral tablets so that the spirits of the dead will not hunger. The food offered is not destroyed. The spirit must be supposed to in some way secure the essence of the food, and the descendants of the dead are permitted to eat what is left.

After burial, the grave is revisited on occasions, food is offered to the departed soul, and the ordinary acts of reverence are performed. Mourning for one's parents is kept up for three years, and the ceremonies usually included under "ancestor worship" are performed for three generations of ancestors—parents, grandparents, and great-grandparents.

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[1] Journal of the North-China Branch of the Royal Asiatic Society, Vol. XLI, 1910, p. 68.

On Chin-min, or Tsin-ming, which comes on the third day of the third moon, all who are able to do so go to the tombs, burn paper money and incense, offer food, light candles, and repair the graves. While all the seasonal festivals are occasions of family reunions and ancestral ceremonies, this is the great Decoration Day of the Chinese people.

Two peculiar practices should be noted. One is that if a person dies away from home he is not removed to his home for the funeral services, for it would be unlucky to take him into the house after he has died elsewhere. Grainger mentions this custom, which is apparently general.[1] In the summer of 1925 the writer saw a woman hastening to a doctor with a sick child in her arms. A little later she returned, still carrying the child, which had just died. On being certain that the infant was dead, she threw it into the Min River. The explanation given was that it was unlucky to take the child into the home after it had died elsewhere.

We sometimes hear of the custom of making a hole through the wall of a house, through which the dead person is taken for burial, and later sealing up the hole, so that the spirit cannot find the way back, which it could do if it were carried through a door. There is an example of this among the Wasi aborigines at Kuan Tsai, near Uen Chuan Shien, where a great hole was made through the wall of the temple-yamen to bury an attendant who had died inside. Later the hole was sealed up.

IV. YINYANG AND FENGSHUI

1. THE YINYANG CONCEPTION

The conception of *yinyang* permeates and saturates the mental, moral, and social life of the Chinese, affecting every phase of their existence. Dr. Arthur H. Smith, in what is perhaps an overstatement, describes this conception:

> This Chinese (and Oriental) habit is at once typical and suggestive. It marks a wholly different conception of the family, and of the position of woman therein, from that to which we are accustomed. It indicates the view that while man is *yang,* the male, ruling, and chief element in the universe, woman is *yin*. "dull, female, inferior." The conception of woman as man's companion is in China almost totally lacking, for woman is not the companion of man, and with society on its present terms she never can be.[2]

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[1] Grainger, Adam, Studies In Chinese Life, 1921, p. 35.

[2] Smith, A. H., Village Life in China, pp. 302-3.

According to Chinese philosophy death and evil have their origin in the *yin,* or female principle of Chinese dualism, while life and prosperity come from the subjection of it to the *yang,* or male principle; hence it is regarded as a law of nature to keep woman completely under the power of man, and to allow her no will of her own. The result of this theory and the corresponding practice is that the ideal for women is not development and cultivation, but submission. Women can have no happiness of their own, but must live and work for men, the only practical escape from this degradation being found in becoming the mother of a son. Woman is bound by the same laws of existence in the other world. She belongs to the same husband and is dependent for her happiness on the sacrifices offered by her descendants.[1]

This statement of Dr. Smith is extreme in some respects, but he is right in his description of the *yinyang* principle, and of its vital connection with Chinese social customs and conceptions.

The *yin* and the *yang* have their source in the great extreme, or the *t'ae gih.*

2. FENGSHUI

In China a great deal is heard about the *fengshui.* Sometimes you see a peculiar rock in the river, interfering with traffic and causing wrecks. You look at the great line of boats that is passing by, realizing that every boat is endangered by the rock. You think of the constant loss of life and property. You know that it would be easy to destroy or to remove the rock in low water. To your suggestion that this be done, your Chinese friend answers, "*P'ang puh teh.*" That is, it must not be touched. Why? Because it is a *fengshui* stone.

Near Gioh Ch'i is a place where a creek makes a great bend, returning practically to its starting point before proceeding again in the general direction of the stream. By cutting through an earth bank less than 15 feet thick, the stream could be made to flow in a straight line, and acres of land could be saved for cultivation. To the suggestion that this be done, the farmer replied that someone had attempted to do this, but that the neighborhood had objected on the ground that it would injure the *fengshui,* causing all to suffer.

There is a *fengshui* stone at Ngan Bien or An Pien, a town about 20 miles up the Yangtse River from Suifu. Some Chinese would like to remove the stone, but the general sentiment of the town will not permit it, although every year boats are wrecked and people are drowned. If that stone were injured, all sorts of calamities might occur in Ngan Bien.

Fengshui stones occur on dry land. About 20 miles up the Min River from Suifu, at Kiang Gioh Ch'i there is such a stone on the

[1] *Ibid.,* pp. 305-6.

north bank of the river. It is peculiar in shape, being high, round, and pointed.

Many *fengshui* stones are vitally related to the welfare of certain towns, cities, or districts. Below the city of P'in Shan, on the bank of the river, is a round stone that is the *fengshui* stone of P'in Shan. The injury of this stone would cause ill-luck to the city of P'in Shan.

There are also *fengshui* trees. A great tree at Shin Kai Si on Mt. Omei is the *fengshui* tree of Chien Way. Another tree on Mt. Omei is the *fengshui* tree of Omeishien. Both are great, majestic trees.

Families also may have *fengshui* stones or trees. Between Ngan Bien and Leo Dong on the Yangtse River, a strange-looking stone has been for many generations the *fengshui* stone of the powerful Lin family of Leo Dong. At Shuin Gien Si, close to the Golden Sands Cave, is a family *fengshui* tree.

Between Suifu and Li Chuang, on the south bank of the Yangtse River, is a large stone that is the *fengshui* stone of the Lo family, who for generations have lived on the north side of the river opposite the stone, and who in the past prospered and accumulated great wealth through the help of this wonderful stone. It is said that formerly when wood was split in the home of the Lo family the rock would move. The Tsang family lived on the opposite side of the river and owned the land on which the *fengshui* stone is situated. The Tsangs were jealous of the prosperity of the Los, so they chiseled and "broke" the stone whose power and influence helped the Lo family. Thereupon the Lo family accused the Tsang family at court, and a long period of litigation ensued, consuming much of the wealth of both families. No satisfactory solution was reached at court, so the two families agreed to settle the matter out of court by each family throwing silver into the river. The family throwing in the most silver would be considered the strongest and the greatest. The Tsang family threw in pewter, but the Lo family threw in silver. Both families are now poor. Because the stone was chiseled or broken, it has lost its power to benefit the Lo family.

In 1924 the magistrate of the Lan Ch'i Shien district issued a proclamation forbidding the cutting of *fengshui* stones lest calamity fall upon the people.

Practically every large town or city has a pagoda that has been built in some prominent place, and some cities have more than one. The pagoda must be correctly situated, and affects for good or ill the *fengshui,* and, through the *fengshui,* all the important interests of a city.

About 80 li up the Min River from Kiating is Shiang Pih Si, or Elephant's Nose Monastery, where there is an unfinished pagoda. When the pagoda was being constructed, two noted scholars suddenly died, and it was concluded that the pagoda was injuring instead of helping the *fengshui*. Work was discontinued, and the pagoda has never been finished. If it had been in the right spot, it would have improved the *fengshui*, and a result would have been that more scholars would be born and developed, and that scholarship in the district would be generally improved.

Before a house is built or a grave is dug, it is necessary to have a specialist tell whether or not the *fengshui* is good. If the *fengshui* of the ancestral grave is good, the family will increase and prosper. If it is bad, the family will decline. The same can be said of the house in which the family lives. Merchants are more apt to enjoy financial prosperity if the *fengshui* of the store is good.

In the summer of 1923 I took a trip to Tatsienlu, which is often called the gateway of Tibet. On the way I saw where the robbers had attacked the home of a wealthy farmer. The father and another relative had been killed, the house had been badly smashed up, and a servant had been wounded, although the robbers had been driven off and no money stolen. The farmer was asked why he did not move into a city where the militia could protect him. The reply was that the *fengshui* of that place was good, so that anybody living on that farm would get rich.

What is this mysterious power or force called *fengshui? Feng* means wind, and *shui* means water. The expression stands for mysterious forces that operate for good or evil on families, cities, and districts. It is apt to be localized in strange or peculiar trees and stones.

Let us note that the man who in English is generally called a geomancer is in Szechuan called a *yinyang shiensen* or a *fengshui shiensen,* the two terms being interchangeable. The former term is commonly heard, and means a professor of *yinyang*. The latter term means a professor of *fengshui*. This suggests a close and vital relation between *yinyang* and that strange, mysterious force known as *fengshui*.

So far the writer has drawn entirely from his own experience. A quotation from Mr. Mortimore and another from the Encyclopaedia Sinica will further elucidate the meaning of *fengshui* and its connection with the *yinyang*.

It is now high time that the location of the grave be determined. In the case of the more wealthy, such an important matter will probably have been attended to by the sons years in advance; and good reason why, for upon the direction of the grave, the surrounding landscape and a score of other circumstances will the future wealth, happiness, or even the life of the descendants, depend. But let us suppose that in this case it remains yet to be done, while, at the same time the family purse is full enough to meet the expense of securing a lucky site. One of the sons deputed by the others, engages a geomancer and sets out with him on the momentous search.

Now, to understand what follows, we must remember that, geomantically viewed, mountain ranges (or, in a flat country, the higher levels) if of a certain conformation are to be regarded as dragons, and the parallel hills with the valleys or depressions on either side of the range constitute the sandy banks and the water, in which the dragon swims forward. Even to the western mind an undulating mountain ridge does not lack the suggestion of being a vast reptile; but to the Chinese, that is to the great majority, this is far more than a mere metaphor, for within the range is believed to flow, like an underground stream, the dragon's vital force or energy and wherever this collects or becomes concentrated deposits of gold, silver, or other precious metals occur. The secret to be discovered then is the exact spot where this throbbing force comes near the surface, or, as it is called, the Dragon's pulse so that when the remains of the parent are lowered into the earth, they will be in a perfect line to receive through the head and into the whole body this wealth-accruing energy. This accomplished, it must naturally follow that his posterity, who are the bone of his bone and flesh of his flesh, will abound in riches. There may be other theories propounded for this belief, but this is the one I have heard.[1]

Feng Shui, wind and water. (The outward and visible signs of celestial *Yang* and *Yin*.) The art of adapting the residence of the living and the dead so as to co-operate and harmonize with the local currents of the cosmic breath (*Yin* and *Yang* q. v.); often incorrectly called "geomancy."

It is believed that at every place there are special topographical features (natural or artificial) which indicate or modify the universal spiritual breath (Ch'i). The forms of hills and the directions of watercourses, being the outcome of the moulding influences of wind and water, are the most important but in addition the heights and forms of buildings and the directions of roads and bridges are potent factors. From instant to instant the force and direction of the spiritual currents are modified by the motions of the sun and moon, (see Astrology), so that at any particular time the directions of the celestial bodies from the point considered are also of great importance.

The professor of *Feng Shui* employs a Lo-pan (graduated astrolabe with compass) to observe directions and astrological harmonies, while at the same time he notices the forms which the spiritual forces of nature have produced.

By talismans (dragons and other symbolic figures on roofs or walls, pagodas on hills, or bridges) and charms (pictures of spirits or "words of power" inscribed on paper scrolls or stone tablets), the unpropitious character of any particular topography may be amended.

Artificial alteration of natural forms has good or bad effect according to the new forms produced. Tortuous paths are preferred by beneficent influences, so that straight works such as railways and tunnels favour the circulation of maleficent breath.

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[1] West China Missionary News, Oct. 1915, pp. 27-28.

The dead are in particular affected by and able to use the cosmic currents for the benefit of the living, so that it is to the interest of each family to secure and preserve the most auspicious environment for the grave, the ancestral temple and the home.[1]

We should note especially the phrase in parenthesis, "The outward and visible signs of celestial *Yang* and *Yin*." Under the heading "YIN and YANG," the following lines are also found in the Encyclopaedia Sinica:

YIN and YANG, The negative and positive principles of universal life. These words meant originally the dark and bright sides of a sunlit bank, and occur on the Stone Drums (8th century B. C.). By the time of Confucius they had acquired a philosophical significance as the two aspects of the duality which Chinese thinkers perceived in all things. Traces of the dual notion occurred in the "Great Plan" of the Shu Ching, but the actual words *Yin* and *Yang* as used in this sense occur first in the pseudo-Confucian commentaries on the I-Ching.

In this way *Yang* came to mean Heaven, Light, Vigour, Male, Penetration, The Monad. It is symbolized by the Dragon and is associated with azure colour and oddness in numbers. In *Feng Shui* raised land forms (mountains) are *Yang*.

Similarly *Yin* stands for Earth (the antithesis of Heaven), Darkness, Quiescence, Female, Absorption, the Duad. It is symbolized by the Tiger and is associated with orange colour and even numbers. Valleys and streams possess the *Yin* quality

The two are represented by a whole and a broken line respectively, thus:—

————   —— ——

Yang   *Yin*

Groups of three such lines are known as "trigrams," groups of six as "hexigrams," and the I-Ching is classified under the sixty-four possible hexagrams.

In connection with the five elements, the *Yin* and *Yang* have been for at least two thousand years used to interpret the processes of nature and they are the fundamental feature in the theories which underlie *Feng Shui*, Astrology, Divination and Medicine.

T'ai (Great) *Yang* means the Sun, *T'ai Yin* the Moon, *Shao* (Lesser) *Yang* the fixed stars and *Shao Yin* the planets, these four being supposed to be the four primary combinations (*Hsiang*) of *Yin* and *Yang*.

Yin and *Yang* are themselves supposed to have proceeded from a "Great Ultimate."[2]

Fengshui, then, is the outworking of the *yin* and the *yang* elements in nature. It is a mysterious potency that affects for good or evil the welfare of families, cities, and districts. It is often localized in strange and awe-inspiring trees and stones. It works according to definite laws which the professor of *yinyang* and *fengshui* can inter-

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[1] Encyclopaedia Sinica, 1917, p. 175.

[2] Encyclopaedia Sinica, 1917, pp. 615-616.

pret by the help of his instrument, the lopan. There is a book or classic which explains the use of this instrument. It is based on the Book of Changes, and the writer has been told that it takes about three years of study to master the science of *fengshui*.

V. INCANTATIONS, CHARMS, AND AMULETS

We are beginning to see that the Chinese of Szechuan Province believe that there is a mysterious potency about them that may do good or evil. This potency is differentiated into the *yang* and the *yin*. The *yang* is good and helpful and the *yin* is evil and harmful. Incantations, charms, and amulets are means by which one endeavors to use this power for his good, especially in keeping away demons, the source of most evils.

1. INCANTATIONS WIDELY USED

Incantations are often used by Buddhist and Taoist priests as parts of their ceremonies, or by the *tuan gong,* a term generally translated by the word sorcerer. The *tuan gong,* like the Buddhist and the Taoist priests, also exorcises demons. In the True Classic of the Bloody Basin we have examples of incantations that are merely transliterations of incantations in the Tibetan language which probably have meaning in the Tibetan, but have none in the Chinese. They are considered very potent, probably the more so because they are mysterious and not understood. Similar incantations are found in the classic of the Gin Gang P'usah, which is Buddhist.

2. NEW YEAR MOTTOES SUPPOSED TO BE POTENT

There are a number of mottoes which are written on colored paper and hung up in the homes on New Year's Day. The Chinese do not consider them to be charms, but regard them more as expressions of their dearest wishes. Yet they have the feeling that expressing the wish will tend to cause the wish to come true. Below are a few examples:

Nien Nien Fah Ts'Ai, "Grow rich year by year."
Sen I Shin Long, "May our business prosper."
Fu Kuei Shuang Chuen, "May wealth and honor be complete."
Chen Tsae Si Tsong, "Right in the very time" of luck and prosperity.

These express the wishes of the family, and there is also the belief that the expressing, reading, and hanging or pasting up of the wishes tends to cause them to be fulfilled.

3. CHARMS TO TRANSFORM UNLUCKY DREAMS TO LUCKY ONES

The people of Szechuan take dreams very seriously. They are much troubled if they have bad dreams, and of course happy to have good ones. There is a charm that is written on red paper and hung on the east wall of a city. By shining on it, the sun transforms a bad dream into a lucky one. The charm is given below:

Translation:

At night I had an unlucky dream.
I paste this on the east wall.
When the sun shines on it,
It will be changed to a lucky omen.

4. CHARMS TO CAUSE BABIES TO SLEEP AT NIGHT

There is evidence that many Chinese parents do not enjoy having their sleep disturbed by crying babies. Charms to cause the child to sleep soundly until daylight are often seen pasted up on the highways. They are written in verse, and show many variations in their wording. They are always written on red paper. It is thought that if the traveler reads the charm it will cause the baby to sleep soundly until daylight. The following is a free translation that gives the sense of these charms:

The sky is bright, the earth is bright.
We have a baby that cries at night.
If the passerby will read this right,
He'll sleep all night till broad daylight.

5. CHARMS WRITTEN ON PAPER

The above examples furnish points of departure in discussing written charms, whose kinds are unnumbered and innumerable. In volumes I to III of Researches Into Chinese Superstitions, Dore has given illustrations of a large variety of written charms. They are written by Buddhist and Taoist priests, and by *tuan gongs.* They are usually given to the user in return for financial contributions which vary according to the size and condition of one's purse.

These paper charms are of all sizes. Some are hung up above the front doors to keep the demons from entering. Others are hung up in the middle of the front room. Some are pasted up on the four sides of the room. Some are pinned on the bed to protect the sleeper. Some are pinned on one's clothing. Some are burnt, the ashes mixed with water, and the water drunk. Nearly all of them are to protect from the various attacks of evil spirits.

The characters of the written charms are often so fantastically written that an ordinary Chinese scholar cannot decipher them. This creates an air of mystery that increases the belief in their potency. Frequently the name of a god is used, indicating that the power of the god is made available in the charm. The paper on which the charm is written is almost always yellow, because Chinese official proclamations are on yellow paper, and the charms are meant to be in the spirit world a kind of official proclamation. This idea and appearance are enhanced by the fact that in Szechuan the written charms are practically always stamped with the official temple seals resembling in color and shape official seals of Chinese magistrates. The official proclamation of the magistrate, stamped with his official seal, is extremely important, and not to be lightly disregarded or disobeyed. The yellow paper and the official seals of the temples are meant to convey the same impression to the demons, thus making the charms more efficacious.

The name of Buddha is often seen on written charms. The word thunder, which is also frequently found, could mean just thunder or the god of thunder, since thunder is thought to be the work of the thunder-god.

6. THE USE OF BLOOD ON CHARMS

If feathers are pasted to a charm by means of chicken blood, it will be more efficacious. Blood is considered very potent. First in efficacy comes human blood, which is seldom used. Second is chicken blood, which is generally used. Third comes duck blood, which is more rarely used because chicken blood is easily obtained.

The writer saw a hunter who had pulled some feathers off one of the birds that he had killed and stuck the feathers to the gun by means of the blood of the bird, believing that this would make the gun shoot more accurately.

7. OTHER CHARMS

Sometimes a boy whose mother is dead will take a lock of her hair and wear it around his neck. The lock of hair is supposed to protect him from evil spirits.

Small images of Buddha are used as trimmings on the hats of boys, and they are believed to protect the boys from harm.

There is a special kind of a brass or copper coin called happiness and long-life money, which is suspended from the backs of boys' hats as charms or amulets. They often have on them the eight figures called the *bah kua,* or images of the 12 creatures that determine lucky or unlucky days. Very often they have on them mottoes in four large characters which express the wishes of the parents for their sons. Among these mottoes are the following:

How Uin Lin Shen, "Good luck fall upon his body," or befall him.
Gin Luh Jia Kuan, "Enter into fortune, advance in official rank."

One of these coins bears the following inscription:

The order of Laotsi. Use this to kill demons, subjugate spooks, behead phantoms, avoid evil influences, and forever guarantee safety.

The newest kind of a charm that the writer has seen in Szechuan Province is the Red Cross emblem. He noticed it first in 1925. Before the Chinese revolution of 1911, the Red Cross and its emblem were practically unknown in this province. Since then the people have seen hospitals and Red Cross Societies marvellously healing the sick, and have assumed that there was mysterious power in the Red Cross emblem. The emblems are used as a protection to boys and are sewed into the garments.

Old bronze mirrors are very efficacious in keeping away demons. The glass mirror, which is comparatively new, is used for the same purpose. It is hung up above the entrances to the homes, or is placed inside the front doors so that a person going into the house will see his own image. The demon who is trying to enter the house sees his own image and becomes frightened at it, for he is a horrible-looking creature, so that he turns and flies away.

The *bah kua,* or eight figures, has come down from the most ancient times, and is considered very efficacious. It can control any calamity, including fire, flood, or pestilence. This is because the demons cause these calamities, and the *bah kua* has power to control demons.

The crow of a rooster frightens away demons, who scamper away when the cocks begin to crow at daylight. In some places geese are raised because their cry is supposed to frighten away demons.

Pieces of amber are worn as charms. The facts that amber when rubbed will pick up pieces of paper, that it sparkles, and that it sometimes has particles of grass or leaves or even insects in it, would naturally tend to set it aside as having unusual power.

Charms of jade are used, especially in the burial of the dead. In the ancient tombs of Szechuan are found jade cicadas that were placed on the tongues of the dead. In northeastern China they are also found in tombs of the same period.

Swords made of old Chinese coins are used as charms in the homes. They have power to keep away evil spirits. Ordinary swords are sometimes used for the same purpose. One old sword of this kind that the writer had in his possession (it is now in the U. S. National Museum) has the seven stars of the great dipper on its blade.

Nearly every Tibetan has a charm-box that he wears suspended on his chest. In these charm-boxes teeth, hair, nailfilings, pieces of clothing, and even the excretions of the lamas are placed. It is thought that anything from a lama possesses wonderful power.

The incantations, charms, and amulets that have been described are illustrations of one of the methods of the natives of Szechuan for procuring happiness, good fortune, and the securities of life. Through them a strange, supernatural power is used to exorcise or keep away demons, who cause diseases and misfortunes.

VI. PUBLIC CEREMONIES AND RELIGIOUS FESTIVALS

I. IMPORTANT PUBLIC CEREMONIES

Through certain ceremonies, the social group seeks to secure the primary needs of life. A few will be described by way of illustration.

As would naturally be expected among a people depending primarily on agriculture, the coming of spring is exceedingly important.

It is a well-known fact that before the Chinese Republic, the Emperor of China, at Peking, took part in a ceremony to bring back or welcome spring, and that as a part of that ceremony he ploughed the first furrows. It is not so well-known that the magistrates observe this custom in other parts of China.

The following is a description by Mr. Grainger of this custom as it is practiced in Chengtu:

> The solar period known as the Beginning of Spring commences about Feb. 5. On the first day preparation is made for the ceremony. Very early next morning a large paper effigy of an ox drawing a plough is exhibited on the Ox-beating Ground somewhere outside the city. The magistrate attends in person accompanied by actors representing the Star of Literature and his monkey Sen. After some mountebank performances with the monkey the Star of Literature exclaims:—
>
> "May the land and the people be peaceful:
> May the wind and the rain be propitious:
> May the fruits of the earth be abundant."
>
> The magistrate thereupon rises, puts his hand to the plough, and waves the ox-goad. This is the signal for a general assault on the ox, which is torn to pieces, and the little ox effigies with which it had been filled are scrambled for by the crowd. Those who are fortunate enough to secure them take them to well-to-do farmers who give presents of money in return for them. These little oxen are supposed to bring luck to the farm for the ensuing year.[1]

[1] Grainger, Adam, Studies in Chinese Life, 1921, p. 49.

In 1925 this ceremony was performed in Suifu on the tweny-first and twenty-second days of the twelfth moon. In the magistrate's yamen a large paper water-buffalo, and also a paper boy called a *ngao mer* had been previously prepared. Over one hundred small water-buffalo made of clay had been placed inside the paper water-buffalo.

On the morning of the twenty-first, the magistrate first worshipped the two paper images in the court of his yamen to the accompaniment of horns that sound a little like Scotch bagpipes. Then the magistrate joined in a procession going out of the North Gate to a special plot of ground where a plow and a live water-buffalo were waiting. In the procession the paper images were carried in front of the magistrate. On reaching the plot of ground, the magistrate again worshipped the two paper images, which had been brought along in the procession, then ploughed three furrows with the plow and the live water-buffalo. The magistrate and other dignitaries drank tea together, after which the procession returned to the yamen through the East Gate. This day's ceremony is called welcoming spring.

The next day the two paper images were again taken in the procession to the plot of ground, which is called the Yin Ch'uen Ba, or the flat where spring is welcomed. The magistrate again did obeisance to the two paper images. There were about 20 officers called the *ch'uen kuan* or spring officials. After the magistrate had worshipped or kowtowed to the two paper images, the 20 spring officials fell upon the paper images with clubs and beat them to pieces. At this point the onlookers rushed up and tried to secure one of the mud images of the water-buffalo. Those who were not successful snatched pieces of the paper images. I was told that these relics were taken by the lucky ones to their homes where they were supposed to protect the inmates from evil spirits. The second day's ceremony is called *da che'uen,* or beat spring. The main object of the two days' ceremony is to induce spring to come so that the crops may grow and prosper.

Rain and fair weather are of great importance. When rain does not fall for a long time, and the hot sun dries up the soil, then the people begin to fear a failure of crops and famine. The price of rice begins to soar, and the people become anxious, if not panic-stricken.

Many go to the temples and pray to the dragon god, for it is his duty to give rain. The south gate of the city is closed. Wet weather comes from the north, and the opposite influences from the south. Usually a fast is proclaimed, which means that animals must not be slain or eaten.

In case rain is not forthcoming, the people try a new strategy. They take the dragon god and the water god out of the temple and leave them in the open to roast in the hot sun. Their own sufferings will cause them to exert their powers and cause rain.

Sometimes there are processions in which a straw image of the dragon is carried. Water is thrown on the straw image, on the participants, and on others who may come within reach.

In the summer of 1923 the writer witnessed a procession of this kind, in which there were more than 20 men and boys. They wore only shoes, trousers, and a wreath or cap made of green willow twigs with the green leaves still on the twigs. Near the center of the procession were a long straw dragon and a water-buffalo on which a boy was riding. Those who were on foot had dippers and were throwing water on each other, on the straw dragon, on the water-buffalo, on the houses, and on anyone who happened to pass by. At the end of the procession they were to pay their respects to one of the gods in a local temple.[1]

There is a ceremony called the *yang miao huei,* which is performed in some districts by Taoist priests at the time of rice-planting. Classics are read or chanted, and there is a procession. The priest pronounces incantations, and papers are hung up on sticks in the rice paddies. When these are finished Ti Kong or Earth Prince and Ti Mu or Earth Mother are worshipped. This ceremony is to encourage the rice to grow.

A picturesque rite is practiced to drive insects away from the fields. After the young vegetables come out of the ground, destructive insects begin to appear. After dark lanterns are carried through the field, and gongs are beaten. This ceremony is supposed to lessen the danger to the crops from insects.

In the spring when the weather grows warm, pestilences are apt to appear. In almost every city or village are held ceremonies to clear the streets of the evil spirits which cause disease.

2. THE GREAT FESTIVALS

Throughout the year there are many calendar festivals, most of which escape the notice of foreigners. Dore has given a calendar for

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[1] The following paragraph is taken from the Herald-Examiner, Chicago, Ill., August 10, 1926.—

> "*Japs Drench Yank as Part of a Prayer. Tokio,* Aug. 18.—The secretary of the American embassy, motoring through Hachioji, near Tokio, on Sunday, was suddenly drenched with water by a crowd before a wayside shrine. Believing an insult was intended, the secretary reported the incident to the foreign office. Investigation reveals that the crowd was performing a ceremony, praying for rain, this ceremony including throwing water on the first passerby."

It seems that such ceremonies to pray for rain are widespread throughout Asia.

the entire year in which every day is either a festival, a birthday of a god, or a lucky or an unlucky day.[1] Grainger enumerates 16 calendar fetes.[2] A writer in the West China Missionary News of November, 1926, describes seven, and states that on all of them there are family reunions and ancestral worship.[3] In the following list of calendar festivals, only those that seem of greatest importance are included. In all of them the ancestral ceremonies have a prominent part.

On New Year's Day all business is discontinued, the best clothing is worn, social calls are made, and in the homes there is feasting and worship of the housegods. The ancestors are commemorated. Some go to the temples and worship the deities there.

The Feast of Lanterns is on the fifteenth of the first moon. At night there are many lights and illuminations. In the homes there are feasts and ceremonies.

Between the tenth and the twentieth of the third lunar month is the Ch'in Min festival, when people visit the graves and remember their dead. Paper money is burnt, food is offered to the dead, the graves are repaired, and the living do obeisance to the spirits of the departed ancestors.

On the fifth day of the fifth moon is Tuan Yang, often called the Dragon Boat Festival. This day commemorates Ch'ioh Uen, an ancient hero who drowned himself because the emperor would not heed his good advice. The festival has practically become a great social holiday when many thousands gather on the banks of the rivers to watch groups of men in dragon-boats chase ducks that have been released in the water by the spectators.

The fifteenth day of the seventh moon might be called the festival of the orphan spirits. Much paper money is burnt to the dead ancestors. The spirits who have no filial descendants have been released from hades. Much spirit money is burnt for their use, after which floating lights are placed on the streams to entice the spirits away.

The Mid-autumn or Chong Ch'iu Festival is on the fifteenth day of the eighth moon. Probably in some parts of China this is the harvest festival, but in Szechuan there are crops all the year, so that at least in some parts of China this seems to be little more than a day to have a good time.

In the eleventh moon there is the feast of the winter solstice, with special offerings to the dead.

[1] Dore, Henry S. D., Chinese Superstitions, 1915-1922, Vol. V, pp. 565-616.

[2] Grainger, Adam, Studies in Chinese Life, 1921, pp. 49-56.

[3] West China Missionary News, November, 1926, pp. 5-12.

On the night of the twenty-third or twenty-fourth day of the eleventh month the Kitchen God ascends to heaven and reports to the Pearly Emperor the conduct of the family during the year. During the appropriate ceremonies for the Kitchen God, there are burnt for him paper money, a chariot for his conveyance, and a letter requesting him to forget the evil deeds of the family and to graciously make a good report to the Pearly Emperor.

In the following words Sven Hedin describes a religious festival in Tibet:

> The jugglery we had witnessed was in every respect brilliant, gorgeous, and splendid, and it is easy to imagine the feelings of humility such a performance must inspire in the mind of the simple pilgrim from the desolate mountains or the peaceful valleys. While the original significance of these dramatic masquerades and their mystic plays is the exorcising and expelling of inimical demons, they are in the hands of the clergy a means of retaining the credulous masses in the net of the church, and this is a condition of the existence both of the church and of the priests. Nothing imposes on ignorance so thoroughly as fearful scenes from the demon world, and therefore devils and monsters play a prominent part in the public masquerades of the monasteries. With their help and by representatives of the King of Death, Yama, and the restless wandering souls vainly seeking new forms of existence in the sequence of transmigrations, the monks terrify the multitude and render them meek and subservient, and show many a poor sinner what obstacles and what trials await him on the rough road to Nirvana through the valley of the shadow of death.[1]

H. B. M. Consul Ogden, who witnessed at Tatsienlu one of the great Tibetan festivals called by foreigners the Devil Dance, said that the dramatization of the religious history of Lamaism, the inculcation of religious instruction and the arousing of feelings of religious devotion and awe in minds that would otherwise find it difficult to receive such instruction, are primary elements in the " Devil Dance." He said that at times the simple Tibetans were so overcome with awe that they would fall upon their faces in worship.

In Szechuan some of the greatest religious festivals are on the birthdays of leading deities, and center about the temples. I have witnessed several, and they are very awe-inspiring. There are processions in which there are often more than 20 deities who are carried in gayly-decorated sedan chairs or on platforms covered by beautiful pavilions. The god in whose honor the festival is held of course has the chief place in the procession. Sometimes soldiers carrying guns are asked to join in the parade; many flags and silk banners are in evidence, and sometimes large lanterns; actors dressed to represent certain deities ride in beautiful sedan chairs, impersonating the deities;

[1] Sven Hedin, Trans-Himalaya, 1909-1913, Vol. 1, p. 315.

high officials ride on horses, and there are musicians playing on native instruments. The streets, homes, and shops are packed with spectators. As the great procession moves slowly along, people in the homes and shops burn incense, candles, and paper money in worship of the deities, and bow reverently to the gods and sometimes even to the actors who impersonate the gods.

Elaborate feasts are held in the temples for those who have helped or contributed. A company of actors may be engaged, who for several days give free theatricals for the hundreds or thousands who flock to see and hear them. The expenses of the feasts and theatricals are borne by the temples, many of which are highly endowed.

There is a prominent social element in these festivals which should not be overlooked. These are great occasions when one can meet his friends and acquaintances, when he is released from the everyday humdrum duties of life, and derives thrill, pleasure, and amusement from the feasts, the procession and the theatricals. In other words, there is the element of play. This is even more evident in the Tibetan festivals which often include horseracing and other contests.

The religious importance of these festivals is also great, They arouse a sense of awe and admiration, so that the simple people feel that there is nothing so grand as their own religion and their own gods. The festival takes advantage of crowd psychology, often teaches religious history or religious ideals through the drama, and ties the affections of the people firmly to the religion and to its gods, its priests, and its temples.

VII. DIVINATION, LUCKY DAYS, VOWS, PRAYER, RELIGIOUS OFFERINGS, AND WORSHIP

I. DIVINATION

Divination is frequently resorted to in Szechuan, and the ways of divining are numerous.

One method is simply to consult a Buddhist or a Taoist priest. In 1925 there was civil war in the province between the numerous war-lords. Before entering the war one of the generals consulted a Taoist priest, while another obtained the opinion of an old Buddhist priest who is considered an authority in occult matters.

A way of divination commonly used in the temples is the *yinyang kua*. A bamboo root is split into two halves in such a way that each half has a flat side and a round side. These two pieces are the *yinyang kua*. In divining, both pieces are thrown on the floor. If two round sides turn up, it is unlucky. If both flat pieces turn up, it is lucky or favorable. If one round and one flat side turn up, it is neutral, and may be considered tolerably good.

In many of the temples are also what look like chopsticks in a round tube. In all there are one hundred of these sticks. After bowing to the god, the person interested shakes the tube containing the sticks until one of the sticks falls out. These sticks are numbered from one to one hundred. Nearby in a convenient place are also one hundred sheets of paper with numbers from one to one hundred. After the stick has fallen out of the tube, the paper with the corresponding number is found. The inscription on this paper tells the fortune of the enquirer.

Sometimes a Taoist priest goes into a trance and while apparently unconscious utters incoherent words. They are supposed to be communications from the spirit world. Others interpret his words.

2. LUCKY AND UNLUCKY DAYS

Lucky and unlucky days are of primary importance, and can easily be determined. It would be disastrous to have weddings or funerals, to make sales or purchases, or to begin an important journey or other undertaking on an unlucky day.

There are two ways of explaining lucky or unlucky days. One is described by Mr. Grainger:

> There are minor deities that rule the sixty years of the cycle, the months of the year, the days of the year, and the twelve Chinese hours of the day. Certain gods are credited with being better rulers than others, and when one of these gods is in office the occasion is auspicious for commencing any undertaking, such as starting on a journey, beginning to build a house, burying the dead, opening a new shop, or going to school. These lucky days are all fixed by the compilers of the National Almanac, a copy of which is to be found in almost every house. The days are classed according to the cycle and the five elements, and what works may be done, and what may not be done are fully indicated.
>
> Fortune-tellers are often asked to select specially fortunate days for weddings, and geomancers choose good days for funerals, and for commencing building operations.[1]

The explanation that has been given the present writer by both the Chinese and the Chuan Miao aborigines is that there are 12 creatures, the rat, the water-buffalo, the tiger, the hare, the dragon, the snake, the sheep, the monkey, the chicken, the dog, the horse and the pig that in turn dominate the days. Certain creatures are lucky and others are unlucky. The days dominated by the unlucky animals are unpropitious,

[1] Grainger, Adam, Studies in Chinese Life, 1921, p. 76.

and vice versa. Lucky and unlucky days are clearly indicated in the Chinese almanac, which is sometimes used as a charm, and which is possessed by nearly every family.

3. OATHS

Oaths are generally made to and in the names of deities, and there are few of the unsophisticated who will break such an oath. The following is an example. The writer was crossing a pass west of Yachow. He had stopped to rest in an inn, for the day was hot and the road was steep. The carriers had drunk some tea and eaten some food purchased in the inn. When they were settling their accounts, the wife of the innkeeper, who had been waiting on them, asserted that one of the coolies had paid for less than he had eaten. The coolie declared that this was untrue. A lively dispute ensued. The head coolie finally took up the matter. To the wife of the innkeeper he said, "Are you telling the truth?" She declared that she was. "Then," he asked, "Will you swear by a certain god, and agree that if it is not true the god may burn down this house?" "No," she said, "I will not swear that oath." The coolie did not pay the extra money demanded, and all were convinced that the woman had been telling a lie.

4. VOWS

Vows are almost inseparable from prayers, expressed or implied, so they will be briefly treated under the discussion of prayer.

5. PRAYERS

The simplest kind of prayer possible is illustrated by that of the magistrate of Chengtu in the ceremony to cause the coming of spring, which has been given on another page. A simple wish is expressed, and no deity is addressed or mentioned. The prayers of many worshippers go just a step beyond this. They burn incense, respectfully bow or kowtow, name or call upon the deity, and express the wish.

The writer was in a rowboat, being ferried across the Min River. A woman was holding a little girl in her lap. As they were passing a Goddess of Mercy who was in a shrine on a cliff overhanging the river, the woman looked up reverently and said, "Kuanyin P'usah, *bao fu wa wa*," or "Goddess of Mercy, protect this child."

Most vows are practically bargains with the deities. They are promises to do certain things *if* the god will grant the worshipper's desires, expressed or implied. A sick person may beseech a god to heal him, and promise if healed to make a pilgrimage to a certain mountain and burn so many sticks of incense and so much paper money. If healed, the supplicant fulfills his vows.

In the country districts south of Suifu one often sees in the wayside shrines straw images of human hands or human feet that have been placed before the idols in fulfillment of vows. A person having a sore hand will beseech the god to heal the hand, promising that if he will the supplicant will present a hand to the god. The same course may be taken in case of sore feet.

The following is the writer's own translation of a prayer to the Kitchen God, which is sealed in an envelope like a letter and burnt on the twenty-third day of the twelfth moon, when the Kitchen God ascends to heaven. Similar letters are often sent to the deities by burning, for they consider that burning them is equivalent to delivering them to the gods:

> I, So-and-So, representing the whole family, reverently and sincerely come and beseech you to hear us. You have great merit in saving the world and nourishing all people. You protect us with virtue and mercy. You control and judge the good and evil deeds of our family. In our cooking, and in our eating and drinking we depend on your mercy. Through all the year you care for us. But we are uncleanly in our habits, and think unclean thoughts, and trouble you. We write you this letter, hoping that you will forgive our sins, and not report them to the Pearly Emperor, thus causing the whole family to be grateful to you.
>
> Date.

We have seen that the prayer often includes the vow, and is a sort of a bargain. The prayers of the people of Szechuan are very practical. They generally express desires for things considered of use in their everyday lives—food, protection, healing, or prosperity—in other words, they are expressions of the universal desire for a happy or satisfying life.

6. RELIGIOUS OFFERINGS

Food and other necessities are offered to the deceased ancestors, who are supposed to need nourishment and money after death precisely as they did while living. The other world is a counterpart of this world, but more shadowy.

The deities also need food and money. Sometimes a whole pig is taken to the temple and offered to the gods. The money is generally paper cash, paper ingots of gold or silver, or paper dollars. These are burnt, and thus made available in the spirit land.

Very little of value is burnt or destroyed. After being offered to the gods, the food is consumed by the priests or by the givers themselves.

We do not find the idea of vicarious sacrifice for others. In what are generally called sacrifices by western writers there is the idea of providing food, money, and other necessities for the ancestors and the gods. The writer has seen idols who are supposed to be addicted to the opium habit, and to whom the worshippers are accustomed to offer opium by smearing it on their lips. Again, there is the idea that gifts will establish friendly relations with the ancestors or the gods and dispose them to deal kindly with the giver and help him in case of need. An element that should not be overlooked is the very natural tendency to sacrifice something valuable or useful to a friend or to a superior. This custom or habit is carried over into religion from the social life and customs of the Chinese.

It is the usual practice, when making social calls, to take gifts to the friends on whom one is calling—cookies, candies, eggs, nuts, a chicken, a duck, or the like. A poor Bible woman in Suifu said that she could not make calls on the church members and enquirers because it would be necessary for her to make presents to those on whom she called, which she could not afford to do. Twice I have returned from Suifu to America on furlough. Both times a large number of Chinese friends gave farewell presents. They varied from beautiful pictures, embroideries, old bronzes and vases to native candies, eggs, and pieces of sugarcane. Even when calling on magistrates on official business it is advisable and often necessary to take a gift. Presents are given at engagements, weddings, and funerals. It is natural for people with such social customs to make gifts to the ancestors and the gods. In Szechuan the killing of the victim is a non-essential part of the ceremony of worship, and the " sacrifices " are gifts rather than sacrifices. They are made to satisfy what are considered real needs of the ancestors and the gods, to establish a friendly relationship or communion, and sometimes merely in accordance with a natural tendency to contribute something valuable to an esteemed friend or to a superior.

7. WORSHIP

The religious acts and ceremonies that we call worship are practiced in the homes, at the graves, at the wayside shrines, and in the Confucian, Buddhist, Taoist and ancestral temples.

Sometimes there are group ceremonies at the wayside shrines, but they are essentially the same as the rites in the homes and in the temples. Often an individual will go to a shrine, light a few sticks of incense, burn some paper money as an offering, make obeisance, utter a prayer or request, and depart.

The burning of incense is to some extent a complimentary act, but incense is pleasing to the smell, and is calculated to put the ancestor or the god in a good humor. As a part of the writer's early language study he had to read with the Chinese teacher the account in the Chinese Bible of Noah's flood. After coming out of the ark, Noah offered burnt-offerings to Jehovah, "And Jehovah smelled the sweet savor"; which apparently caused Jehovah to be in a good humor and therefore more propitious, so that Jehovah determined not to curse the ground any more for man's sake, nor again ever to smite all the living.[1] As the writer read that passage, it came to him that this is exactly the conception that the Chinese worshipper has of what occurs when he burns incense before his ancestors or his gods.

The first and fifteenth of each month are special times for ceremonies of respect and commemoration to one's ancestors in the homes, where at dusk every day the people worship the housegods. A bell is struck to awaken the gods and to notify them of the presence of the worshipper. A few sticks of incense are burnt. Very often not a single word is uttered. The worshipper simply bows his respects and departs.

In the temples there is "worship" by individuals or by groups. Every day at daylight and at dusk a priest goes to each god, lights a stick or two of incense, strikes a bell or gong, bows to the deity, and goes on. A worshipper who is not a priest may enter a temple and worship all the idols as described above without uttering a word. His worship is merely establishing friendly relationships and expressing reverence—but of course he expects this to be beneficial to him. If there is something special on the heart of the worshipper, then he is apt to utter a prayer and perhaps burn paper money.

More elaborate worship is performed by a number of priests for the individual or for the community. Portions of scriptures are generally chanted, and musical instruments—bells, gongs, and sometimes drums and horns, are used. At times these ceremonies are beautiful. At other times they sound monotonous and discordant to the foreign ear. One of the most beautiful and impressive ceremonies that the writer has heard was that of an evening worship in the lower Wan Nien Si Temple, or the Monastery of Ten Thousand Years, on Mt. Omei. It was performed by the temple priests before the god P'ushien who rides on the bronze elephant.

In the temples there is much reading or chanting of scriptures. This is considered an act of great merit, helping the individual to secure

[1] Genesis, chapter VIII, verses 20-22.

the approval and favor of the gods and prosperity. It is not at all necessary that the priest or the person for whom the scriptures are read understand. In Tibet the "prayer wheel" and the "prayer flag" have been invented so as to accommodate the masses who cannot read and write, and to enable a person to acquire a maximum amount of merit with a minimum amount of effort.[1] While reading, the Chinese priest beats a wooden fish with a wooden mallet, one stroke for every word. There is a legend that the Buddhist scriptures were once lost in a sea or in a river, and were swallowed by a great fish. The fish was caught, and by beating compelled to give the scriptures back. The wooden fish is therefore beaten, even by Taoist priests, when scriptures are ceremonially read.

While affection, awe, and reverence are strong motives in worship, fear also has a prominent place. Many of the gods are so made as to inspire fear.[2] Near Ch'anglinshien is a wayside shrine in which is a terrible-looking god. In his hand is a club, which is raised as if to strike. On the shrine these words are inscribed:

> What audacity you have, that you dare
> come and look at me.
> Quickly repent. Do not go and harm people.

Children are taught to fear the idols. Mothers tell them that if they do not worship the gods they will get the stomach ache.

One day in the city of Ngan Lin Ch'iao the writer visited one of the largest temples in company with a high school student. Both the student and his parents were Christians, and the student's father was one of the leading merchants of the city. That day the temple was nearly deserted. A carpenter was working in a distant room, and occasionally he would hit a board with a loud bang. As they walked among the deities, some of which were fearful in appearance, the student was evidently frightened. He started at every loud noise, and would not let his foreign friend strike any of the gongs or bells in front of the idols. He expected the writer to be frightened, and asked, "Are you afraid?" Many of the Chinese fear the gods, and because they fear they worship. Some of the gods are purposely made terrible in appearance so as to inspire fear. This story is also of interest

[1] The writer was told by Tibetans at Tatsienlu and by aborigines at Songpan that the so-called prayer wheels and prayer flags are not really for prayer, but primarily and almost entirely for reading scriptures, and to secure the help of gods and prosperity.

[2] The fact that terrible gods are very efficacious against demons is doubtless an important reason for their development, especially in Tibet.

because the student, who worshipped only the Christian God, considered the idols in the temples to be real gods, and was afraid of them.

In Szechuan the motives for the worship of the gods are fear, awe, reverence, affection, and the desire to secure the help of the divinities in living a happy and successful life.[1]

VIII. TEMPLES AND SACRED PLACES

1. THE RELATION OF THE TEMPLE TO THE COMMUNITY

Temples are considered more or less the property of the community. Practically everybody contributes towards their support—in fact, they must contribute. At stated or at special times the priests go from house to house, leaving at each home some evidence that the inmates have contributed. Sometimes the different temples divide a city into districts, each temple collecting in its own district. At other times one temple will collect over the whole city. In one town, if a family refuses to contribute, the priests will place an image or some other evidence before the door of the house. This is considered a great disgrace. People begin to crowd around, and finally in self-defense the family is compelled by general disapproval to make the contribution.

2. CONFUCIAN TEMPLES

Most Confucian temples have in them only the tablets of Confucius, his disciples, Mencius, and other noted Confucian scholars. Occa-

[1] The following event took place at Ch'anglinshien. There had been no rain for so long that the crops were in danger. The people and the priests had been praying for rain. The magistrate went for a visit to the P'utaogin Temple outside the city, where there are several dragon gods. He remarked that if the gods would send a heavy rain that night he would thoroughly repair the temple, a thing which was much needed. It was not stated whether or not the magistrate prayed to the gods, but it was assumed that the gods knew what he had said. Possibly the priests prayed especially to the dragon gods to send rain so that the temple might be repaired. At any rate, there was a great rain that night, and the crops were saved, and the magistrate repaired the temple.

Additional note on vows.—At K'ai Shan Ch'u Dien, on Mt. Omei, which means the first monastery opened on the mountain, I saw a farmer and his wife worshipping. They were pilgrims who were visiting the temples on the mountain. Before a famous bronze image of Mi Leh Fuh, the Buddhist Messiah, they divined by means of the *yinyang kua*. Twice they consulted, but both times the result was unlucky. The pilgrims were frightened. Then the priest said, "Quickly make a vow." I could not hear what was said, but the lips of the woman moved as she made her vow. Then the divination was repeated, and the results were "lucky" or good. They felt that because of her vow, which we may regard as a bargain with the deity, the god changed her luck from bad to good.

sionally one will see an image of Confucius, resembling the ordinary images or idols found in the Buddhist and Taoist temples. The greatest ceremony in the Confucian temples comes on the birthday of Confucius.

3. CONTENTS OF THE BUDDHIST AND TAOIST TEMPLES

The Buddhist and Taoist temples are really homes for the gods and for the priests. They also contain rooms for the entertainment

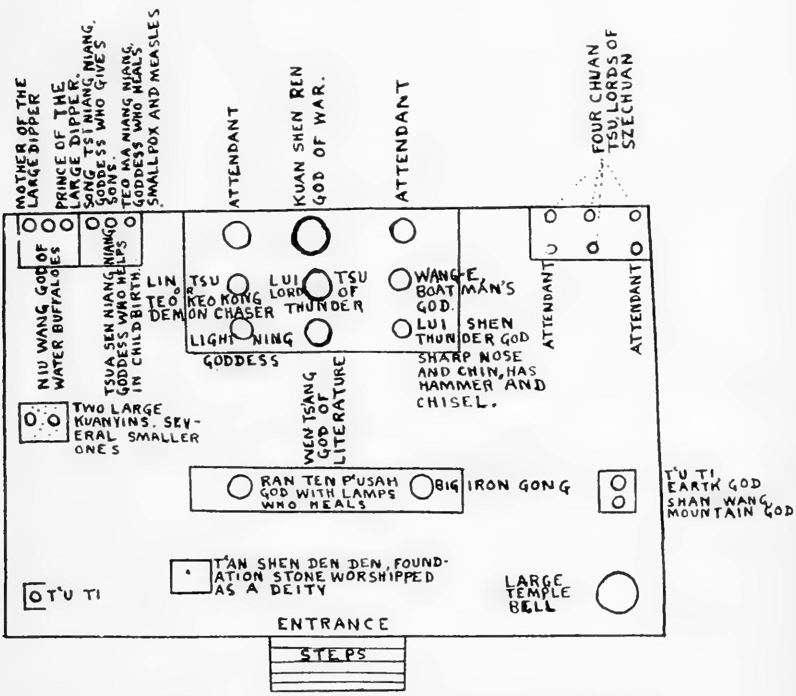

FIG. 6.—Diagram of a Buddhist temple called Ta Tsang Fu, three miles west of Suifu, Szechuan, China.

of guests, who are generally given a cup of tea, a large kitchen where feasts can be prepared, a goodly number of square dining tables, dishes, seats, and benches, besides large and small drums and bells, ceremonial robes, and scriptures and instruments of worship used by the priests.

4. SOURCES OF TEMPLE INCOMES

In addition to the collections that we have described many temples have incomes from endowments. Some are quite prosperous because of the possession of farms or houses. Practically all temples occasionally ask for contributions. Adherents give according to their ability when the priests conduct funerals, exorcise demons, or help by reading the scriptures.

5. TEMPLES AS SACRED PLACES

Temples are sacred places. Often the trees in the temple enclosures are also sacred, and must not be cut down. Occasionally sacred groves or trees are to be found near and on the grounds owned by the temples. Sometimes the temples are built in ordinary places in a city or village, or by the roadside, and the places are apparently holy for no other reason than the presence of the temples. Yet there is a very noticeable tendency to build temples, when possible, in places where the natural beauty or the strange scenery arouse the feelings of wonder and awe. Such places are apt to be sacred spots or holy mountains, though not always. Very often where there are imposing hills inside of the city walls temples will be found on their summits.

At Suifu the Taoist temple called Pan Pien Si is situated on the side of a very steep hill overlooking the Min River. The situation is so beautiful that practically every artist who comes to Suifu paints the temple and its surroundings. Across the Min River from Suifu is a large, cracked rock through which Chu Ko Liang is supposed to have marched his soldiers in order to deceive the aborigines who then were in possession of Suifu. This is also the scene of a temple.

Up the Min River from Suifu is Tao Si Kuan, a Taoist temple. It is situated on a tremendous rock that reaches half-way across the river so that it changes the direction of the stream. In this rock there is a deep natural cave that is exposed in low water, but covered in high water. The river rushes fiercely past the rock, especially in high water, and part of the year there is a strong eddy on the opposite side of the stream flowing in the opposite direction from the main current. Boats are sometimes wrecked here. The place is such a one as will naturally arouse fear, wonder, and awe.

At Shuin Gien Si or Shiong Gien Si there is a Buddhist temple in a cave half-way up a perpendicular cliff. The rock is limestone, and the cave is a natural one inside which there is dripping water which is believed to have power to heal diseases. This cave can be reached only by means of steps hewn out of the solid rock. A tree which stands very near the steps is a *fengshui* tree. The temple has several stories, the first story being on a level with the flat ground under the cliff, and the last story being in the cave itself. The stone of the cliff is

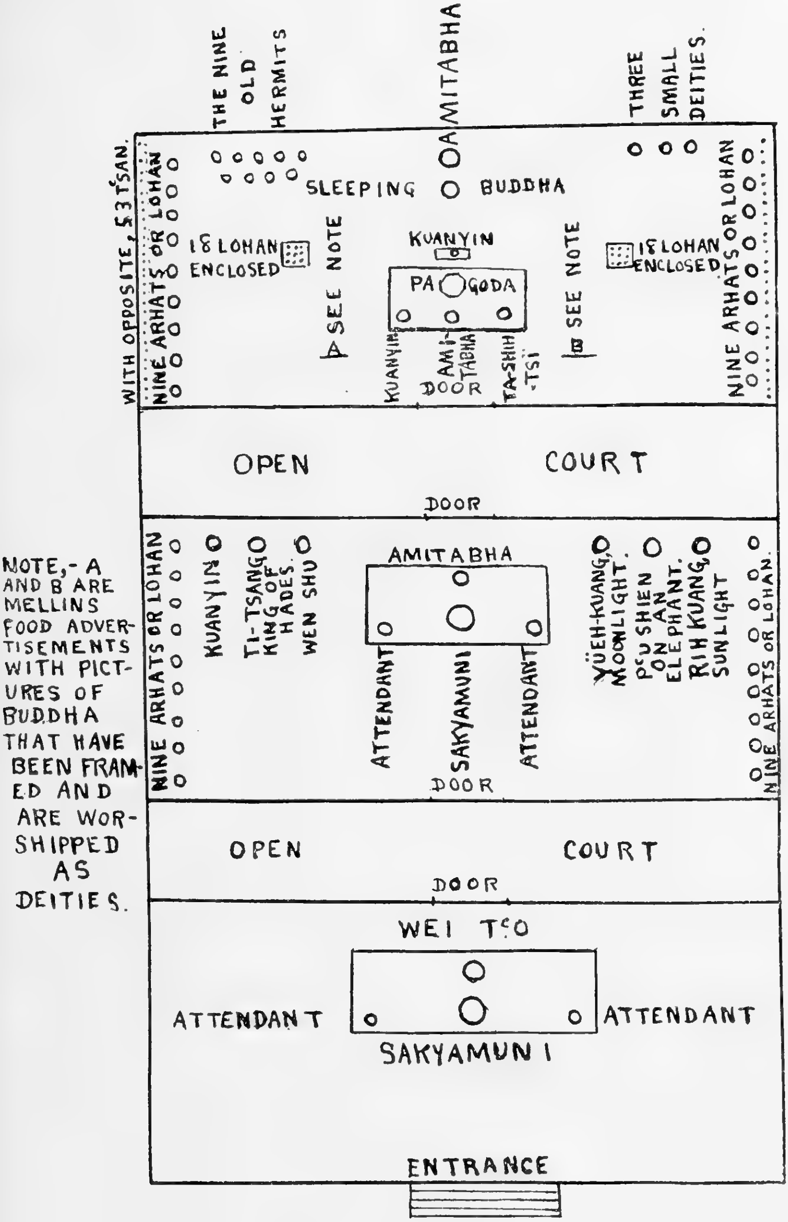

Fig. 7.—Diagram of the famous Gieu Lao Dong, or temple of the nine old hermits, Buddhist, on Mt. Omei, Szechuan, China.

slightly yellow, so that it is thought to resemble gold dust. The temple is therefore named Gin Sha Dong, or the cave of golden sands. On the top of the cliff trees of a forest can be seen, but the sides are so steep that they are bare of vegetation. Here again a place of marvellous beauty that naturally arouses feelings of wonder and awe has been chosen as the location for a temple, a holy place set aside for the worship of the gods.

At Ch'anglinshien there is a temple in which is a mineral spring. Because of the mineral in the water, groups of air-bubbles come up from the bottom which to the Chinese seem to resemble bunches of grapes. They call the temple P'utaogin, or grape well. The hill back of this temple is verdant with beautiful bushes and trees. In the temple grounds are a pond and several large trees. Across the plain from the temple high mountains rise to the sky. Here again a scene of marvellous natural beauty that arouses feelings of admiration, wonder, and awe has been chosen as the place for a temple.

Another illustration is Huang Long Si or the Yellow Dragon Gorge, which is reached from Songpan by crossing a mountain pass over 14,000 feet high. Beginning at the base of a snow mountain called Shueh Bao Din Shan, the stream flows down a canyon for about ten miles, when it joins another stream that flows at right angles to it. The water in this stream is so full of mineral that the mineral substance is deposited all the way down the canyon, forming a bright yellow stone. In many places the water trickles down into a series of terraced pools resembling rice paddies on a hillside, with the outer banks rounded into irregular shapes. Similar pools are found in the Yellowstone Park, but there are many more of them in the Yellow Dragon Gorge. The crystal-clear blue water and the bright yellow stone give these pools a beautiful appearance, which is enchanced by the surrounding forests that cover all the hillsides, and by a wonderful variety of flowers. At the head of the gorge are lofty mountain peaks that are perpetually covered with snow, and great ribs of white snow reach far down the mountainsides.

This district would be very interesting to the geologist. In one place the stream has deposited so much of the mineral that a waterfall has been formed. Along the stream the mineral substance is deposited mostly near the edge where the water flows less swiftly, so that the stream constantly builds up banks for itself. There are places where the stream bed is from five to thirty feet higher than the surrounding land. The lowest spots are old, abandoned beds of the stream. Leaves, sticks, and trees that fall into the water are encased in the mineral and buried deeper and deeper.

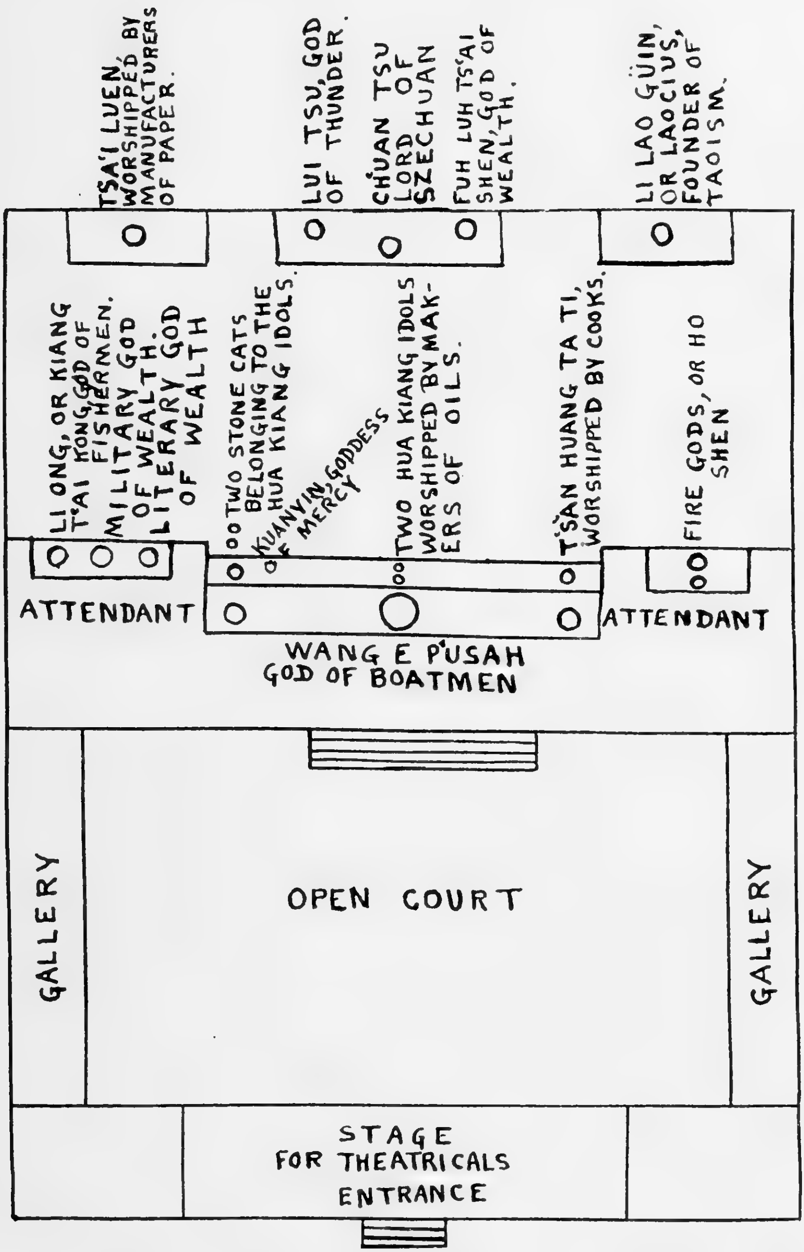

FIG. 8.—Diagram of the Wang E Miao, or temple of Wang E, the boatmen's god, at Li Chuang, Szechuan, China. This is a Taoist temple.

Several temples are situated in the Yellow Dragon Gorge, the most important being the three temples at the head of the canyon called respectively the Lower, the Middle, and the Upper Yellow Dragon Temples. In the upper temple is the Yellow Dragon God himself, called Huang Long Tsen Ren, or Yellow Dragon True Man. He is not a real dragon, but an old man with a long white beard, and with bright yellow clothing resembling in color the yellow rock of the stream bed. He is the chief god or ruler of the district. Outside the temple and in front of it is a large stone altar where the aborigines worship, using cedar twigs as incense. The Chinese do not use this altar, but worship inside the temples.

The official who was overseeing the temples when I visited them in 1924 said that the first temple was built in the time of Tao Kuang, who ruled China from 1821 to 1850. I was unable to get any information about the origin of the worship of the Yellow Dragon God at this place. The existence of the stone altar used only by the aborigines suggests the question, did the aborigines first worship the Yellow Dragon God here on an altar under a clear sky, and the Chinese come later, build temples, and unite with the aborigines in the worship of the Yellow Dragon God?

Now Chinese and aborigines alike worship at these temples. Streams of pilgrims are constantly coming and going and there is a great annual festival attended by thousands, and which lasts for three days. The Yellow Dragon Gorge, with its temples, its sacred places, and its deities, now holds as large a place in the religious life of the Songpan district as Mt. Omei does in central Szechuan. It is a place of many natural wonders that has become a holy of holies.

6. SACRED MOUNTAINS

From very early times the emperor of China has visited the four great sacred mountains in the four districts, and on their summits performed the official worship of heaven. Mountains have been the natural elevations on which the cult of heaven was performed.

Mt. Omei is a sacred mountain in Szechuan that is famous among both Chinese and foreigners. There are three smaller sacred mountains, and possibly others. One is south of Suifu near the Yunnan border. It is called Gien Feng Shan, or Sharp Wind Mountain. This has long been a sacred place. It stands out higher than the surrounding mountains, and is pointed. Because it is higher than the neighboring peaks, it is apt to be windy. Hence its name, sharp or pointed windy mountain. Formerly the Taoists were in possession, and had

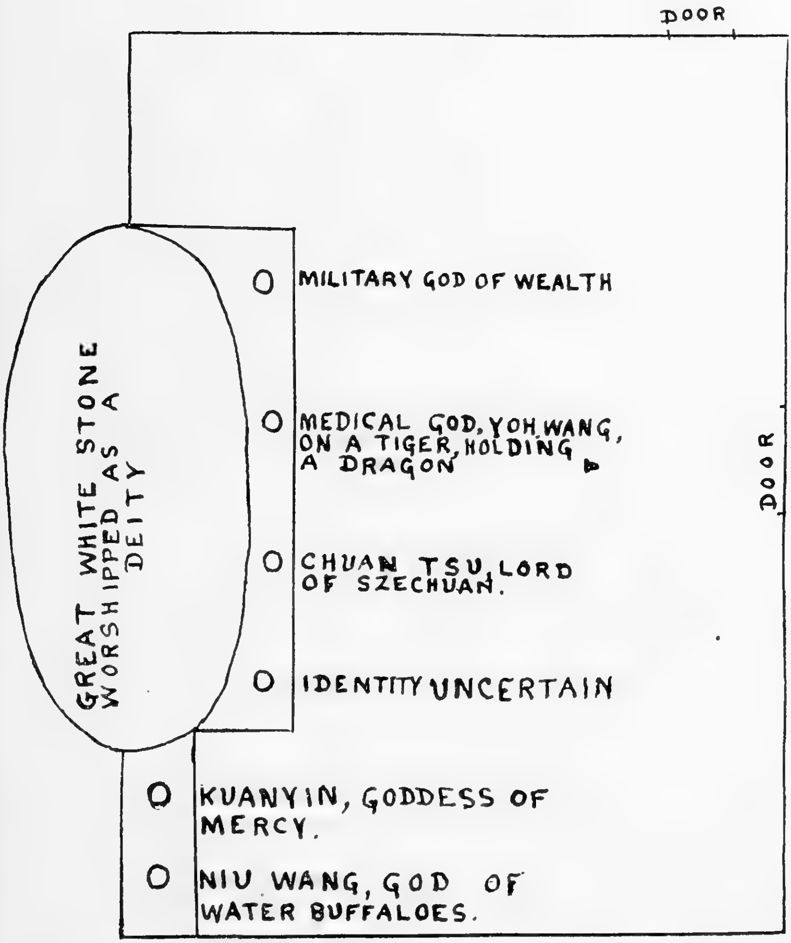

FIG. 9.—Small temple in the country near Suifu, Szechuan, China. First the white stone was worshipped as a god. Later the temple was built and other gods added.

two temples. Now the Buddhists are in control. Pilgrims from the surrounding townships go to this mountain to worship.

East of Suifu near Ngan Lin Ch'iao is Fuh Lai Shan, a Buddhist sacred mountain. Its name means the mountain to which Buddha came. A legend relates that one of the Buddhas in a temple on this mountain flew there. Large numbers of pilgrims go to Fuh Lai Shan from nearby districts. The mountain stands out conspicuously above the surrounding hills, and its top is covered with trees.

Washan, possibly the highest mountain in central Szechuan, is also a sacred mountain with many natural wonders. On every side is a sheer precipice, with only one path over an unbelievably narrow ridge by which one can ascend to the summit. Near the top one can only proceed by climbing perpendicular cliffs by means of ladders. This beautiful and majestic mountain stands out above its neighbors, and has long been a sacred mountain. In former years three temples were located on the top, but now there is only one, which is visited by pilgrims from nearby towns and farms. Mt. Omei has overshadowed Washam as a sacred mountain.

Virgil C. Hart, in "Western China," says that Mt. Omei is a center of natural wonders the like of which may not be found elsewhere on the globe. On the Chinese map of Mt. Omei prepared for pilgrims there are three short poems or verses expressing the profound feelings and emotions that stir the hearts of the worshippers because of the wonderful natural beauties of the mountain and its religious associations. Free translations are given below:

The land of the eastern dawn is near heaven.
At the parting of the clouds P'ushien is visible.
The picture revealed cannot be fully comprehended,
But many glorious peaks can be seen.

To here the Kuen Luen Range extends its veins.
A great marvel is this.
Heaven borrows the stars to display it,
And in all the seven layers (of the mountain) the caves open (to display wonders).

P'ushien came out of the west.
The King of Han named this spread-light precipice.
Uen Gioh of the T'ang Dynasty was here exalted (to divine rank).
In the Manchu Dynasty there appeared here a living P'ushien.
May his majesty reveal himself on this mountain-top.
Ten thousand bright lights fly over the abyss to welcome him.

One of the earliest Europeans to travel in west China was E. Colborne Baber, whose article, Travels and Researches in the Interior of

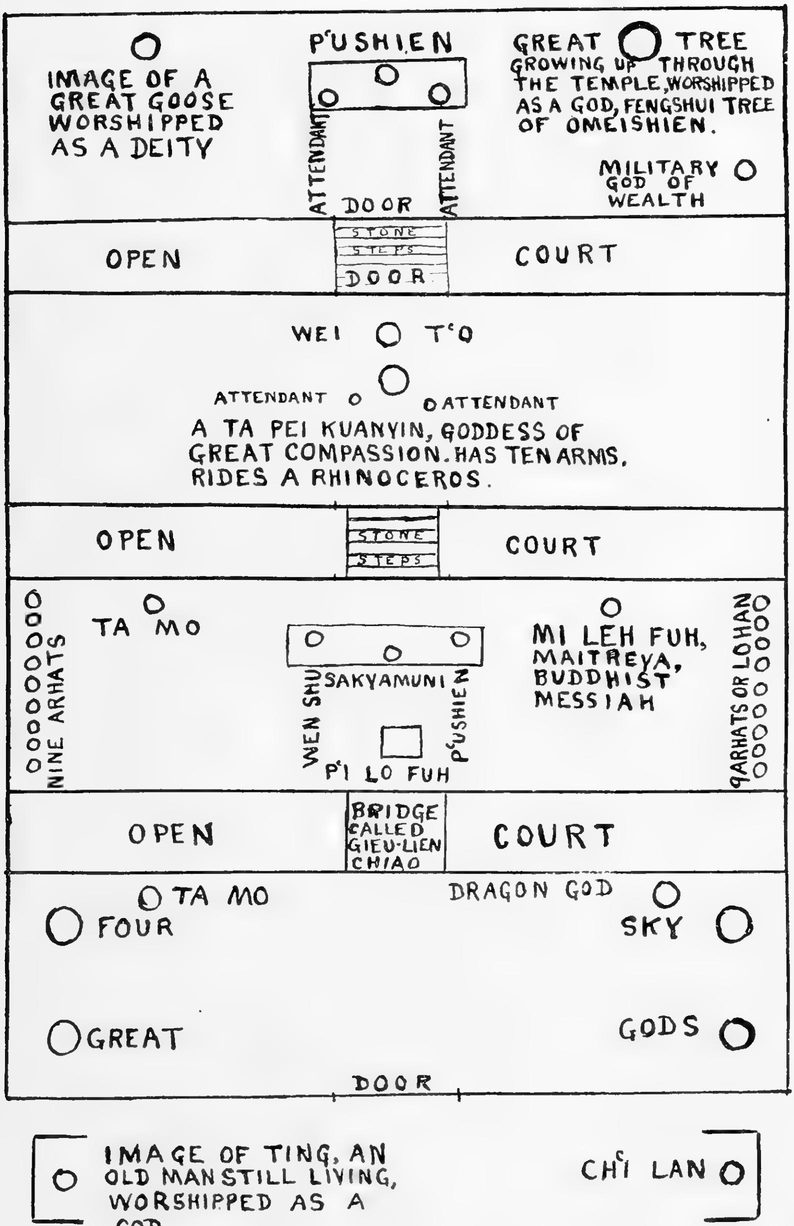

Fig. 10.—Diagram of the Ta O Si, or temple of the great goose, a Buddhist temple on Mt. Omei.

China, was published in the supplementary papers of the Royal Geographical Society in 1886. He vividly described his impressions of Mt. Omei:

> The plain begins to break up into hills a few miles below Mei-chou. Some hours before reaching that point my attention had been attracted to a dim but sharp-edged object rising high above the southwestern horizon, which I took to be a cloud; but at last noticing that its profile did not change, I pointed it out to a boatman, who replied with a certain contempt. "Don't you know Mt. Omei when you see it?" From the point where I first caught sight of it, its distance was more than fifty miles. There must be something in the conditions of its position which greatly exaggerates its size, for when it is seen across the level country from the edge of which it rises, the mind at once refuses to believe that any mountain can be so high. How it looks from a nearer point of view I cannot affirm, for I have ascended it, travelled all round it, and three times passed close under it, without ever seeing it again, as it was always clothed in mist. Perhaps the mirage of the wide plain lends it an illusive majesty which is enhanced by its remarkable outline. Its undulating ridge gradually rises to the summit at the southern end, where, from its highest knoll, it is suddenly cut sheer down to the level earth—or nearly so, for the lower fourth part was hidden by clouds—forming a precipice, or, it may be, a series of precipices, which it is disagreeable to think of.[1]

Mt. Omei is visible on clear days from distant parts of the province. Clear mountain streams, waterfalls, rugged limestone cliffs, forests of evergreen trees, natural caves, and a precipice six thousand feet high and almost pependicular make this mountain one of the most beautiful in the world. Little wonder that it is sacred and is the religious center of millions of people, a mecca to which pilgrims go from all over China and from Tibet.

These illustrations are sufficient to show that in Szechuan there is a tendency to erect temples and shrines in places whose natural beauty or strangeness arouse feelings of awe and wonder; that such places often become sacred, the seat of superhuman power; and that magnificent mountains which stand out prominently in the landscape and possess exceptional beauty or marvellous scenery are apt to become sacred.

IX. THE GODS IN SZECHUAN PROVINCE

The study of the gods in China is not a simple task. While some are primarily Buddhist and others Taoist, many of them are found in both Buddhist and Taoist Temples. Distinct, clearcut classifications are nearly impossible. One god may have several functions. Amitabha is a god of compassion who also protects from demons and gives

[1] Baber, E. Colborne, Travels and Researches in the Interior of China, Royal Geographical Society, Vol. 1, 1886, page 30.

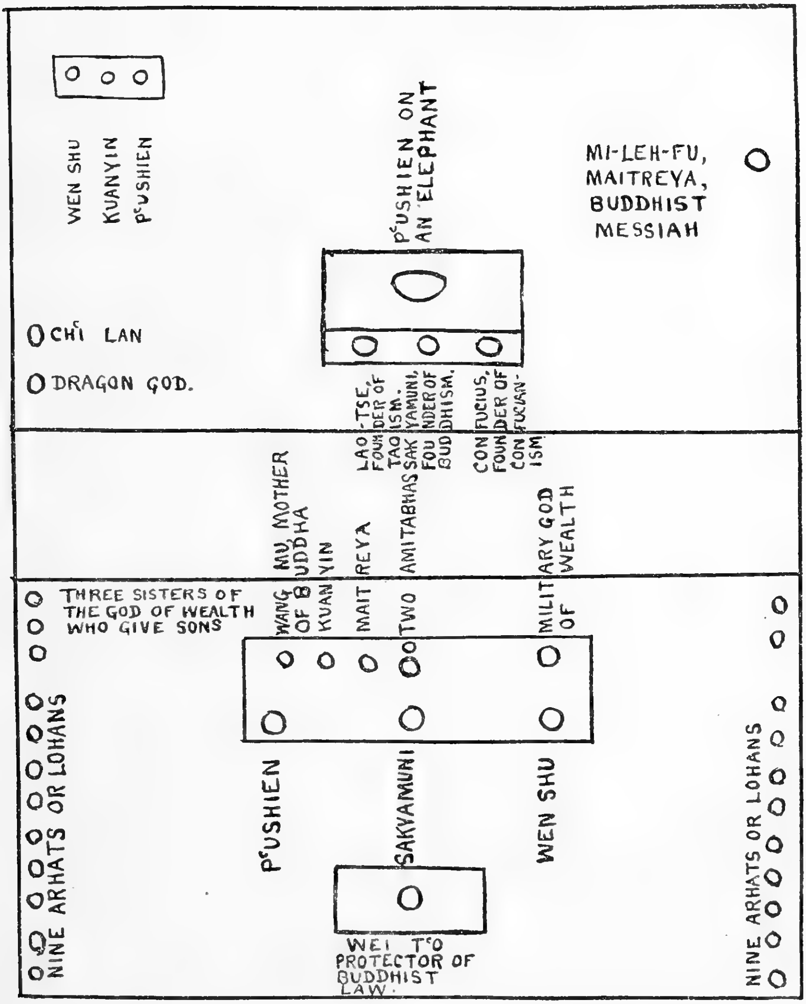

FIG. 11.—Diagram of the O Üin Ngan temple, Buddhist, on the summit of Mt. Omei.

happiness. Kuanyin is in Tibet a male god, and in China generally a female known as the Goddess of Mercy. She can undergo almost any transformation that will enable her to help men. Often she is represented with a vial of magic water in her hands. The number of her arms varies from two to one thousand. Sometimes she holds a baby in her lap, and is called the Song Tsi Kuanyin, or the Goddess of Mercy who gives sons. She may even transform herself into an odd-looking demon-god who rescues the suffering souls in hades.

I. DIFFERENT REPRESENTATIONS OF THE GODS

A god may exist without any visible representation. Occasionally the images have disappeared from the shrines, but often the worship goes on just the same. T'ien Lao Yeh, or the Old One in Heaven, is a well-known god, but there seem to be no images of him.

To the Chinese worshipper it seems desirable, if not necessary, to visualize in some way the god who is worshipped. Sometimes this is accomplished by merely inscribing the name of the deity on paper, wood, or stone. The commonest housegod consists of a red scroll of paper hung on the wall in the most prominent place, on which are written in large characters *T'ien, Di, Guin, Ch'in, Si, Wei,* or the throne of Heaven, Earth, Rulers, Relatives, and Scholars. This really includes the enlarged family of superiors or elders to whom one owes filial piety or gratitude. From heaven or the sky come rain and sunshine, two things that are indispensable to life and happiness. Earth yields coal and other minerals, vegetables, fruits, grasses, and trees. *Guin* really signifies the emperor and his rulers so that it indicates the imperial government. There has therefore been a tendency in some localities to substitute the word *kueh,* or country, which is more in harmony with the new patriotism. In general, however, the use of the word *guin,* has been continued, giving it the meaning of rulers, those who are the parents and protectors of the people. The word *ch'in* means relatives or elders, and particularly one's ancestors. *Si* signifies scholars or teachers, most highly respected because of their learning and because they are the educators of the young. This is one of the most difficult gods for a Chinese to give up on becoming a Christian. It is worshipped as a god, incense is burnt to it, and people pray and make obeisance to it. Sometimes the name of a god is written on a board and set up to be worshipped.

A further stage beyond this is the drawing, painting, or printing of the image of the god. In wayside shrines round stones will some-

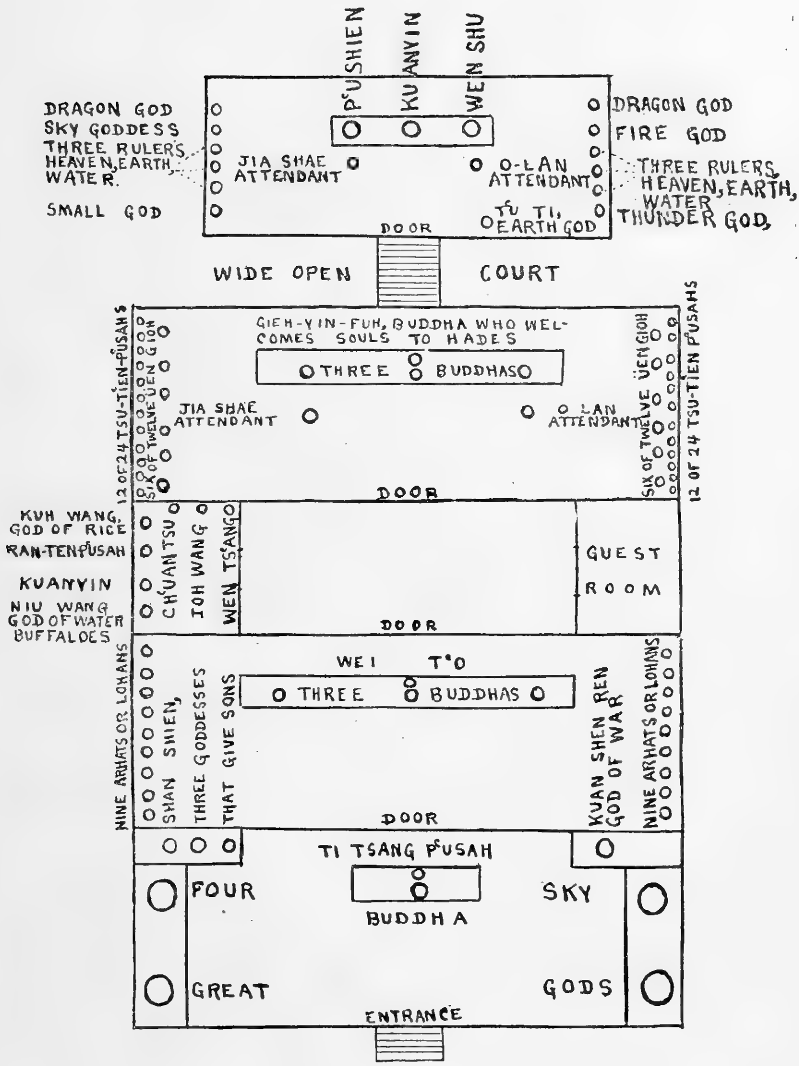

FIG. 12.—Buddhist Ti-Tsang temple east of Suifu between the villages Gi-Tien-Pa and Muh-Jia-Pin.

times be seen on which a picture of the god has been painted. They are recognized and treated as real gods. The pictures of the door gods are printed or painted on paper and pasted on the outsides of the doors. At Chengtu a number of gods are printed in bright colors on paper and distributed or sold to the people at New Year time. They are pasted up in the homes to help protect them. The image of the Kitchen God, which is found in practically every kitchen, is generally printed on paper. On Mt. Omei there are three advertisements of a prepared food that have been framed and are worshipped as gods because they have on them excellent images of Buddha. They were probably brought up from India or Burmah. A well-known biscuit company also has an advertisement on Mt. Omei that has been framed and is treated as a god.

The next step is the making of clay, wooden, stone, or metal images. Some of these are only a few inches high, but others are gigantic in size. The stone image of Buddha across the river from Kiating is probably two hundred and fifty feet high. Many of these images portray the characteristics that the god is supposed to possess. Some are like fierce warriors, but others, like Kuanyin and Amitabha, are more kindly in appearance.

Is the god really present in the image? Is the image to be regarded as the deity himself? In Szechuan Province the answer is yes. When the people or the priests pray to an idol they feel that they are praying to a real god who can understand and help them. Beyond this they do not think. They simply regard the image as the god himself. The following explanation, given by a priest on Mt. Omei, is of special interest. The god is only one and invisible, but in each temple may be an image of the god. He is in space, but he is capable of being anywhere, and when the people worship him in the presence of the image, he is there, and becomes actually embodied in the image, *so that the image is the god.* Probably the images were first made for commemoration, but they have come to be regarded as the gods themselves. The common people treat them as living and efficacious beings.[1]

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[1] One day the writer was sitting on a sandbank beside the Min River. He took a stick and drew in the sand a picture of the Goddess of Mercy. A farmer boy came along and looked at the picture. He was told, "This is Kuanyin P'usah. You had better worship her." He looked at the picture a moment, and then worshipped it.

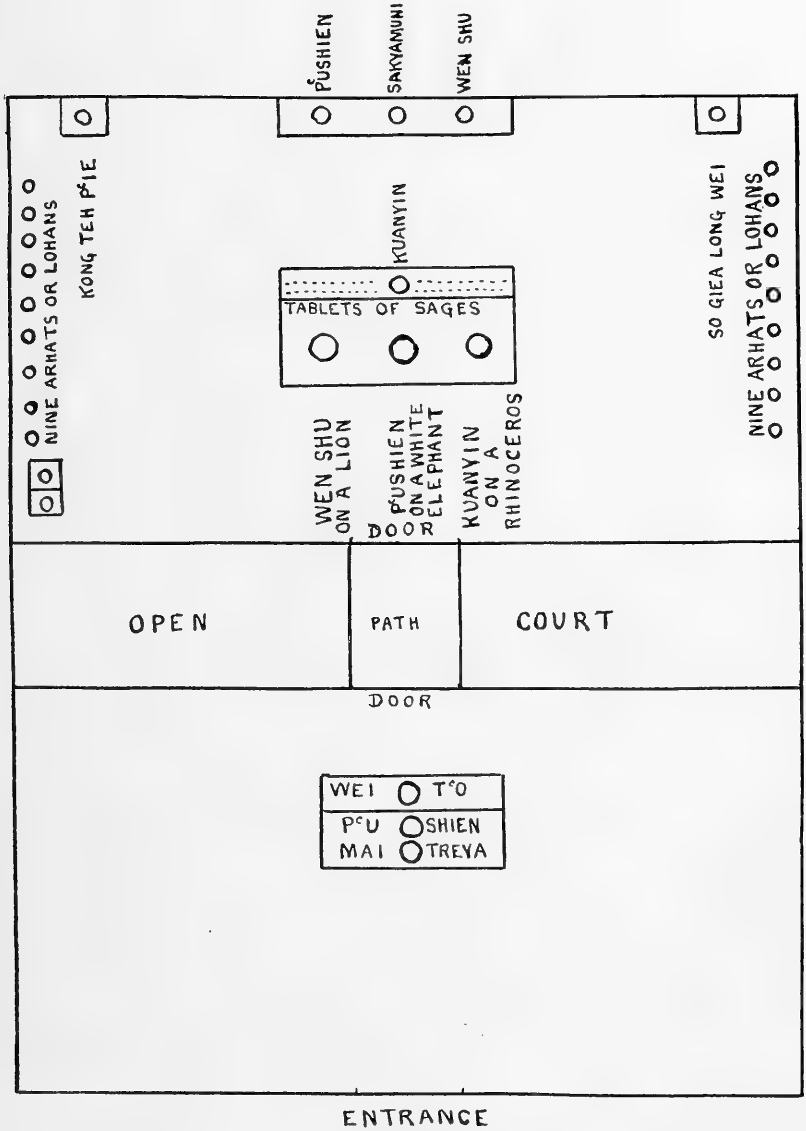

FIG. 13.—Diagram of the main floor of the Shih-Wa-Tien, or pewter tile temple, on the summit of Mt. Omei, Szechuan Province, China.

To the common people of Szechuan Province the presence of the image of a deity suggests the actual presence of the deity who is imaged.[1]

2. THE LIST OF GODS

This enumeration, which can be only a partial one, will begin with those which are distinctly Taoist or Buddhist. U Huang Shang Ti, the Pearly Emperor, and Lao Tsi or Li Lao Guin, the reputed founder of Taoism, are primarily Taoist gods, although both are sometimes found in Buddhist temples. Kuanyin P'usah, while she was brought into China and is widely used by the Buddhists, is now as commonly seen in Taoist as in Buddhist temples. The Buddhists have a medicine god, Yoh Si Fuh, while the Taoists have one called Yoh Wang or Medicine King. Both are miraculous healers, and are probably the same god with different names. Amitabha, Sakyamuni, Wei To and Jia Lan, the two protectors of Buddhist temples, Mi Leh Fuh, the Buddhist messiah, the eighteen Lohans or Arhats, and many others are seen only in Buddhist temples. With many of the gods, however, it is impossible to say whether they are primarily Buddhist or Taoist, for they are found in the temples of both religions.

Some of the gods are highly specialized; that is, they have only one or two duties to perform for the worshipper or for society. The buffalo god cares for the water-buffalo, which is the principal animal used in farming. There is a horse god who cares for horses, a sheep god, and a medicine god. The Kuh Wang, or grain god, causes the rice to grow abundantly. The Song Tsi Niang Niang is a goddess who

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[1] In a Doctor's thesis, The Origin and Development of T'ien and Shangti, Mr. Kuen Ih Tai states that the Miao and the kindred tribes of aborigines in China are ghost or demon-worshippers (p. 92). The writer has had several years of contact with the Chuan Miao and some with Hua Miao. The evidence is that the Miao, like the Chinese, fear demons as the source of diseases and calamities, and that they exorcise them, but do not worship them. The following lines from Among the Tribes in Southwest China, by Samuel R. Clarke, are illuminating.—

> At first we were inclined to think that the Miao worshipped demons, but when again and again they denied this, and seemed unfeignedly amused at the idea of worshipping demons, we concluded that we were mistaken. The performances they go through, which seem to us like religious rites, are done to drive away or keep away the demons, and to counteract their evil influences. If a man is ill, or his cattle sick, if he has had bad luck, or any misfortune befalls him, he attributes this to demons; and a wizard or exorcist is summoned. (Pp. 67-69.)

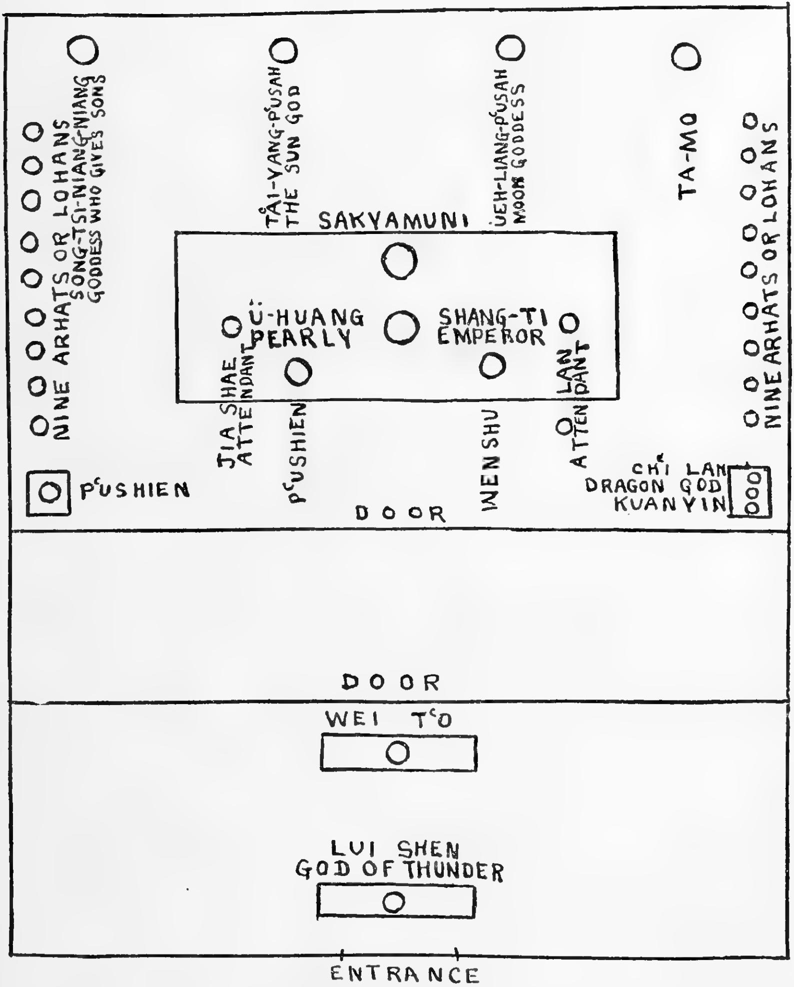

FIG. 14.—Diagram of the Buddhist temple Lui Tong Pcin, or thunder cave flat, Mt. Omei, Szechuan, China. Thunder, which echoes loudly from the sides of the mountain, is thought to emanate from a nearby cave, hence the name of the temple.

does nothing else but give sons. The Deo Ma Niang Niang heals measles and smallpox. The Tsua Sen Niang Niang aids in securing a quick and safe delivery at childbirth.

A few gods are found in almost every home. One has already been described—the red scroll that is hung up in the central and most important place in the main room. Merchants sometimes substitute for this the god of wealth, who is also represented by appropriate characters on a scroll of red paper. There are also two door gods. The main entrance of a Chinese home generally has double doors which open inward, and one god is pasted or painted on each door. They are guards of the home to keep demons from entering. Every home also has a Kitchen God. He is painted or printed on paper and pasted up near the kitchen stove where he supervises the household economy, preventing extravagance. The classic to the Kitchen God also indicates that he looks after the moral conduct of the inmates of the home. His position in the kitchen would make it very convenient for him to do so. On the twenty-third day of the twelfth moon he ascends to heaven and reports the conduct of the household to the Pearly Emperor. He returns and is formally welcomed and his image pasted up on New Year's Eve. The classic of the kitchen god, while in many respects similar to that of the bloody basin, has a higher moral tone, and more nearly represents the moral and religious ideals of the Chinese people.

There are five gods that are often found in shrines, or unprotected from the weather, at intervals along the roadsides to protect the travelers from the demons that might do harm. One is the Goddess of Mercy who is apt to be found anywhere that people are in need of her help. The second is called T'ai Shan Shih Kan Dang, or the T'ai Shan stone that dares. It is generally made of stone, and the inscription is meant to imply that the stone is from the sacred Mount T'ai Shan, and therefore surcharged with power. The image of a fierce being having four tusks and holding a dagger in his mouth is carved on the top of the stone. He is made terrible in appearance so as to inspire fear in the hearts of the demons. A third deity is Lin Kuan, or Deo K'eo Kong, the prince whose mouth is like a peck-measure. He wields a club, and in his fierce wrath opens his mouth so wide that it resembles a peck-measure. He is primarily a demon-chaser. Under one of these images the writer saw an inscription which means. "When he points with his finger the demons depart. At a glance of his eye all diseases are healed." A fourth wayside god is the Tu Di P'usah or the local god of earth. He is a minor official

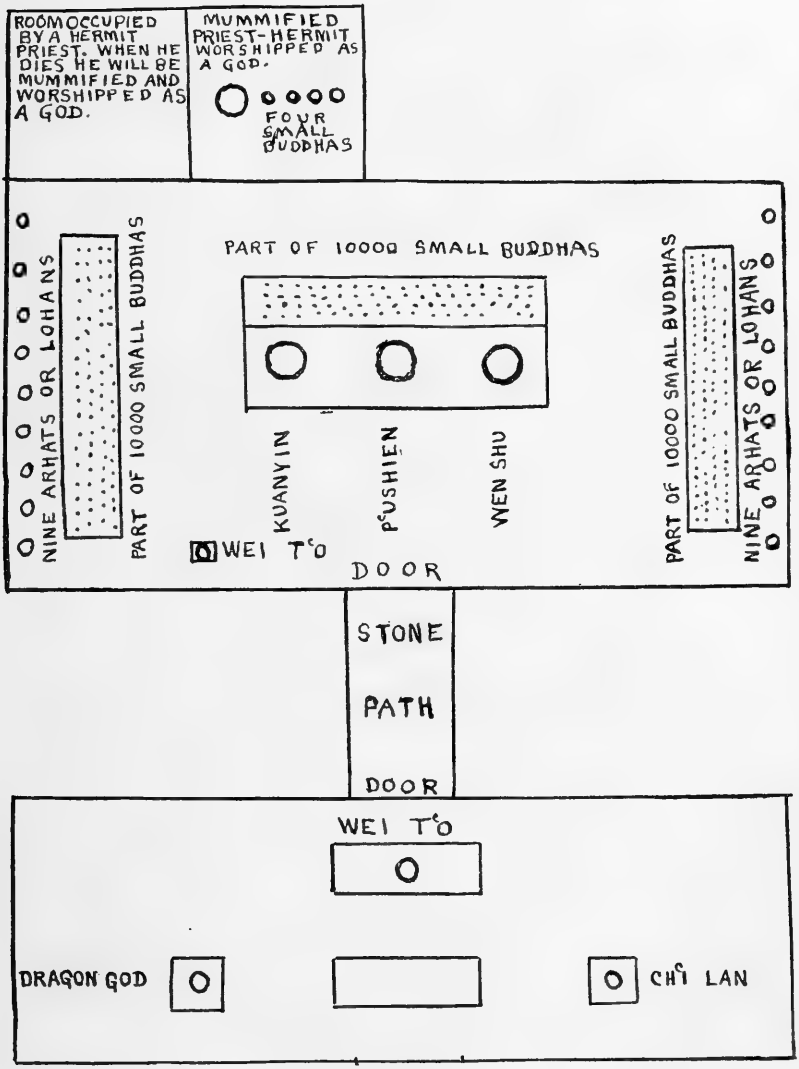

Fig. 15.—Diagram of the Buddhist temple on Mt. Omei called Wan Fuh Din, or peak of 10,000 Buddhas. The temple is supposed to contain 10,000 Buddhas.

who controls a limited territory. His spouse is generally with him. The inscription most commonly seen on his shrine is

Bao ih fang ch'in Gih,
Yu si giai p'ing an.

This means. " He guarantees that it is lucky all about, and protects the peace in all directions." Finally, there is Amitabha, or Omeitofuh, as he is called in Szechuan. He is a kindly, loving savior of men who in his compassion will help them whenever they call on his name. His earlobes are long, indicating Indian influence. Omitofuh and T'ai Shan Shih Kan Dang often have no shrines, but stand exposed to the weather. In Szechuan Province philosophical Buddhism has practically no place. The Buddhism of Amitabha, who rules the western heavens which is a paradise for the souls of the dead, is the Buddhism that has won the hearts of the people. As the Tibetans repeat over and over " Om-mani padme-hum," so the most devout Buddhists repeat as they tell out the beads of the rosaries, " Lan u Omitofuh." On Mt. Omei the pilgrims greet each other with " Omitofuh." In the numerous places by the wayside Amitabha stands ever ready to help the traveler who is in need.

Some of the gods are apparently nature deities. All of them are propitious if reverenced and worshipped. Some have very definite functions. The Sun God and the Moon Goddess have doubtless come down from antiquity. There is a water god who controls rain, and a mountain god who controls mountains. There are idols representing the seven stars of the dipper, heaven, and earth. The Fire God prevents disastrous fires. There is a lightning goddess who carries a looking-glass, the thunderer who carries a hammer and chisel and whose nose and mouth hook downwards like a semi-human creature, and the Lord of Thunder, who controls the lightning goddess and the thunderer. There are also the Earth Prince and the Earth Mother, and many others. On Mt. Omei, in the temple of Gieu Lao Dong, are two gods called Sunlight and Moonlight.

A large number of the gods are deified heroes. Among these are the God of War who was a famous warrior in Szechuan; Ch'uan Chu, the Lord of Szechuan, who is given the credit for the development of the great irrigation system on the Chengtu plain; Wang E. P'usah, the god of boatmen, and Lu Ban, the god of carpenters. A very interesting trio are Fuh Shi, Shen Long, and Shuen Uen Shang Ti, who are always found together. The first two wear leaves instead of clothes. They are legendary heroes who lived before the Chinese learned to make and to wear clothing. Shuen Uen Shang Ti, who is

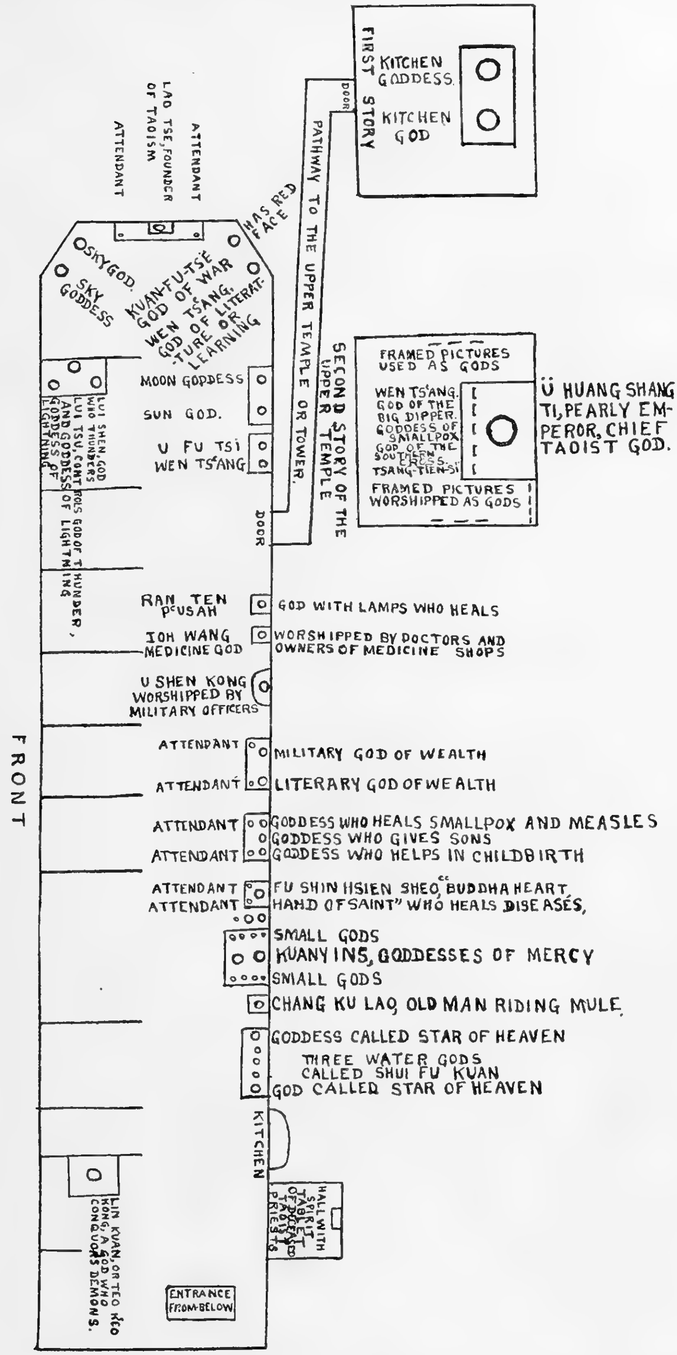

FIG. 16.—Diagram of the Pan Pien Si, a Taoist temple overlooking the Min River at Suifu, Szechuan Province, China.

very well dressed, is reputed to have taught the Chinese how to make and to wear clothing.

At the gateway of the Ta O Si temple on Mt. Omei is an idol which is the image of a man who is still living—at least, he was in the summer of 1925. He is an old man who is deeply devoted to Buddhism, and who has given much money to the Ta O Si temple He was therefore deified while he was still alive. The writer has heard of a similar case in Yachow.

The mummified priest is a peculiar form of a deified hero. The Wan Fuh Din temple and the Ch'ien Fuh Temple on Mt. Omei each have one of these. They were priests who in their respective temples went into seclusion until they died, when they were mummified and worshipped as gods. Another god who is said to be a mummified priest is across the river from Kiating near the Great Buddha. Still another is the principal deity of the T'ai Tsi Miao, a temple near the summit of Mt. Omei. It is claimed that the last one is the mummified son of an emperor. He helps the worshippers secure the birth of sons.

In Tibet there is another form of the deified man, the Hoh Fuh or Living Buddha. He is thought to be a reincarnation of a god. Tradition says that there was once such a reincarnation of P'ushien on Mt. Omei. That is what is meant by the sentence quoted on a previous page. " In the Manchu Dynasty there appeared here a Living P'ushien."

Not a few of the gods in the Buddhist and Taoist temples are great religious leaders who in the past have rendered distinguished service to their religious organizations, and who consequently have been deified.

Every occupation has its patron deity. Scholars worship Uen Ts'ang P'usah, the God of Learning, expecting that he will assist them in acquiring knowledge. Merchants worship the God of Wealth who helps them secure financial prosperity. Lu Ban is the God of Carpenters. Rice planters worship Kuh Wang. There is a God of Brewers. No boatmen will begin a journey without first worshipping Wang E. Physicians and owners of medicine shops worship Ioh Wang, the God of Medicine. There are gods of butchers and of cooks. At Li Chuang there is a god of the coolies who carry water, and one for people who gather leaves and twigs for fuel on the river banks, on the hillsides, or in the forests. In a temple at Ngan Lin Ch'iao there are two idols who are worshipped by thieves, and who assist them in their undertakings. They themselves are said to be experts at stealing.

Near Suifu on the Yangtse River is a small temple known as the White Stone Temple. Originally there was only a large, white stone, taller and whiter than the others. People began to worship it, and ascribed to it the power of healing. Later a temple was built around it, and a few common idols were added. The stone is still worshipped, and for a few cash one can purchase a tiny bit of the rock, which will cause him to recover from illness if he will grind it to sand, soak it in water, and drink the water. Probably the process began with the natural sense of awe aroused because of the size and whiteness of the stone. This stone is not worshipped because a deity has taken up his abode in it, but because the stone itself is thought to be a god with beneficent power that is more than human.

Near the town of Shuin Gien Si, south of Suifu, there formerly lived a man who ran an oil factory. He had some large, fine bulls to run the stone rollers. He prospered, and the value of his bulls increased. Finally he burned incense to his largest bull and worshipped it as a god. His action was, in his own mind and those of his Chinese friends, the natural result of his growing sense of gratitude, wonder, admiration, and awe towards the bulls that contributed so much to his prosperity. I have heard Chinese make a similar explanation of the development of the worship of the Sun God, the Moon Goddess, the Fire God, the Thunder God, and of other deities.

At Suifu, two old cypress trees are worshipped as divinities. It is not that gods dwell in them, but that the trees themselves are gods. They are said to have been planted in the Ming Dynasty, or possibly earlier. It is asserted that they once made a pilgrimage to Mt. Omei Two men giving their names as Beh, or White, worshipped at the different shrines and temples on the great sacred mountain, and promised contributions. They said that they were brothers from Suifu. Later a priest came to Suifu to collect the money. He could not find any brothers named Beh, but when he heard of the two cypress trees, *beh sou,* he knew at once that the two pilgrims were the two cypress trees. I have been told by aged priests who were experts in such traditions that very old trees, especially cypress trees, are able, after many years, to develop into tree-deities. There is a tendency in some localities to burn incense to aged trees or to the stumps of these trees. This is especially noticeable on Mt. Omei, on Washan, and at the Yellow Dragon Gorge.

Near Kiang K'eo is a large banyon tree that is worshipped because a spirit or ghost has taken its abode in the tree. The people began to worship it about 1917. It is called a Huang Geh Giang Guin, or " General Banyon." Its leaves are used to heal all kinds of diseases.

Incense is burnt to it. If one's feet are sore, he can get well by hanging a pair of straw sandals on the tree.

In the region between Kiating and Chengtu turnips often grow to a very large size. The Chinese say that they sometimes weigh from twenty-five to a hundred pounds, requiring two men to carry them. When such a turnip is found, it is called a Turnip King, and is regarded as a god of turnips. It is placed on a table or on a platform, divine honors are paid to it, and a company of actors are engaged to give theatricals in its honor. Then there is a great feast to which the neighborhood is invited. As a result of thus honoring the Turnip King, it is thought that turnips will prosper in that locality. But the high cost of living may destroy this custom. All the expenses are borne by the farmer on whose land the Turnip King develops. Prices are rising, so that the farmers feel that they cannot afford to pay the expenses of the ceremonies and of the feast. Therefore, when a turnip develops beyond a certain size, the farmers are apt to pull it up and sell it or throw it into a ditch.

At Ngan Lin Ch'iao, near Suifu, there is an idol called a Yinyang P'usah, which is half male and half female. It represents the important *yin* and *yang* forces, the male and female principles in nature. The left side is male, the right side is female. The left eye and ear and the left side of the mouth are large, and the right small, so that the face has a lopsided appearance. The left foot is natural, and the right foot bound. The left side is dressed like a man, and the right side like a woman. On the whole, this is one of the queerest deities that the writer has seen.

One god that is worshipped in Szechuan is called the T'an Shen Den Den. It is really a foundation-stone such as is used under the wooden pillars of houses and temples. The climate is very damp, especially in the summer, and wood decays easily. It is therefore customary to put foundation-stones under the wooden pillars to keep them from rotting and to protect them from the ravages of white ants. For some reason these are occasionally worshipped as deities, set in places of honor, and regarded as very efficacious. Wealthy people spend much money in their worship, and in return it is thought that they will cause one's family to prosper. However, the poor people believe that they have bad tempers, and that if worshipped too economically they will become spiteful and do injury in the homes where they are kept. Some poor families that cannot afford to worship with elaborate ceremonies simply throw the idols away, but the majority carry them to a temple where priests and pilgrims can accord the worship that their majesties demand. Foundation-stones hold up tremendous weights, and seem to exhibit a peculiar power to preserve the wooden pillars from decay and from the attack of white ants. It is not strange, therefore, that the untutored have marvelled at the qualities displayed, and have come to treat the foundation-stones as beings with superhuman power.[1]

The gods of Szechuan present a wonderful variety in form and character. They vary from the invisible T'ien Lao Yeh to written characters representing the gods, pictures painted or pasted on wood or paper and images of all kinds in the homes and in the temples. They are thought to have marvellous intelligence and superhuman power which they use to help the faithful against demons and in their struggle for a full and satisfying life. The practical nature of the religion of Szechuan is shown by the fact that every occupation has a patron deity and every god has some task or tasks that are beneficial to men. In Szechuan Province the gods are means or agencies for securing the satisfactions of men's fundamental needs, his helpers in the quest for a happy, safe, and satisfying life.

X. SUMMARY AND CONCLUSION

In the study of the popular religion in Szechuan Province, the *mana* concept, that of a strange and mysterious potency permeating all striking, powerful, strange, and mysterious things is a primary key for the understanding and interpreting of that religion. In the popular reaction this mysterious potency is connected with an emotional response to the unknown, danger-filled or helpful environment. When men philosophize about it, it is differentiated into the *yin* and the *yang,* which are included in the *t'ai gih* or great extreme.

Demons also play a large part in the lives of the people of Szechuan. They are disgruntled spirits of the dead who must be appeased and exorcised. They are the causes of all diseases and all other calamities. Many of the gods and most of the charms are to furnish protection from demons.

[1] There is evidence that in earlier Chinese history it was customary for the Chinese to bury human beings or animals under foundation-stones. In some countries such practices have given an awed attitude and a sense of holiness to the corner-stone. In some old Chinese legends *kuei* are associated with foundations. This may have given the T'an Shen Den Den its spiteful and dangerous character. In Szechuan the foundation-stone is sometimes worshipped as a god, but the writer has so far been unable to trace any connection between the old custom of burying people under foundations and the present worship of foundation-stones as deities. Not all foundation-stones are worshipped, but some are.

The element of luck, which is greater in primitive life, does much to maintain if not to create the belief in a mysterious potency, lucky days, and various customs generally classed together as superstitions. One day everything goes well: game is killed, and all have plenty. At other times the boats get wrecked, no game is found, people become ill, and all goes wrong. To the more primitive mind, unable to give scientific explanations, and lacking scientific methods and means of controlling nature about him, the things that we have been describing seem perfectly natural.

The emotions of awe and wonder, and the emotional thrill, allied to the *mana* reaction, are elements that are exceedingly important, and which lie near the heart of the primitive religions. The organized religions of Szechuan, perhaps more or less unconsciously, have become past-masters in arousing these emotions. In large temples, located on hills that are seen far and wide or on spots noted for the wonders of their natural phenomena, great deities, wearing the clothing of temporal rulers and often wearing crowns and covered with gold-leaf, priests with beautiful official robes and masters of the rites, incantations, and ceremonies, and great festivals that are the crowning religious and social events of the year—all these arouse wonder, admiration, and awe, and result in the loyalty of the common people to their religious organizations.

The social customs, ideals, and conceptions are clearly reflected in those of religion. The attitudes, customs, and practices that have to do with priests and gods are duplications of those of the Manchu Dynasty. The customs of this world are carried over into the world of the departed spirits, so much so that the souls of the dead must be given food and money. China is now being swept from end to end by democratic ideals, so that anything that even smacks of monarchy is taboo, but there has so far been almost no effect on religious ideals, rites, and ceremonies.

Under Tsang Tao Lin and other leaders Taoism, many centuries ago, gained the adherence of the masses in China by identifying itself with the popular religion that has come down among the lower classes of the Chinese from ancient times. Buddhism came to China from India, a high, philosophical religion, but for centuries was unable to win the masses until it, like Taoism, identified itself with the religion of the common people. Today it is a rival of Taoism as a popular religion of Szechuan. The Chinese love life in this world, and nirvana has no appeal to them, but the religion of Amitabha, the merciful ruler of western heaven, with Kuanyin, the merciful goddess, has won the hearts of the people. Many of the indigenous gods of China are found both in the Buddhist and in the Taoist temples. There has been a great deal of mutual borrowing. Even the Pearly Emperor is found in the Buddhist temples, and in Taoist temples can be found pictures or images representing the transmigration of souls, a conception which the Buddhists brought with them from India, and scenes representing the judgments and punishments of hades, which were originally Buddhist.

Religion in Szechuan is exceedingly practical. Every phase of it, every rite and ceremony, every god or temple, has to do with the satisfying of some human need that is felt to be important. They are the techniques that have been worked out and used during the past centuries by the masses of untutored people as a means of securing satisfaction of the primary needs of man—food, sex, protection from enemies, from the forces of nature, and from disease, and play. To these people in their environment, such techniques have seemed and still seem most natural and reasonable. They are facing many difficulties and perplexities, but they are as capable as any other race of people on earth, and the writer ventures to hope and to believe that in the centuries to come they will make educational, social, moral, and religious contributions that will enrich the civilization of the whole world.

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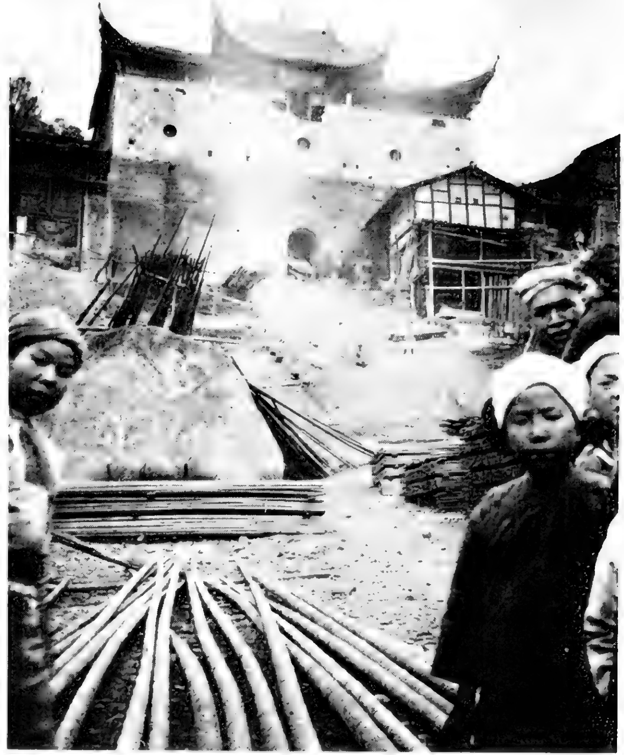
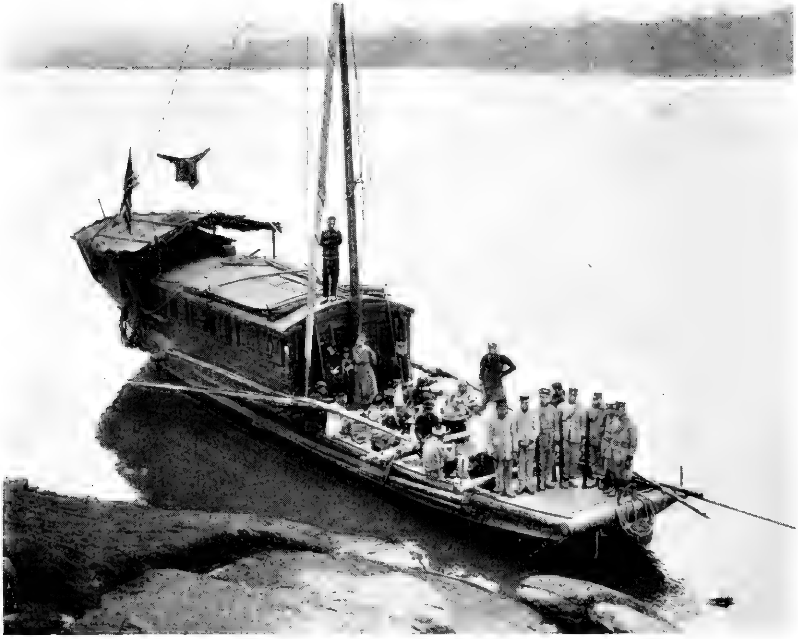
1. View of the Yangtse Gorges above Ichang, China.



2. The main gateway to a city on the Yangtse River above Chungking, China. This important and imposing gateway has been sealed because it is believed that its *fengshui* is not good, and therefore if the gateway were used the city would suffer calamities of some kind.



1. A houseboat on the Yangtse River. Mrs. Graham and two children are standing near the mast. The soldiers who are escorting the boat are in the front.

2. The city of Nan Kuang near Suifu, Szechuan, China.

1. Terraced rice fields in Szechuan Province.

2. A large waterwheel made of bamboo and used for irrigation in Szechuan. The wheel is propelled by the force of the stream.

1. A Suifu Taoist priest in his ceremonial dress, with two instruments with which he performs wonderful deeds and exorcises demons.

2. A Chinese god, U ER E, and his two wives. They are opium eaters, and opium can be seen smeared on his lips. This picture was taken in the Dong Yoh Miao, a Taoist temple at Li Chuang, near Suifu, Szechuan Province, China.

1. The "Chicken-footed God," who leads the souls of the dead to judgment. It is considered good luck to hang a chicken foot on the chain suspended from the hands of the god.

2. One of two aged cypress trees at Suifu that are regarded as gods. The belief is not that deities have taken up their abode in the trees, but that the trees have become gods. There is a legend that these trees once made a pilgrimage to Mt. Omei.

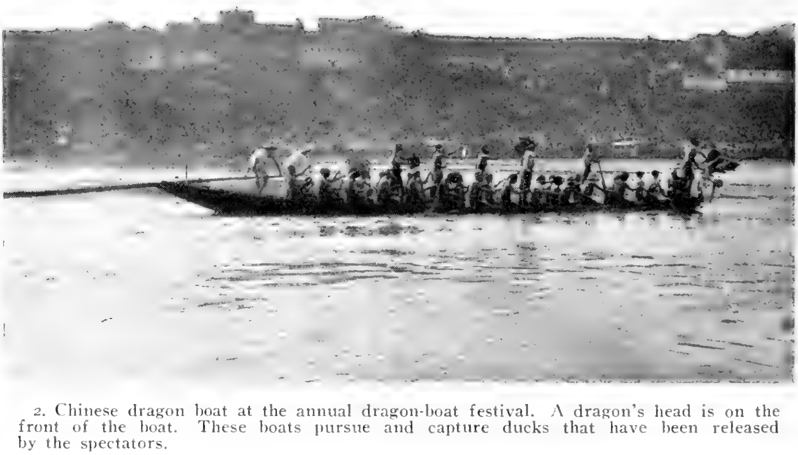
1. A god with four eyes found in the P'utaogin temple at Ch'anglinshien, south of Suifu. The third and fourth eyes enable a god to see demons, and virtue and guilt.

2. A *yingyang p'usah*, a god that is half male and half female, found at Nganlinchiao, near Suifu, Szechuan Province, China. The left side is supposed to be male, and the right side female. This god represents the *yin* and the *yang*, the male and female principles of Chinese philosophy combined in one individual.

1. A large white stone near Suifu that is worshipped as a god. The idea is not that a deity or a spirit has taken up its abode in the rock, but that the stone is a god. A temple has been built around the stone, and other idols have been added.

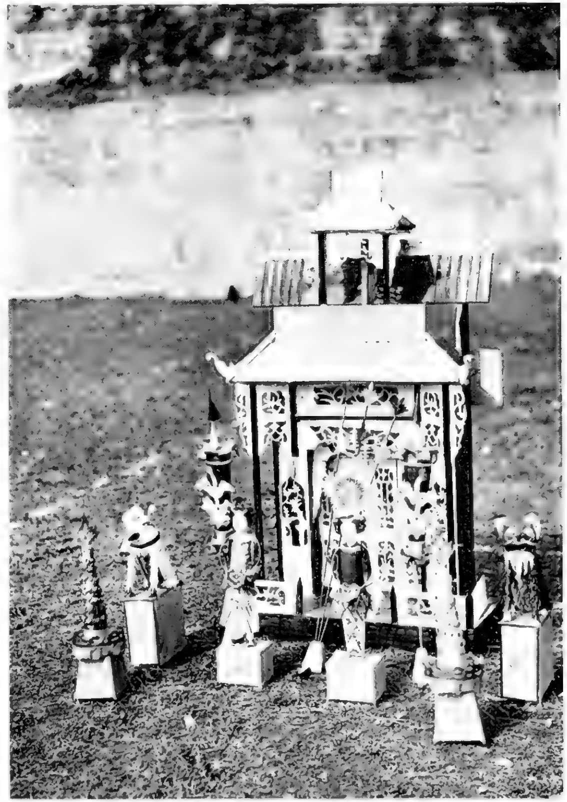
2. Part of a great retreating army trying to cross the Min River at Kien Wei, Szechuan, China, in 1925.

1. A poor widow and her son carrying coal at Nan Kuang, near Suifu, Szechuan Province, China

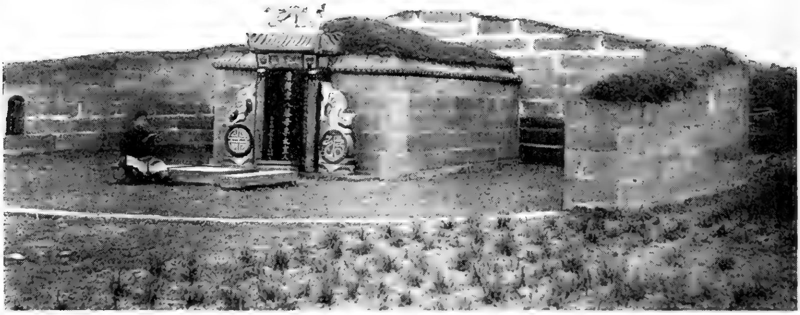


2. Chinese dragon boat at the annual dragon-boat festival. A dragon's head is on the front of the boat. These boats pursue and capture ducks that have been released by the spectators.

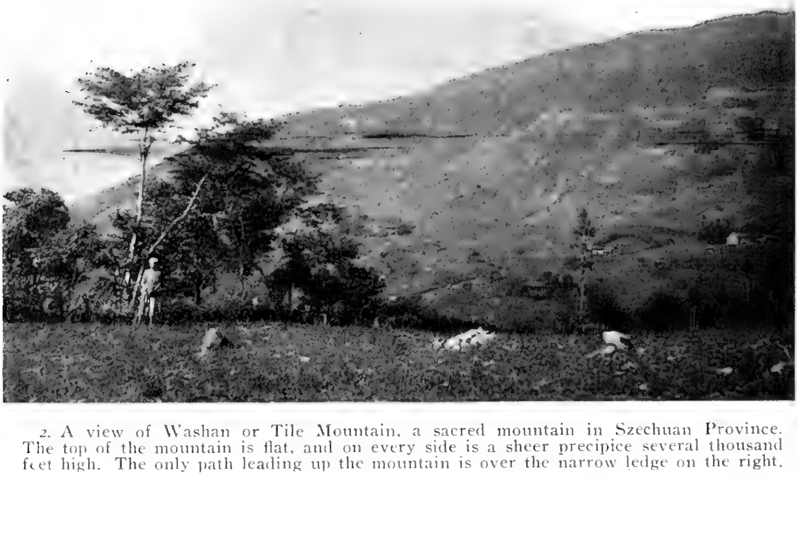
1. The Golden Sand Cave Monastery at Shiung Gien Ssu, south of Suifu. There are several sections or stories, the last one being in a natural limestone cave on the side of the cliff. The tree is a *fengshui.*



2. Articles that are burnt at funerals for the benefit of the departed souls. They are a house, a manservant and a maid-servant, a lion and an elephant for ornament, and a gold hill and a silver hill to supply the soul with wealth. These are made of paper and wood. In addition quantities of "paper money" are usually burnt. By burning they are thought to be transformed into things for use of the departed souls in hades.



1. A grave at Suifu, Szechuan, China, erected by a student for his deceased grandmother. A house and lot were sold to pay the cost of this tomb.



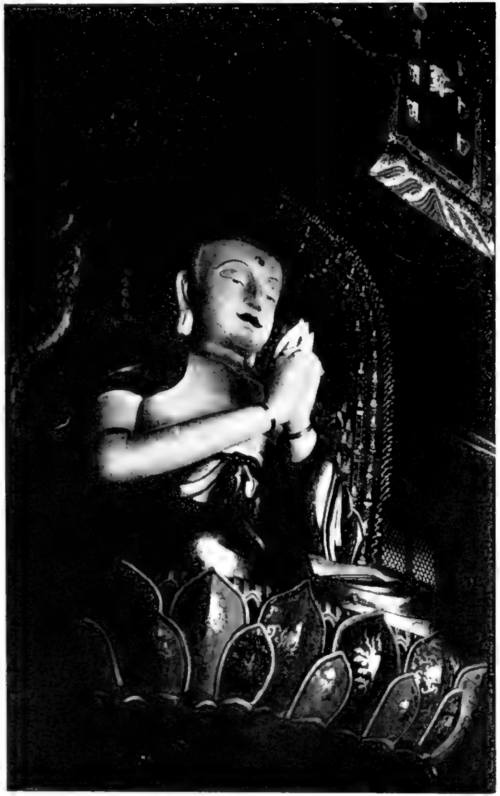
2. A view of Washan or Tile Mountain, a sacred mountain in Szechuan Province. The top of the mountain is flat, and on every side is a sheer precipice several thousand feet high. The only path leading up the mountain is over the narrow ledge on the right.

1. A Chuan Miao aborigine farmer from Szechuan Province, near Suifu.

2. The West Gate of Kiating, Szechuan, China, through which many thousands of pilgrims go each year on pilgrimages to Mt. Omei.

1. One of the four ladders by which rocks are surmounted on the path to the top of Washan. This is one of the shortest and least perpendicular of the four ladders.

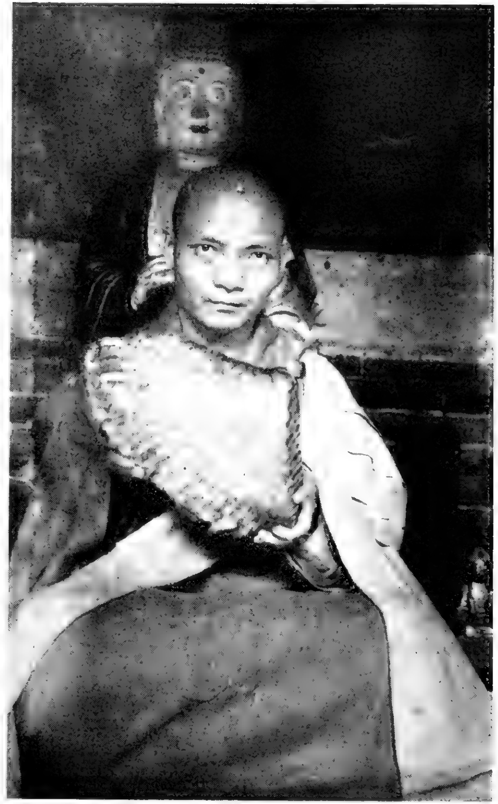
2. A view of one of the perpendicular sides of Washan or Tile Mountain.



1. A Buddha in meditation. This picture was taken at the Ta Fuh Ssu temple near Omeishien, Szechuan Province, China.

2. The great thousand-armed Goddess of Mercy at the Ta Fuh Ssu temple, near Omeishien, Szechuan Province, China. This goddess actually has one thousand hands and arms with which to perform deeds of mercy. The hands may be seen in rows above the head of the goddess. The figure is covered with gold, and including the arms and hands is nearly 100 feet high.

1. A deity with tusks at the Ta Fuh Ssu, or Great Buddha Monastery, at Omeishien, Szechuan, China.



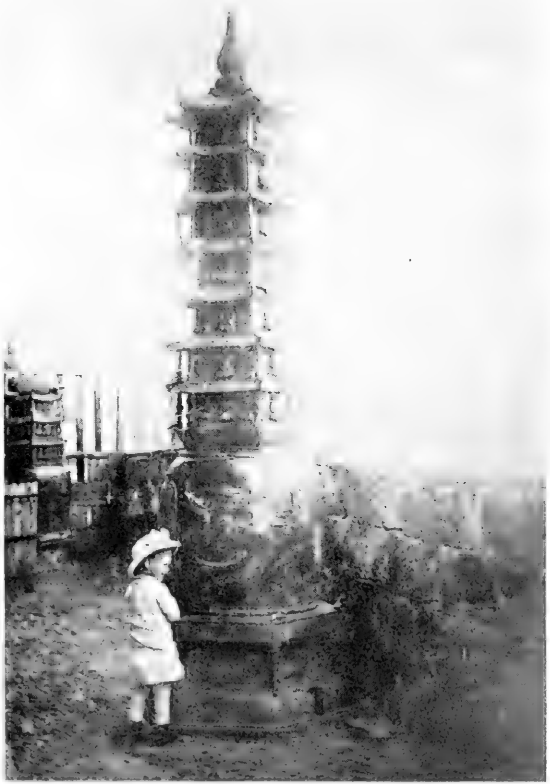
2. Buddhist priest at the Lower Wan N'en Ssu temple, Mt. Omei, Szechuan Province, China. In his hands is what is thought to be Buddha's tooth, but which is a fossil mammoth tooth.

1. The Buddhist abbot at Hua Lien Ssu, or Lotus Flower Monastery, on Mt. Omei. The stone is thought to be a petrified lotus flower.

2. An image of a tiger in a shrine by the roadside near the summit of Mt. Omei. It is worshipped as a god.

1. View of Mt. Omei from Shin Kai Si. Mt. Omei is one of the four great sacred mountains of China and has many Buddhist temples and monasteries. There is a sheer precipice of 6,000 feet from the "Golden Summit."

2. The most sacred shrine on Mt. Omei, that of P'ushien, the patron deity of this mountain. P'ushien's image is back of the glass windows and is invisible.



1. A bronze pagoda on the summit of Mt. Omei which was erected in the Ming Dynasty. Coins that have been rubbed on this pagoda are thought to be potent as charms to protect the owner from demons.

2. D. C. Graham looking down at the great precipice from the summit of Mt. Omei. This precipice of 6,000 feet is supposed by some to be the highest in the world.

1. A view of Tatsienlu from the compound of the China Inland Mission. The Catholic cathedral can be seen in the foreground.

2. One of the greatest of living Tibetans, a "living Buddha," who is worshipped as a god. He is the head of one of the three great religious sects in Tibet, and is thought to be the ninth reincarnation of the chief disciple of the founder of lamaism in Tibet.

1. A Tibetan lama performing a religious dance. Beyond the lama a large trumpet 15 feet long may be seen.

2. A great bridge made of large bamboo ropes or cables at Kuanshien, Szechuan, China.

1. Aborigine stone buildings at Kuan Tsae, or Ts'ao P'o, near Wenchuanshien, Szechuan, China. The building in the foreground has been used as a magistrate's yamen, a lamasery or temple, and a fortress.

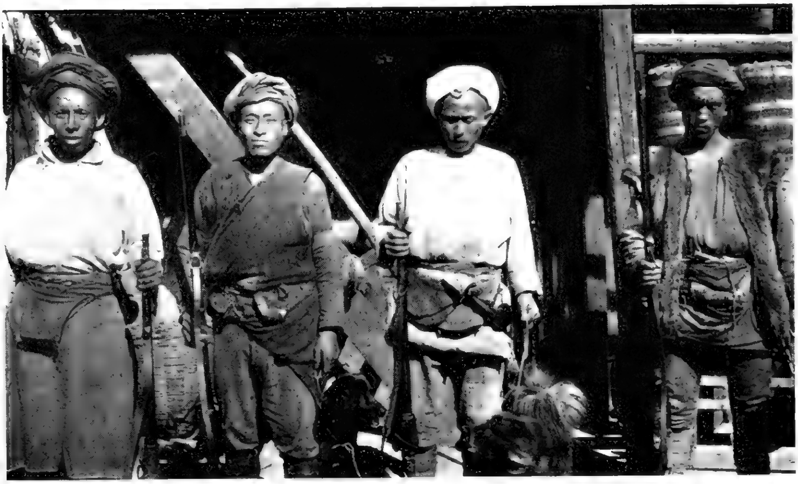
2. Shifan aborigine pilgrims at the Yellow Dragon Gorge, near Songpan, Szechuan Province, China.

1. A typical aborigine at Songpan, Szechuan, China.

2. A Shifan lama with his instruments of worship, the handdrum and the bell. A silver charmbox is suspended from his neck.

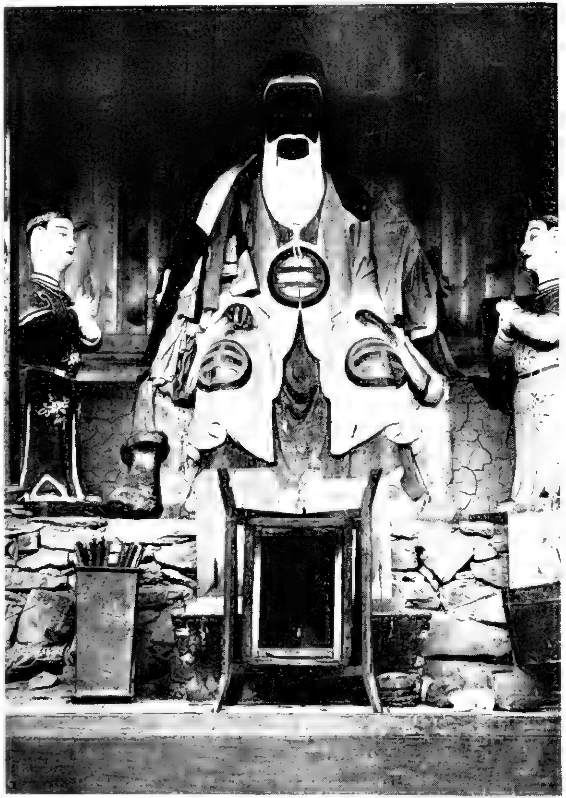
1. Shifan aborigine pilgrims at the Yellow Dragon Gorge, near Songpan, Szechuan, China.

2. A Mohammedan soldier and a dragon god at a shrine in the Yellow Dragon Gorge. The head of the dragon is made of lime and clay. The body is a stump of a tree.



1. Four Wasi aborigine hunters from Kuan Tsae, near Wenchuanshien, Szechuan, China.

2. Aborigine women of the Ch'iang tribe, at Wenchuanshien, near Mowchow, Szechuan, China.



1. The Yellow Dragon God, the chief deity of the Yellow Dragon Gorge. His robes are the same color as the yellow rock in the stream bed.

2. A stone altar outside the Upper Yellow Dragon Temple, Yellow Dragon Gorge, near Songpan, Szechuan, China. The Chinese worship inside the temple. Prayer flags may be seen in the rear. The man in the foreground is a Chinese militia officer.

1. Natural terraces in the Yellow Dragon Gorge made by the deposit of mineral substances in the water. There are hundreds of these terraces, which are very beautiful.

2. The Smithsonian collecting expedition leaving the Yellow Dragon Gorge for Songpan in 1924. On the extreme left is Yang Fong Tsang, a Chuan Miao aborigine hunter. Near the center is D. C. Graham. Other members of the party are an escort of six soldiers, one netter, two taxidermists, and coolies who have charge of the pack animals.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 5

DRAWINGS BY A. DEBATZ IN LOUISIANA, 1732-1735

(WITH SIX PLATES)

BY
DAVID I. BUSHNELL, JR.

(PUBLICATION 2925)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DRAWINGS BY A. DeBATZ IN LOUISIANA, 1732-1735

By DAVID I. BUSHNELL, JR.

(With Six Plates)

A. DeBatz, by whom the drawings were made, appears to have been an architect or engineer and he may have been connected with the military forces of France then stationed in Louisiana. The time of his arrival in Louisiana is not known, nor has it been ascertained when, if ever, he returned to France. But a document recently discovered in New Orleans may reveal the location of his earlier home, before he came to America. This is a marriage contract, dated New Orleans, October 27, 1736. It is written in French but the first part, translated, reads: "There were present in their own persons sieur Adrien de Bat called Ricard a master mason of New Orleans, son of Sieur Alexander de Bat and Jeanne Ricarde the wife and mother, Native of Montaterre in Picardy, diocese of Beauvaise, party of the first part. . . . ." (Numbered 6199.)

Alexander de Bat, the father, mentioned in the contract, is believed to have been the author of the sketches. The spelling of the name differs but that is of little importance. Consequently it may be assumed he migrated from Montaterre in Picardy to Louisiana, and that he arrived soon after the settlement of New Orleans. Dates and legends attached to drawings and documents make it possible to trace his movements during a brief period. Thus he was at the Acolapissa village, on the Mississippi above New Orleans, April 15, 1732; in the Natchez country May 13, 1732; in New Orleans June 22 and July 29, 1732; in New Orleans January 24 and April 30, 1735; in Mobile September 7, 1737.

In addition to the drawings belonging to this collection, five documents bearing the signature of DeBatz are known. These are:

Plan of a church in New Orleans. Original drawing is now in the National Archives, Paris. Dated New Orleans, July 29, 1732.

Petition to sell a piece of land in New Orleans. Original now in the Louisiana State Museum, New Orleans. Dated New Orleans, January 24, 1735. (Numbered 5202.)

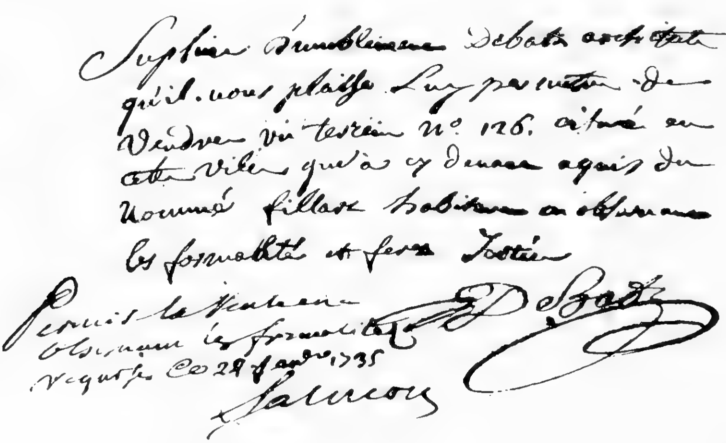
Marriage contract witnessed by DeBatz. Original now in the Louisiana State Museum, New Orleans. Dated New Orleans, April 30, 1735. (Numbered 5294.)

Two maps, redrawn by DeBatz from sketches by Indians, were reproduced in *Journal de la Société des Américanistes de Paris,* Nouvelle Serie, Tome XIII, Fasc. 1. Paris, 1921. The two drawings by DeBatz are now in the National Archives, Paris. Dated Mobile, September 7, 1737.

His name has not been discovered in any of the numerous manuscripts relating to the troubles with the Natchez, Chickasaw, or other tribes with whom the French came in contact during the years mentioned. The few drawings known to exist prove him to have been a careful observer and to have been interested in the manners and customs of the Indians. His sketches are crude but graphic. The drawings now reproduced for the first time are the earliest known to have been made in Lower Louisiana, and they are likewise believed to be the oldest pictures existing of members of the Acolapissa, Atakapa, Choctaw, Fox, Illinois, and Tunica tribes.

The paper has turned yellow with age but the colors remain clear and bright, and many details are shown with great exactness, some of which, unfortunately, are lost in the photographs.

The work of DeBatz in the lower Mississippi Valley compares with that of Jacques Lemoyne de Morgues in Florida, and of John White in Virginia, during the latter part of the 16th century. And although the drawings were made by DeBatz at a much later day, the natives with whom he came in contact were no less primitive in their manners and ways of life; consequently the three groups of pictures are of equal interest and importance. The six pictures now reproduced are in the private collection of the author.


Supplie humblement Debatz architecte
qu'il vous plaise luy permettre de
vendre un terrain No. 126. situé en
cette ville qu'il a cy devant acquis du
nommé Villars habitant en observant
les formalités et fera justice
DeBatz
Permis le vendeur
observant les formalités
requises ce 28 janv. 1735
Salmon

Petition (5202) dated Jan. 24, 1735. Signed DeBatz.

1

TEMPLE, AND CABIN OF THE CHIEF. ACOLAPISSA. 1732

Two centuries and more ago, when the French entered Lower Louisiana, many tribes occupied the region near or bordering the Mississippi. The scattered native villages differed in size and importance but may not have varied greatly in general appearance. One custom was followed in common for as DuPratz then wrote: "All the people of Louisiana have temples, which are more or less well cared for according to the ability of the nation." Some were quite simple in form and resembled the habitations in the nearby or surrounding villages, others were more elaborate and of greater size, and such was the temple which stood in the village of the Acolapissa during the spring of 1732. This settlement was probably a short distance up the Mississippi from the site of the earlier village of the same tribe which was visited by Charlevoix just 10 years before when he described it as "the finest in all Louisiana." Three carved and painted figures of birds, probably quite similar to those so clearly shown in the sketch of the Acolapissa temple, are mentioned as having surmounted like structures which had formerly stood in the villages of the Taensa and Natchez. These and other temples in Lower Louisiana served as burial places for the chiefs of the tribes.

The cabin of the Acolapissa chief, as given in the sketch, was probably a typical habitation of the region and time, but among some tribes rectangular cabins were also erected.

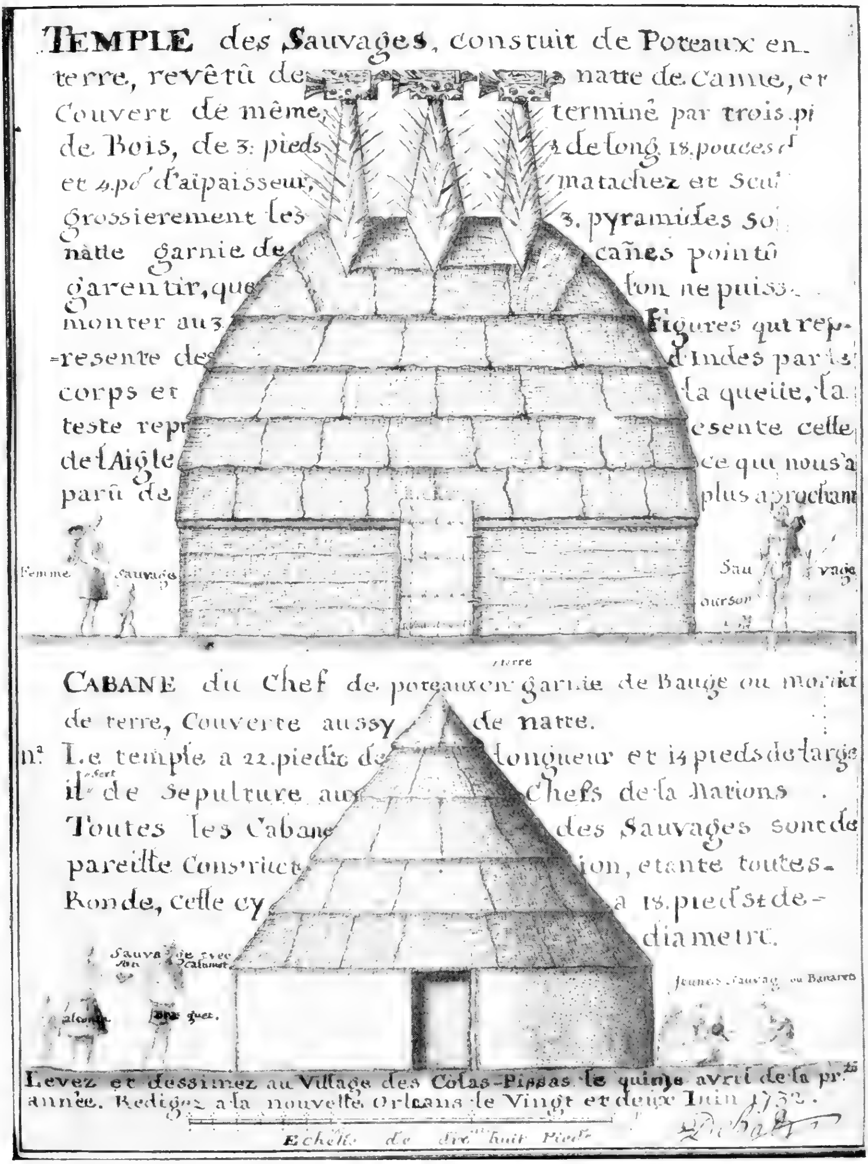
Temple of the Savages, constructed of posts in the ground, covered with mats of cane, and roofed with same, ending in three [stakes] of Wood, $3\frac{1}{2}$ feet long, 18 inches [wide] and 4 inches thick, crudely colored and [sculptured]. The 3 pyramids [are of] reedwork trimmed with pointed canes [to] prevent one climbing to the 3 figures, the body and tail of which represent turkeys and the head that of the eagle, which seemed to us the most like it.

Cabin of the Chief, of posts in the ground plastered with clay or earth mortar, also covered with mats.

n? The temple is 22 feet long and 14 feet wide; it serves as the sepulcher for the chiefs of the nation.

All the Cabins of the savages are of similar construction, all being round, this one is 18 feet in diameter.

Surveyed and sketched at the Village of the Acolapissa the fifteenth of April of the present year. Redrawn at New Orleans the twenty-second of June 1732. DeBatz.



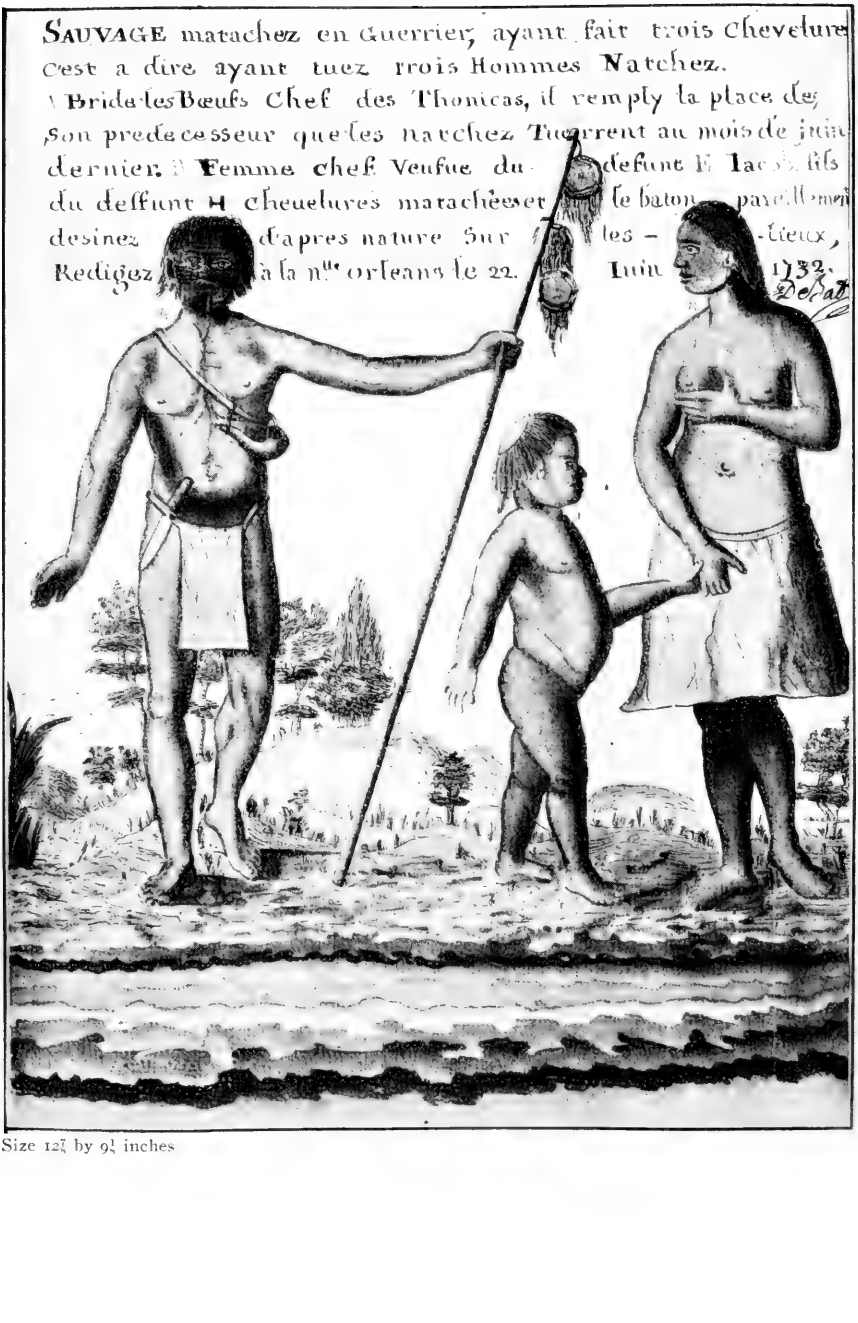
Size 12⅝ by 9 inches

2

BUFFALO TAMER, CHIEF OF THE TUNICA. 1732

The spring of 1731 found the Natchez scattered and wandering as a result of the destruction of their villages during the wars of the preceding years. Soon they appealed to the French for a pardon, and asked that they might settle near the Tunica; permission was granted them to erect a village not less than two leagues from that of the Tunica, but they were to come unarmed. Later a large number of Natchez arrived at the Tunica village where they were received and given food, and Charlevoix related how the Tunica and their new guests " danced till after midnight, after which the Tonica retired to their cabins, thinking that of course the Natchez would also go to rest. But soon after—that is to say, one hour before day, for it was the 14th day of June [1731]—the Natchez . . . . fell upon all the cabins and slaughtered all whom they surprised asleep. The head chief ran up at the noise and first killed four Natchez; but, overborne by numbers, he was slain with some twelve of his warriors. His war chief, undismayed by this loss or the flight of most of his braves, rallied a dozen, with whom he regained the head chief's cabin; he even succeeded in recalling the rest, and after fighting for five days and nights almost without intermission remained master of his village." The name of the Tunica chief killed in this encounter and whose wife and child escaped was Cahura-Joligo, and evidently Bride-les Boeuf, or Buffalo Tamer, was his successor. Buffalo Tamer may have been the war chief mentioned by Charlevoix.

Savage adorned as a Warrior, having taken three scalps, that is to say having killed three Natchez men. *A*. Buffalo Tamer Chief of the Tunica, he takes the place of his predecessor whom the Natchez killed in the month of June last. *B*. Woman chief widow of the defunct. *E*. Jacob son of the defunct. *H*. Scalps ornamenting the staff likewise drawn from nature on the spot. Redrawn at New Orleans the 22 June 1732. DeBatz.



Size 12¾ by 9¼ inches

3

TREE NEAR SITE OF THE NATCHEZ TEMPLE. 1732

This tree, considered a great rarity by the French and evidently regarded with awe by the Natchez who "held it in great veneration," is believed to have been an Osage orange, *Toxylon pomiferum.*

The tree probably stood near the temple and not far from the Village of Valleur, therefore in the immediate vicinity of the severe fighting between the French and Natchez during the latter part of February, 1730. The French were intrenched near or surrounding the temple while the Natchez held the village, having constructed what the French termed Fort de la Valeur. The great Natchez temple was destroyed at that time, on or about February 23, 1730.

Unknown Tree. This Tree is now standing among the Natchez. The Savages preserved it and held it in great Veneration, taking from it some branches or twigs to cast into the Sacred fire which they maintained perpetually in their Temple which was built near the said Tree. The French burned and destroyed this Temple in February 1730. According to the report of the most ancient of this Colony this Tree is the unique and only one in this Province. *A*. Branch covered with these Leaves of the natural size and Color. *B*. Flower of pale White color. *C*. The starting point of the leaf, a scar remains when the leaf falls, which forms a Bud and it may be seen how many leaves it produced.

The Tree is always Green.
Sketched from nature at the village of Valleur the 13 of May later Redrawn at New Orleans the 22 June 1732. DeBatz.
25 feet high.

Size 12⅝ by 9⅛ inches

4

ILLINOIS, FOX, AND ATAKAPA. 1735

During the year 1735 the French took many Illinois Indians to Lower Louisiana, probably to New Orleans, to assist in the war against the Chickasaw. From the interesting drawing made at that time it is evident that not only warriors but women and children made the long journey down the Mississippi. In the sketch the chief, on the extreme left, is shown with his right hand resting on the head of a Whooping Crane, *Grus americana,* which may indicate that the bird had been domesticated. This would agree with a statement by Lawson, who, when referring to the Congaree of North Carolina, wrote: "they take storks and cranes before they can fly and breed them as tame and familiar as dung-hill fowls."

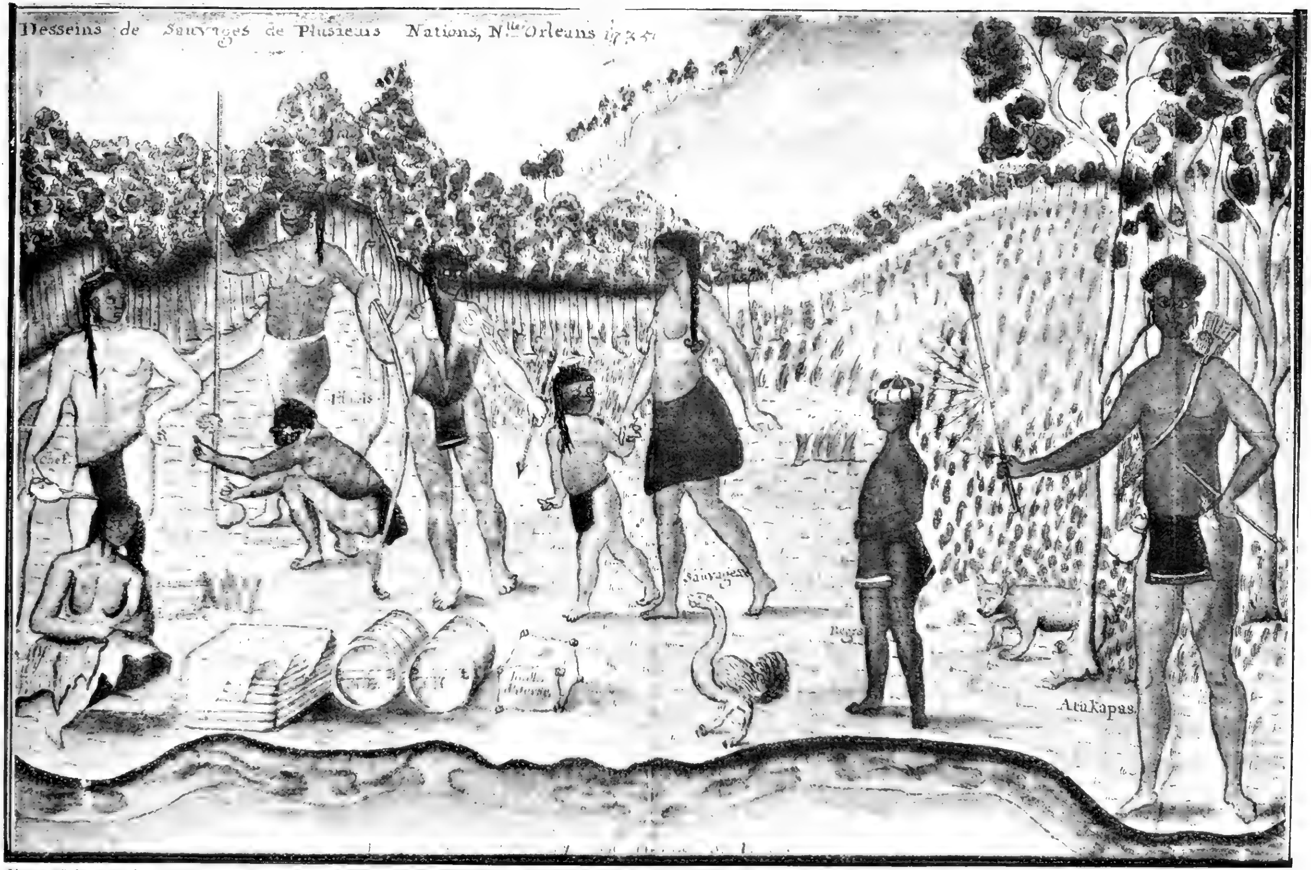
The Fox woman was evidently a captive taken by the Illinois in their then recent war with that tribe.

The Atakapa is represented holding a calumet in his right hand and a small pipe in the left, with a quiver filled with arrows on his back, but no bow.

The sketch was probably intended to represent the bank of the Mississippi, and at the bottom appears the words: "Balbahachas. Missysipy ou fleuve St. Louis." DuPratz described the Mississippi and mentioned the various names by which it was then known, and continued: "Other *Indians,* especially those lower down the river, call it *Balbancha;* and at last the *French* have given it the name of *St. Louis.*"

Drawing of Savages of Several Nations, New Orleans. 1735

Balbahachas. Mississippi or River St. Louis.



Size 11¾ by 17¾ inches

5

CHOCTAW WARRIORS, NATCHEZ CHIEF

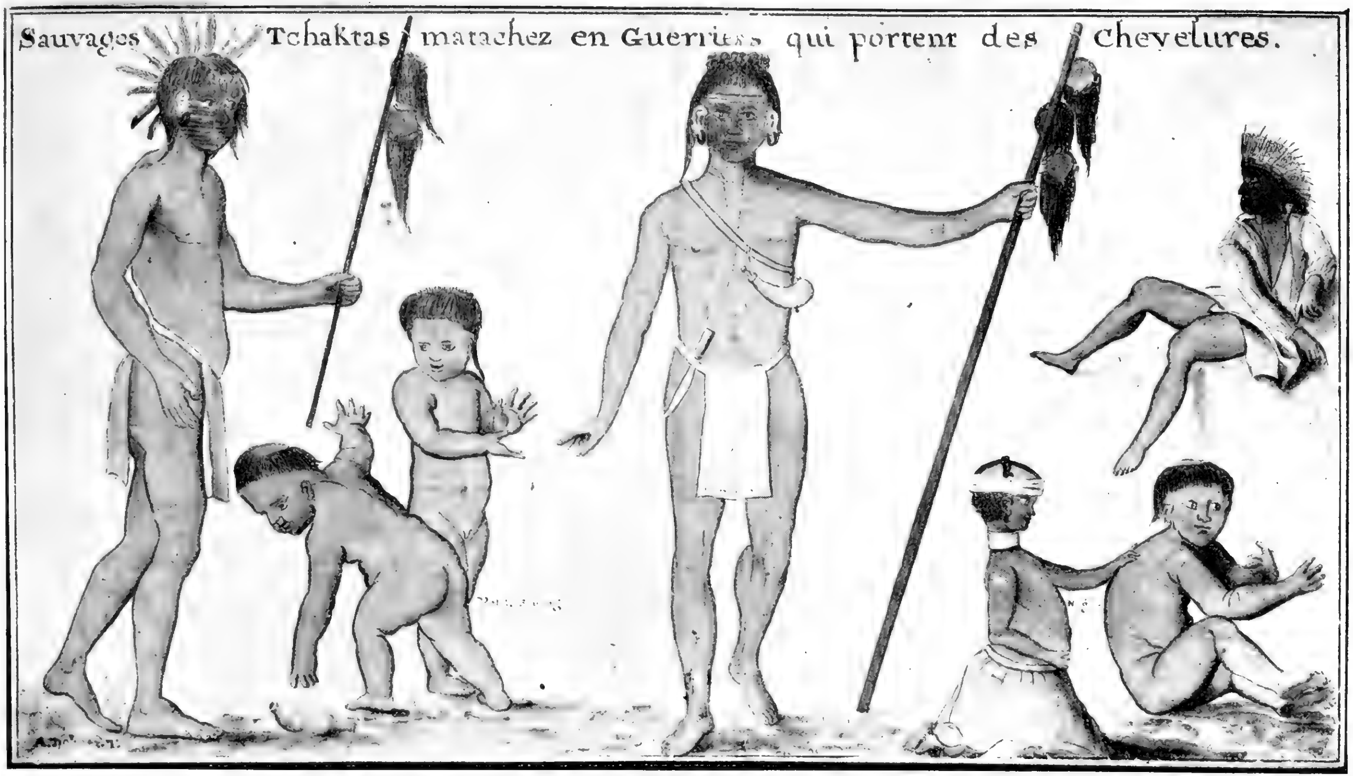
The massacre of the French by the Natchez occurred late in the year 1729. A large number of Choctaw warriors soon joined the remaining French and late in January, 1730, Le Sueur reached the scene of devastation accompanied by a force of many hundred Choctaw. The warriors sketched by DeBatz may have been some of that wild group.

Two young children are shown playing a game.

The seated figure, on the right, evidently represents a Natchez chief, wearing a crown of feathers as described by DuPratz. Early in the spring of 1725 the great Natchez chief Stung Serpent died at the principal Natchez village. When prepared for burial the body was viewed by French officers. DuPratz then wrote: "we found him on his bed of state, dressed in his finest cloaths, his face painted with vermilion, shod as if for a journey, with his feather-crown on his head." And when describing the dress of the Natchez he again mentioned the feather-crown in these words: "The chief ornament of the sovereigns is their crown of feathers; this crown is composed of a black bonnet of net work, which is fastened to a red diadem about two inches broad. The diadem is embroidered with white kernel-stones, and surmounted with white feathers, which in the fore-part are about eight inches long, and half as much behind. This crown or feather hat makes a very pleasing appearance."

Choctaw Savages painted as Warriors, carrying Scalps.

A. Debatz. T.



Size 8¼ by 14¾ inches

6

WINTER COSTUME

Buffalo skins, dressed so as to allow them to become soft and pliable and without removing the hair, were used by the Indians throughout the Mississippi Valley to protect them from the cold of winter. Such robes were often decorated on the inner side by designs painted in several colors. This sketch shows a robe decorated with a simple design in red and black.

The drawing has not been identified but is believed to have been made to represent an Indian belonging to one of the tribes living at that time in the vicinity of New Orleans. The figure suggests the sketch of the "Atakapas" shown in Plate 4, and it may have been intended to portray one of that tribe in winter dress.

A Savage in winter dress.

Size 9½ by 4½ inches

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 6

YAKṢAS

(With 23 Plates)

BY
ANANDA K. COOMARASWAMY
Keeper of Indian, Persian, and Muhammadan Art
Museum of Fine Arts, Boston

(Publication 2926)

CITY OF WASHINGTON
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BALTIMORE, MD., U. S. A.

YAKṢAS

By ANANDA K. COOMARASWAMY

(With Twenty-three Plates)

1. INTRODUCTION

In centuries preceding the Christian era, when the fusion of races in India had already far advanced, the religion of India passed through its greatest crises and underwent the most profound changes. Vedic ritual, indeed, has survived in part up to the present day; but the religious outlook of medieval and modern India is so profoundly different from that of the Vedic period, as known to us from the extant literature, that we cannot apply to both a common designation; medieval and modern Hinduism is one thing, Vedic Brahmanism another. The change is twofold, at once inward and spiritual, and outward and formal.

No doubt we are sufficiently aware of the spiritual revolution indicated in the Upaniṣads and Buddhism, whereby the emphasis was shifted from the outer world to the inner life, salvation became the highest goal, and knowledge the means of attainment. But while this philosophic development and spiritual coming of age have gradually perfumed (to use a characteristically Indian phrase) the whole of Indian civilization, there are here a background and ultimate significance given to the social order, rather than the means of its actual integration; the philosophy of the Upaniṣads, the psychology of Buddhism, indeed, were originally means only for those who had left behind them the life of a householder, and thus in their immediate application anti-social. But few in any generation are ripe for the attainment of spiritual emancipation, and were it otherwise the social order could not survive. The immediate purpose of Indian civilization is not Nirvāṇa or Mokṣa, but Dharma; not a desertion of the household life, but the fulfillment of function. And here, in Karma-yoga, the spiritual support is found, not in pure knowledge, but in devotion to higher powers, personally conceived, and directly approached by appropriate offices (*pūjā*) and means (*sādhanā*). In the words of the *Bhagavad Gītā:* " He who on earth doth not follow the wheel (of activity) thus revolving, liveth in vain. . . . . He that doeth that which should be done, he is the true Monk, the true Yogī, not the recluse who refrains from actions. . . . . Whatsoever thou doest, do thou that as an offering to Me; thus shalt thou be liberated. . . . . He who offereth to Me with devotion a leaf, a flower, a fruit, or water, that I accept. . . . . Howsoever men approach Me, even so do I welcome them, for the path men take from every side is Mine."

In the earlier Vedic books there is a total absence of many of these most fundamental features of Hinduism properly so called; it is only in the Brāhmaṇas and Upaniṣads (and afterwards, much more definitely in the Epics) that the ideas of *Saṁsāra* (the cycle of birth and rebirth), *Karma* (causality), religious asceticism and Yoga, and *Bhakti* (devotion to a personal deity) begin to appear, and the same applies to the cults of Śiva, Krishna, Yakṣas, Nāgas, innumerable goddesses, and localized deities generally. It is natural and reasonable to assume that these ideas and deities derive, not from the Vedic Aryan tradition, but, as De la Vallée-Poussin expresses it, from " un certain fond commun, très riche, et que nous ne connaissons pas parfaitement."[1]

There is much to be said for Fergusson's view (*Tree and Serpent Worship*, p. 244) that " Tree and Serpent worship," *i. e.*, the worship of Yakṣas and Nāgas, powers of fertility and rainfall, " was the primitive faith of the aboriginal casteless Dasyus who inhabited northern India before the advent of the Aryans." But in using language of this kind, a certain degree of caution is necessary; for, in the nature of things, it is only the popular and devotional aspect of these " primitive faiths " of which we are able to recover the traces, and there may well have existed esoteric and more philosophical phases of the same beliefs. We do not know how much of Indian philosophy should really be traced to Āgamic rather than Vedic origins. Indians themselves have always believed in the existence of theistic scriptures, the Āgamas, coeval in antiquity with the Vedas; and if the existence of

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[1] For these groups of ideas as foreign to the Vedas, and for their indigenous source, see De la Vallée-Poussin, *Indo-Européens et Indo-Iraniens; L'Inde jusque vers 300 av. J. C.*, Paris, 1924, pp. 303, 315-6, 320, etc.; Senart, E., *Castes*, pp. xvi-xvii; Jacobi, H., *The Gaina Sutras*, S. B. E., XXII, p. xxi; Keith, A. B., *Religion and philosophy of the Veda*, Harvard Oriental Series, vols. 31, 32, pp. 132, 193, 258; Macdonell, A., *Vedic Mythology*, pp. 153, 154; Vogel, J. Ph., *Indian Serpent lore*, 1926; Charpentier, J., *Über den Begriff und die Etymologie von pūjā*, Festgabe Hermann Jacobi, 1926.

It is to be noticed that all the clans particularly associated (so far as the materials here relied upon are concerned) with Yakṣa worship, are by no means completely Brahmanised, and probably are not of Aryan origin (De la Vallée-Poussin, *L'Inde . . . .*, p. 182).

such scriptures is beyond proof, it is at least certain that religious traditions, which must be spoken of as Āgamic in contradistinction to Vedic, are abundant and must reach far back into the past. This past, moreover, has been proved by recent archeological discoveries to have been much more ancient and to have been characterized by a much higher culture than had been formerly recognized. And we know so well the continuity of Indian racial psychology during the historical period, that we cannot but believe that long before this period begins the Indians had been, as they are today, essentially worshippers of personal deities.

In the beginning, when Aryans and non-Aryans were at war, in the period of military conquest and greatest social exclusiveness, and before the two elements had learned to live together, or had evolved a conception of life covering and justifying all its phases, a divergence between the two types of religious consciousness had been profound; in those days the despised worshippers of the *śiśna* (phallus) might not approach the Aryan sacrifice. As time passed the dividing lines grew fainter, and in the end there was evolved a faith so tolerant and so broad that it could embrace in a common theological scheme all grades of religious practise, from that of the pure monist to that of savages living in the forests and practising human sacrifice.

Now, regarding the accomplished fact, it is not always easy to distinguish the separate elements that made so great a creative achievement possible. We are apt both to over- and underestimate the significance of what we describe as primitive animism.

Hinduism, quantitatively regarded, is a worship of one deity under various aspects, and of genii and saints and demons, whose aid may be invoked either for spiritual or for altogether material ends. This Hinduism, in the period we have referred to, broadly speaking, that of the last three centuries before Christ, was not so much coming into existence for the first time, as coming into consciousness and prominence.

Dr. Vogel, in *Indian Serpent Lore,* has very recently and very admirably studied the old Indian (or perhaps we ought rather to say, the Indian aspect of the widespread Asiatic) cult of Nāgas or Dragons, guardian spirits of the Waters.

In the following pages I have attempted to bring together, from literary and monumental sources, material sufficient to present a fairly clear picture of an even more important phase of non- and pre-Aryan Indian "animism," the worship of Yakṣas and Yakṣīs, and to indicate its significance in religious history and iconographic evolution.

2. YAKṢAS AND YAKṢATTVA ("GENI-HOOD")

The status of a Yakṣa as typically represented (1) in the later sectarian literature and (2) in modern folklore will yield an imperfect, and indeed an altogether erroneous idea of the original significance of Yakṣattva if not examined with cautious reservations. As remarked by Mrs. Rhys Davids:[1]

> The myth of the yakkha, and its evolution still, I believe, await investigation. The English equivalent does not exist. "Geni" (djinn) is perhaps nearest (cf. *Pss. of the Sisters,* p. 30). In the early records, yakkha as an appellation is, like nāga, anything but depreciative. Not only is Sakka so called (M. I, 252), but the Buddha himself is so referred to in poetic diction (M. I, 383).[2]
>
> We have seen Kakudha, son of the gods, so addressed (*Kindred Sayings,* II, 8); and in D. II, 170 the city of the gods, Alakamandā, is described as crowded with Yakkhas ("gods"). They have a deva's supernormal powers. . . . . But they were decadent creatures, degraded in the later era, when the stories of the Jātaka verses were set down, to the status of red-eyed cannibal ogres.

And it may be added that it was only natural that in losing their importance as tutelary deities, the Yakṣas in popular folklore, influenced no doubt by the prejudices already referred to as apparent in the sectarian literature, should likewise have come to be classed with the demoniac Rākṣasas.[3] Their fate in this connection may be compared with that of the Devas at the hands of Zoroaster, or that of the older European mythology under the influence of Christianity (*e. g.,* in Saxo Grammaticus). Notwithstanding this, it is quite possible to gather both from the sectarian and the semi-secular literature a great deal of information incidentally presenting unmistakable evidences of the Yakṣas' once honorable status, their benevolence toward men,

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[1] *Book of the Kindred Sayings,* I, 1917, p. 262. In the above citation, M. is *Majjhima Nikāya* and D. is *Dialogues of the Buddha.* An excellent article on Yakkhas in Buddhist literature will be found under *Yakkha* in the P. T. S. Pali Dictionary.

[2] Elsewhere the Buddha finds it necessary to say that he is not a Deva, Gandhabba, or Yakkha (*Anguttara Nikāya,* II, 37).

[3] For gigantic or cannibal Yakṣas see *Kathāsaritsāgara,* Tawney, I, pp. 127, 337, II, p. 594. For the cult of Yakṣas (Siṁhalese, *Yakā*) surviving as "devil-worship" in Ceylon see Callaway, *Yakkun Nattanawā,* London, 1829; Upham, E., *History and doctrine of Buddhism,* 1829; Parker, *Ancient Ceylon,* London, 1909, Ch. IV and Yakā, Yakkhas in Index (p. 153, a dead man speaking in a dream says, "I am now a Yakā"). For an excellent general account of non-Aryan deities, local and tutelary, beneficent and malevolent, see Whitehead, H., *The village gods of South India,* Oxford, 1916 ("in many villages the shrine is simply a rough stone platform under a tree"), also Mitra, S. C., *Village deities of Northern Bengal,* Hindustan Review, February, 1922, and Enthoven, R. E., *The folklore of Bombay,* Pt. III, *Tree and snake worship.*

and the affection felt by men toward them. As remarked by Lévi (*loc. cit. infra*), "le Yakṣa est essentiellement un personage divin étroitement associé par la tradition aux souvenirs locaux . . . . ils rappellent de bien près nos saints patronaux."

The word Yakṣa[1] is first found in the *Jaiminīya Brāhmaṇa* (III, 203, 272), where, however, it means nothing more than "a wondrous thing." In the sense of a "spirit" or genius, usually associated with Kubera (the chief of Yakṣas) it does not appear before the period of the *Gṛhya Sūtras* where Yakṣas are invoked together with a numerous and very miscellaneous host of other major and minor deities, all classed as Bhūtas,[2] "Beings," in the Gṛhya ritual at the close of Vedic studies;[3] in a somewhat later book they are possessing spirits of disease.[4] The *Śāṅkhāyana Gṛhya Sūtra* mentions Māṇibhadra.

In the *Śatapatha Brāhmaṇa,* Kubera is a Rākṣasa and lord of robbers and evil-doers: this may only mean that he was an aboriginal deity, alien to Brahman orthodoxy. In the Sūtras he is invoked with Īsāna for the husband in the marriage ritual, and his hosts plague children (cf. Hāritī in her original character).

The following Yakṣas and Devatās are represented and named at Bharhut: Supavasu Yakho, Virudhako Yakho, Gaṅgita Yakho, Suciloma Yakho, Kupiro Yakho (Kuvera), Ajakālako Yakho; Sudasana Yakhi, Cadā (Candā) Yakhi; Sirimā Devatā, Culakoka Devatā, Mahakoka Devatā.

Yakṣas by name or as a class are much more familiar figures in the Epics. In the *Rāmāyaṇa,* 3, 11, 94, we find *yakṣattva amaratvam ca,* "spirithood and immortality" together, as boons bestowed by a god or gods. Men of the Sāttvik ("pure") class worship the gods (Devas), those of the Rājasik ("passionate") class, Yakṣas and

[1] The word Yakṣa occurs in the following forms, which are here retained in citations:

Sanskrit, *Yakṣa,* (*f.*) *Yakṣī, Yakṣiṇī:* Pali, *Yakkha, Yakkhī, Yakkhiṇī:* Prakrit, *Jakkha, Jakkhiṇī;* Siṁhalese, *Yakā, Yakī.*

The word is perhaps of indigenous non-Aryan origin. The later *Rāmāyaṇa* proposes an explanation which looks like mere folk etymology: Brahmā created beings to guard the waters, and of these some cried "rakṣāmah," "let us guard," and others "yakṣāmah," "let us gobble," becoming thus Rākṣasas and Yakṣas. The idea is perhaps derived from the big belly which is the most constant feature in Yakṣa iconography.

[2] Śiva is "Bhūteśvara," and Yakṣas are often called Bhūtas; the word Bhūta may mean "those who have become (Yakṣas)," cf. *Mahāvaṁsa,* Ch. X, verse *yakkha-bhūta,* "those that had become Yakṣas."

[3] *Śāṅkhāyana Gṛhya Sūtra,* IV, 9; *Āśvalāyana G. S.,* III, 4; *Pāraskara G. S.,* II, 12. (Keith, *Religion and philosophy of the Veda,* p. 213.)

[4] *Mānava Gṛhya Sūtra,* II, 14: Keith, *ib.* p. 242.

Rākṣasas, those of the Tāmasik ("dark") class, Pretas and Bhūtas (*Mahābhārata,* 6, 41, 4); in other words, the Yakṣas are ranked below the Devas, but above the goblins and ghosts and here distinguished from Bhūtas. But very often they are not clearly distinguished from Devas and Devatās. The Yakṣas are sometimes sylvan deities, usually but not always gentle, like the Vanadevatās (Hopkins, *Epic Mythology,* p. 57; *Āṭānāṭīya Suttanta*).

Kubera or Kuvera (Vaiśravaṇa, Vaiśramaṇa, also in Buddhist literature Vessavaṇa, Pāñcika, Jambhala, etc.),[1] is one of the Four Great Kings (Mahārājas), or Eight Great Devas, a Lokapāla, Regent of the North (sometimes, with Indra, of the East), and the chief of all Yakṣas, whence his epithets Yakṣendra, Deva Yakṣarāja, etc. He is a god of power and productivity: worshipped especially for treasure (as Dhanada, Vasuda, giving wealth).[2] His city Āḷaka situated on Mt. Kailāsa (also the abode of Śiva) is a magnificent walled town, where dwell not only Yakṣas, but also Kiṁnaras, Munis, Gandharvas and Rākṣasas. Very possibly, as M. Goloubew (Ars Asiatica, X) has suggested, the whole of the ceiling of Cave I at Ajaṇṭā may be regarded as a representation of the Paradise of Kuvera. When Kubera repairs to a convention of the gods, he is accompanied by a great host of Yakṣas, collectively designated *Vaiśravaṇa-kāyika-devas.*

Kubera has many beautiful palaces, groves, gardens, etc., on Mt. Kailāsa. These need not be referred to in detail, but it may be remarked of the grove Caitraratha that its trees have jewels for their leaves and girls as their fruits.[3]

The cult of the Lokapālas or Four Great Kings (N. Vaiśravaṇa, E. Dhṛtarāṣṭra, S. Virūḍhaka, W. Virūpākṣa) was extensively developed in Khotān, where they are represented as standing on demon *vāhanams.*[4] Vaiśravaṇa is here very frequently represented with

[1] For Jambhala see Foucher, *L'Iconographie bouddhique de l'Inde,* I, p. 123, and II, p. 51; his śakti is Vasundhārā, the Earth-goddess. He may be surrounded by eight Yakṣiṇīs, Bhadrā, Subhadrā, etc. (ibid., II, 85).

[2] He might be styled Mammon: but not in a bad sense of the word, for from the Indian point of view wealth, prosperity and beauty are rewards of innate virtue, of which, according to the doctrine of *Karma,* Mammon could only be the dispenser. Cf. *Mahābhārata,* 12, 74, 3 f.

[3] Both motifs are of interest on account of their occurrence in decorative art, the Bharhut coping reliefs showing many forms of jewel-bearing creepers (*kalpa-latā*), and medieval art, especially in Ceylon (*nārī-latā* designs, plate 22, fig. 3) many examples of creepers with girls as their flower or fruit. The latter motif, too, may have some connection with the later Arab legends of the Wāqwāq tree.

[4] Stein, *Ancient Khotān,* figs. 30, 31, and pl. II; *Serindia,* p. 870.

shoulder flames. In this connection it should be safe to identify the flaming Kankālī Ṭīlā figure (pl. 16, fig. 2) with Vaiśravaṇa; the corpulent body in any case is that of a Yakṣa, and the flames represent the fiery energy inherent in a king.

Of Kubera's Yakṣa followers we learn a good deal: they possess the power of assuming any shape, the females particularly that of a very beautiful woman (so that an unknown beauty is asked if she be the goddess of the district, or a Yakṣī);[1] they are kindly, but can fight fiercely as guardians (Kubera himself is a "world-protector," and it is chiefly as attendants, guardians and gate-keepers that the Yakṣas appear in Buddhist art, equally in India and in the Far East); they are sometimes specifically grouped with Nāgas, more often with gods, Gandharvas and Nāgas; they are known as "good folk" (*Puṇyajana*) and appear to be countless in number, though few are individually named. Māṇibhadra (Maṇivara, Maṇicara, Maṇimat) in the *Mahābhārata* (5, 192, 44 f.) is a Yakṣarāja, and Kubera's chief attendant. He is invoked with Kubera as a patron of merchants; this may be the explanation of the statue at Pawāyā, set up by a guild (*goṣṭha*) (pl. 1, fig. 2).[2]

Gaṇeśa is undoubtedly a Yakṣa type, by his big belly and general character: but he is not cited by name in any lists. He is effectively and perhaps actually equivalent to Kubera or Māṇibhadra.[3] But the earliest representation of an elephant-headed Yakṣa seems to be that of the Amarāvatī coping, Burgess, *Stupas of Amaravati and Jaggayyapeta,* plate XXX, 1 (here pl. 23, fig. 1); and this is not a Yakṣarāja, but more like a *guhya* or *gaṇa*. Gaṇeśa is son of Śiva, who is himself called Gaṇeśa (Lord of hosts) in the *Mahābhārata*. Gaṇeśa as elephant-headed deity does not appear in the Epic except in the introduction which is a late addition. The figure of Gaṇeśa begins to appear quite commonly in Gupta art, about 400 A. D., *e. g.,* at Bhumara, plate 18, figure 1; at Deogaṛh (pilaster left of the Anantaśayin panel).

There is some confusion of Yakṣas and Rākṣasas, who according to one tradition have a common origin; both have good and evil qualities, benevolent and malevolent as the case may be; very often the same descriptions would apply to either, but the two classes are not identical, and broadly speaking we find the Yakṣas associated with

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[1] *Mahābhārata,* Vana Parva, Ch. CCLXIII (Draupadī).

[2] There exists a "story of the Mahāyakṣa Māṇibhadra" in MS.; see Hoernle in Congr. Int. Orientalistes, 12, Rome, 1899, Vol. I, p. 165.

[3] Cf. Scherman, *Dickbauchtypen in der indischen Götterwelt,* Jahrb. as. Kunst, I, 1724. Also M. F. A. Bulletin, No. 154.

Kubera, the Rākṣasas with Rāvaṇa, who is their chief. Yakṣas as a rule are kindly, Rākṣasas bloodthirsty.[1]

Yakṣas are not only the attendants, but also the bearers of their Lord Vaiśravaṇa. They play, indeed, the part of bearers or supporters in all kinds of situations where their attitude is one of friendly service; thus, they are constantly represented as supporting the four legs of Kanthaka, on the occasion of the Abhiniṣkramaṇa (Great Renunciation, or Going Forth of the Buddha).[2] They bear, too, the pavilion in which the Bodhisattva descends to take incarnation in the womb of Māyā Devī (pl. 21, fig. 1). In connection with Vaiśravaṇa, and other deities, the Guhyas appear in crouching dwarfish forms as supporters; in fact, as "vehicles" (*vāhanam*) as in plate 3, figure 1, etc. Some of these types have been preserved with remarkable fidelity in Far Eastern art, in the case, for example, of the Jikoku-Ten of the Kondō, Nara, Japan,[3] so closely resembling the Kubera from Bharhut (pl. 3, fig. 1), and the Śiva figure of the Guḍimallam liṅgam (pl. 17, fig. 1). In the case of Śiva, the Yakṣa vehicle in later images (Naṭarāja, etc.) has come to be regarded as a demoniac symbol of spiritual darkness (*apasmāra puruṣa,* or *mala*).

Kuvera is also "Naravāhana," but the Naras here in question are not men, but mythological beings variously described, sometimes as bird horses, which may possibly explain the occasional representation of winged Atlantes (pl. 13, figs. 2 and 3, also Foucher, *L'art gréco-bouddhique* . . . ., fig. 314). The interpretation Naravāhana = borne by men, is later.

As Atlantes, supporters of buildings and superstructures (pl. 13, figs. 1, 2, 3), and as garland-bearers (pl. 23, figs. 1, 2) Yakṣas are constantly represented in early Indian art (Bharhut, Sāñcī, Gandhāra, etc.). Those who support Kuvera's flying palace are designated Guhyas (*Mahābhārata,* 2, 10, 3); Kuvera is Guhyapati. The Guhyas are essentially earth-gnomes (cf. pl. 13, fig. 1). The Yakṣiṇī of *Kathāsaritsāgara,* ch. XXXVII, who carries a man through the air, is called a Guhyakī.

Some Yakṣagrahas (demon possessors, causing disease) are attendants of Skanda, who is sometimes called Guha, a name which

[1] For a detailed summary of the Epic accounts of Kubera and the Yakṣas, see Hopkins, *Epic Mythology,* p. 142 ff., also pp. 30, 38, 57, 67 ff., 145, 148, etc. See also Waddell, *Evolution of the Buddhist cult,* J. R. A. S. Any connection with the Greek Kabeiros is very improbable (Keith).

[2] E. g., Foucher, *L'art gréco-bouddique du Gandhāra,* 1, pp. 357, 554 ff., and figs. 182-4, ch.; Stein, *Serindia,* p. 858.

[3] For the Nara figure see *Nara Horyūjī Okagami,* Vol. 38, pl. 7, or Warner, *Japanese sculpture of the Suiko period,* fig. 35.

may be related to the Guhyas, attendants of Kuvera (Hopkins, *Epic Mythology*, pp. 145, 229).

Yakṣas (like Nāgas) are sometimes regarded as constructive or artistic genii: thus Hsüan Tsang, Bk. VIII, speaks of the Aśokan remains at Pāṭaliputra as having been built by genii (Yakṣas).[1]

Kubera himself can be regarded as the first smelter of gold.[2]

Comparatively few individual Yakṣiṇīs are mentioned by name; the *Mahābhārata* (3, 83, 23) speaks of a Yakṣiṇī shrine at Rājagṛha as "world-renowned." But it is beyond doubt that Yakṣiṇīs were extensively worshipped, in part as beneficent, in part as malevolent beings. In the latter aspect they do not differ essentially from their modern descendants, such as the Bengali Sītalā, goddess of smallpox, or Olābībī, goddess of cholera. The Seven Mothers (who are in part connected with Kubera), the Sixty-four Joginīs, the Ḍākinīs, and some forms of Devī, in medieval and modern cults, must have been Yakṣiṇīs. In Southern India, indeed, to the present day, nearly all the village deities are feminine. Mīnākṣī, to whom as wife of Śiva, the great temple at Madura is dedicated, was originally a daughter of Kubera, therefore a Yakṣiṇī. Durgā was originally a goddess worshipped by savage tribes.

The case of Hāritī is too well known to need a long discussion. To sum up her story, she was originally a Magadhan tutelary goddess, wife of Pāñcika and residing at Rājagṛha; she was not ill-disposed, for her name Nandā means Joy. She was called even in Hsüan Tsang's time the Mother of Yakṣas, and the people prayed to her for offspring. But Buddhist legend has it that she had begun to destroy the children of Rājagṛha by smallpox, and so earned the name of Hāritī, "Thief," by which she is known to Buddhism; metaphorically, she was said to "devour" them, and is represented as an ogress, and it was as an ogress that the Buddha encountered her. The Buddha adopts the expedient of hiding her last-born child (Piṅgala, who had been a human being in a previous life, the Yakṣa birth being here a penalty); she realizes the pain she has been causing others, and becomes a convert; but as she can no longer seek her accustomed food, the Buddha promises that she shall receive regular offerings from pious Buddhists, as a patroness of children and fertility. This reads more like an explanation or justification of a cult than a true account

[1] Beal, *Buddhist Records*, II, p. 93. *Cf.* also Laufer, *Citralakṣaṇa*, pp. 189, 190, where a late Tibetan author ascribes Aśoka's works at Bodhgayā to Yakṣas and Nāgas, and speaks of certain Indian medieval sculpture and paintings as like the art-work of the Yakṣas.

[2] Hopkins, *Epic Mythology*, p. 146.

of its origin; probably this was the best way to provide an edifying sanction for an ancient animistic cult too strong to be subverted. Hāritī is also constantly represented together with Pāñcika, forming a Tutelary Pair (Gandhāra, Mathurā, Java, etc., pl. 15, fig. 1; pl. 21, figs. 3-5).[1]

A Yakkhiṇī by name, or rather, epithet, Assa-mukhi ("horse-faced") plays an important part in the *Padakusalamāṇava* Jātaka. There may be specific reference to this *Jātaka* whenever a horse-headed Yakkhiṇī is represented on the medallions of Buddhist railings[2] (pl. 12, fig. 1). But the Kiṁnaras and Kiṁpuruṣas, and Gandharvas too, typically half-human, half-equine, are a class of beings frequenting forests and mountains (cf. the *vaḷava-mukha* Cetiyā, of Paṇḍukābhaya, *infra*, p. 16) and as such are sometimes naturally represented as a part of the scenery, and in such cases there need be no reference to the *Jātaka*.[3]

In the *Maṇicūḍāvadāna* a Yakṣiṇī undertakes to bring about a marriage, and to this end has the marriage "represented" (*mūrtivaivāhikaṁ karma*, presumably in a painting).[4]

In the Jaina *Bhagavatī Sūtra* (Hoernle, *Uvāsagadasāo*, Appendix) Puṇṇabhadda and Māṇibhadda are called powerful Devas, and they appear together to those who practise certain austerities. Another work gives the following list of "Devas" who are obedient to Vaiśramana: Puṇṇabhadda, Māṇibhadda, Salibhadda, Sumaṇabhadda,

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[1] For Hāritī see Foucher, *The Buddhist Madonna*, and *Tutelary Pair*, in *The beginnings of Buddhist art; L'art gréco-bouddhique du Gandhara;* Vogel, *The Mathura school of sculpture*, A. S. I., A. R., 1909-10, p. 77; Watters, *On Yuan Chwang*, I, 216; Beal, *Records* . . . ., I, 110; Waddell, *Lamaism*, p. 99; Chavannes, in T'oung Pao, 1904, p. 496 f.

[2] Mitra, R., *Buddha-Gayā*, pl. XXXIV, 2; Foucher, in Mem. conc. l'Asie orientale, III, 1919, pl. I; Waddell, *Report on excavations at Pāṭaliputra*, pl. I. Perhaps also Ajaṇṭā, Cave XVII (Griffiths, pl. 142, b).

[3] At Bhājā, HIIA, fig. 27, lower r. corner; Mandor, HIIA, fig. 166. Kiṁnaras in Indian literature and art are of two types (1) horse-headed, as above, and (2) half bird, half human (siren type). Both kinds are musical, and may be classed in this respect with Gandharvas. The masculine horse-headed type is rare: examples in *Cat. Ind. Collections, Boston, V. Rajput Painting*, No. CLIX (called Gandharvas, one Nārada), and in Arts et Archéologie khmèrs, II, fig. 56, *bis*. Most likely the horse-headed type is not a Kiṁnara at all.

[4] In the *Svayambhu Purāṇa*, De la Vallée Poussin, J. R. A. S., 1894, p. 315. Here we have the normal connection of Yakṣiṇīs with human marriage. The *mūrti-vaivāhika* motif appears also in Bhāṣa's *Svapnavāsavadatta*, and is represented in a Rajput Painting of the eighteenth century (*Cat. Ind. Coll.*, V, *Rajput paintings*, p. 189).

Cakṣurakṣa, Purṇarakṣa, Savvana, Savvajasa, Savakāma, Samiddha,[1] Amohe, Asaṁta. It may be remarked incidentally that nearly all these names of Yakṣas are auspicious, implying fullness, increase, prosperity, etc.

As we have seen, Yakkhas are often called Devas in the Jaina books, where, as Śāsana Devatās, they are usually guardian angels. But it is not at all clear whether the "false and lying Devas" who persecute the followers of Mahāvīra in the *Uvāsagadasāo*, §§ 93 f., 224, etc., are to be regarded as Yakkhas or not. That they should be so regarded in one case at least (§ 164) is suggested by the fact that the Deva here appears in an *asoga* (aśoka)-grove and takes possession of objects laid on an altar. It may also be remarked that the Deva of § 93 is an expert shape-shifter, which is a characteristic power for Yakkhas; the text speaks of the "Pisāya (Piśāca) form of the Deva," and it may be that the Yakkhas, like the more orthodox Brāhmaṇical deities had their *śānta* and *ugra* forms. But even if these false and lying Devas are Yakkhas, it need not be forgotten that their objectionable qualities are emphasized in the interests of Jaina edification.

The Āṭānāṭīya Suttanta (*Digha Nikāya*, III 195 f.),[2] however, speaks of good and bad Yakkhas, the latter being rebels to the Four Great Kings (Kubera, etc.). If any of these assail a Buddhist monk or layman, he is to appeal to the higher Yakkhas; Vessavaṇa himself supplies to the Buddha the proper invocation, and gives a list of the Yakkha chiefs; the list includes Ind(r)a, Soma, Varuṇa, Pajāpati,[3] Maṇi (-bhadda), Āḷavaka, etc. It will be observed that the first four mentioned are orthodox Brāhmaṇical deities; but this is not the only place in which Indra (Sakka) is spoken of as a Yakkha. Vessavaṇa (Kubera) goes on to say that there are Yakkhas of all ranks who do, and others who do not believe in the Buddha, "But for the most part, Lord, Yakkhas do not believe in the Exalted One."[4]

Another list of Yakṣas is to be found in the *Mahāmāyūrī*,[5] a work which goes back to the third or fourth century A. D. In this list we

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[1] In *Mahāvaṁsa*, I, 45, the Deva Samiddhisumaṇa inhabits a *rājāyatana*-tree in the Jetavana garden at Sāvatthī: he had been a man in Nāgadīpa.

[2] S. B. B., vol. 4 (*Dialogues of the Buddha*, 3). This text contains much valuable information on Yakkhas.

[3] With Pajāpati, cf. Prajāpatī, name of a Joginī, Patainī Devī temple (A. S. I., A. R., Western Circle, 1920, p. 109).

[4] A similar distinction of good and bad Yakṣas is made in *Mahāvaṁsa*, XXXI, 81, "Moreover, to ward off the evil Yakkhas the twenty-eight Yakkha chieftains stood keeping guard." The twenty-eight Yakṣarājas are again referred to in *Lalita Vistara*, Ch. XVI.

[5] Lévi, S., *Le catalogue géographique de Yakṣa dans le Mahāmāyūrī*, J. A., 1915.

find *Nandi ca Vardhanaścaiva nagare Nandivardhane,* "Nandi and Vardhana, these twain, have their seat in the city of Nandivardhana"; a Chinese commentator on the *Avataṁsaka Sūtra* has stated that this city was in Magadha, as indeed the Sūtra itself implies. All this is of interest because two Yakṣa statues (pl. 2, figs. 1 and 2) have been found near Patna, and they bear inscriptions of which one reads *yakha ta vaṭa naṁdi.* The conclusion arrived at by Gangoly, that the pair represent the tutelary Yakṣas of Nandivardhana may be correct.[1] But the *Mahāmāyūrī* list has also a Nandi Yakṣa of Nandinagara, separately mentioned. There are several Nandinagaras known; one is frequently mentioned in the Sāñcī inscriptions. It seems to me that the Patna figure designated as the Yakṣa Nandi in the inscription may just as well be Nandi of Nandinagara as Nandi of Nandivardhana; this would leave the second statue unidentified, as it is not named in the inscription. In the same list Māṇibhadra and Purṇabhadra are called brothers. Others mentioned include Viṣṇu, Kārttikeya, Śaṅkara, Vibhīṣaṇa, Krakucchanda, Suprabuddha, Duryodhana, Arjuna, Naigameśa (tutelary Yakṣa of Pañcālī), Makaradhvaja (=Kāmadeva, the Buddhist Māra), and Vajrapāṇi. The last is said to be the Yakṣa of Vulture's Peak, Rājagṛha, where is his *kṛtālaya* ("made abode," evidently a temple); in the *Yakkha Suttas* Sakka (? Indra), who is called a Yakkha of Māra's faction, may not be the same as the Yakṣa Vajrapāṇi. Naigamesa is the well-known antelope-headed genius, Indra's commander-in-chief, who both in Brāhmanical and Jaina mythology is connected with the procreation of children.[2]

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[1] Gangoly, O. C., in Modern Review, Oct. 1919. Also Chanda, R., *Four Ancient Yakṣa statues,* Univ. of Calcutta, Anthropological Papers, 3 (Journ. Dep. Letters, IV, Calcutta, 1921), and references there cited.

[2] It will be seen that the list includes the names of orthodox Hindu deities, Epic heroes, and others. Suprabuddha in Buddhist legend is the father-in-law (rarely the grandfather) of the Buddha, and is one of the five persons who suffered condign punishment for crimes committed against the Buddha or the Order, one of the others being the Yakṣa Nandaka. Krakucchanda is a former Buddha.

Śaṅkara is one of the well-known names of Śiva, whose close connection with Yakṣas is shown in many ways, *inter alia,* by the existence of numerous temples dedicated to him under names which are those of Yakṣas, *e. g.,* the Virūpākṣa temple at Paṭṭadkadal. Śiva's followers called Pāriṣadas are huge-bellied like Yakṣas. Cf. Hopkins, *Epic Mythology,* pp. 221-222.

For Naigameśa(ya) (Nejameṣa, Naigameya, Hariṇegameṣī) see Winternitz in J. R. A. S., 1895, pp. 149 ff.; Keith, *Religion and Philosophy of the Veda,* p. 242. Naigameṣa in the Epic is generally a goat-faced form of Agni. As Hariṇegameṣī he plays an important part in the conception and birth legend of

In Buddhist works the Yakkhas are sometimes represented as teachers of good morals, and as guardian spirits. Thus in *Thera-therī-gāthā,* XLIV, Sānu Sutta,[1] Sānu had been the son of a Yakkhiṇī in a former birth; now this Yakkhiṇī "controlling" (as Spiritualists would say) Sānu, warns and advises his present human mother as follows:

Your son has a tendency to roam, wherefore bid him rouse himself. Tell him what the Yakkhas say:

"Do nought of evil, open or concealed,
If evil thou doest or wilt do,
Thou shalt not escape from evil e'en though thou flee."

But more often, as in the *Āṭānāṭīyā Suttanta,* the Yakkhas are said to be unbelievers, to whom the ethics of the Buddhas are distasteful; they "haunt the lonely and remote recesses of the forest, where noise, where sound, hardly is, where breezes from the pastures blow, hidden from men, suitable for meditation. There do eminent Yakkhas dwell, who have no faith in the word of the Exalted One."[2]

In the Vijaya legend the aboriginal inhabitants of Ceylon are called Yakkhas.[3] One of Vijaya's men follows a bitch, who is the Yakkhiṇī Kuvaṇṇā in disguise; she bewitches him, and all those who follow him, but cannot devour them, as they are protected by charmed threads. Vijaya follows, overcomes the Yakkhiṇī, and obtains the release of the men; Kuvaṇṇā takes the form of a beautiful girl, and Vijaya marries her (almost the Circe motif!). She enables him to destroy the invisible Yakkhas who inhabit the land, and he becomes

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Mahāvīra (in the *Kalpa Sūtra,* see Jacobi, S. B. E., XXII). In the *Antagaḍa Dasāo* we find him worshipped (Barnett, *Antagaḍa Dasāo,* p. 67, cited below, p. 25). He is represented in an early relief from Mathurā (Smith, *Jaina stupa of Mathura,* pl. XVII) with an inscription in which he is designated Bhagavā Nemeso; also in some other early but mutilated reliefs in the Mathurā Museum., and regularly in the illustrations to the Jaina manuscripts of the *Kalpa Sūtra* (Coomaraswamy, *Cat. Indian Collections,* Museum of Fine Arts, Boston, pt. IV).

Māra, and his hosts of deformed demons, is brilliantly represented at Sāñcī, north *toraṇa,* middle architrave, back (pl. 23, fig. 3). In a medieval relief at Sārnāth he is provided with a *makaradhvaja* (Ann. Rep. Arch. Surv. India, 1904-05, p. 84): as Kāmadeva, with Rati, at Elūrā, in the Kailāsa shrine, he also has a *makaradhvaja.*

[1] Rhys Davids, *Psalms of the Brethren,* p. 48. *Cf. ibid.,* p. 245, the older and later attitude side by side, the Yakkha, though a cannibal, being invoked as the guardian of a child.

[2] *Dīgha Nikāya,* III, 195 (Rhys Davids, *Dialogues of the Buddha,* Part 3, in S. B. B., IV).

[3] *Mahāvaṃsa,* Ch. VII.

king. Later, he repudiates her and marries a human princess. She returns to the Yakkhas, but is killed as a traitress. Her two children became the ancestors of the Pulindā (perhaps the Veddas, who are still worshippers of Yakkhas; perhaps as ancestors?). In this story the Yakkhas, though credited with supernatural powers, seem to be regarded as aborigines themselves.

Not only may a human being be reborn as a Yakṣa, but vice versa.[1] A very interesting case of such a rebirth appears in the Indrakīla inscription, near Bezwāḍā, of the ninth century. This inscription occurs on a stele, sculptured with reliefs illustrating the Kiratārjuna episode of the *Mahābhārata;* the stele was set up by one Trikoṭṭi-Boyu, who regarded himself as an incarnation of the friendly Yakṣa who at Indra's behest guided Arjuna to the inaccessible Indrakīla hill, there to wrestle with Śiva and to receive the *Pāśupata astram.* Extant texts of the Epic do not mention any Yakṣa, but some version of the story must have known him, and Trikoṭṭi-Boyu regarded him as an ancestor.[2]

3. YAKṢAS AS TUTELARY DEITIES (PATRON SAINTS) AND GUARDIAN ANGELS

In many cases Yakṣas have been human beings attached to the service of a community or individual, and, reborn as a spirit or geni, continue to watch over those whom they had formerly served. Thus, from a Tibetan source[3] we get the following story connected with the times of king Bimbisāra, a contemporary of the Buddha:

> At that time one of the gate-keepers of Vaisali had died and had been born again among the demons. He gave the inhabitants of Vaisali the following instructions: "As I have been born again among the demons, confer on me the position of a Yakṣa and hang a bell round my neck. Whenever foe to the inhabi-

[1] The doctrine of reincarnation is not Vedic, and in view of the suggestions of indigenous origin that have been plausibly made, it is of interest to note how constantly the idea of rebirth is connected with the Yakṣa mythology, in which a Yakṣa may have been, or may again become a human being. Hodson, T. C., *The Primitive Culture of India,* p. 7, and Lecture V, *passim,* shows that a belief in reincarnation is widely spread amongst primitive tribes in India (Khonds, Bhuiyas, Garos, etc.). The Lushais (p. 105) desire to escape from the mortal coil of reincarnation. Santals say that "good men enter into fruit-trees" (Sir W. Hunter, *Annals of Rural Bengal*). According to a Buddhist tradition Kuvera himself was once a very charitable Brahman (S. B. B., IV, p. 193, note 4).

[2] Sastri, H. K., *The sculptured pillar on the Indrakila hill at Bezwada,* Ann. Rep. Arch. Surv. India, 1915-16.

[3] Schiefner, A., *Tibetan tales from the Kah-gyur* (Ralston, p. 81).

tants of Vaisali appears, I will make the bell sound until he is arrested or has taken his departure."[1] So they caused a Yakṣa statue to be prepared and hung a bell round its neck. Then they set it up in the gatehouse, provided with oblations and garlands along with dance and song and to the sound of musical instruments.

The same Tibetan sources show that the Śākyas honored a Yakṣa by name Śākyavardhana (" He who prospers the Śākyas ") as a tutelary deity. This tradition is recorded in the Tibetan Dulva;[2] we need not believe in the miracle, but there is every possibility that there was a tutelary Yakṣa of the Śākya clan, and that the Śākyas presented their children in the temple. Moreover, the Presentation is four times illustrated at Amarāvatī (pl. 20, also Fergusson, *Tree and Serpent Worship*, pls. LXIX, XCI, 4, and Burgess, *Buddhist stupas . . . .*, frontispiece, detail left of center, and pl. XXXII, 2). According to the text,

It was the habit of the Śākyas to make all new-born children bow down at the feet of a statue of the Yakṣa Sākyavardhana (*Sākya-sphel* or *spel*); so the king took the young child (the Bodhisattva, Siddhārtha) to the temple, but the Yakṣa bowed down at his feet . . . . and when the king saw the Yakṣa bow down at the child's feet he exclaimed, " He is the god of gods," and the child was therefore called Devatideva.

The same tradition is found in the Chinese *Abhiniṣkramaṇa Sūtra* (the late sixth century Chinese version by Jñānakuṭi),[3] but the temple is called a Deva temple, and the Deva's name is Tsang Chang, for which the equivalent Dīrghāvardana is suggested. The story is much more elaborated in the *Lalita Vistara*, Ch. VIII, where the temple is full of statues of gods (Śiva, Sūrya), and all bow down to the child; this is obviously a later development.

In the Jaina *Uttarādhyayana Sūtra*, Ch. III, 14-18, it is stated as a general rule that Yakṣas are reborn as men when their stock of merit (acquired, of course, in a previous life on earth) is exhausted.

Not only human beings, but even animals may be reborn as tutelary Yakṣas. The following story of the Jaina saint Jīvaka is related in the Tamil classic, the *Jīvaka-cintāmani*:[4] Jīvaka rescues a drowning dog,

[1] As regards the bell; it should be observed that the voice of Devas and Yakṣas is often said to be like the sound of a golden bell (*e. g.*, *Saṁyutta Nikāya*, Yakkha Suttas, § 8 (Commentary), and Sakka Suttas, II, § 10 (Commentary). For Yakṣas with bells see plate 12, figure 2; plate 13, figure 3; and plate 18. For a very similar story from the *Divyāvadāna* see Appendix.

[2] Rockhill, W. W., *Life of the Buddha from Tibetan works in the Bkah-Hgyur and Bstan-Hgyur*, p. 17; Csoma de Köros, *Analysis of the Kah-Gyur*, Asiatic Researches, XX, p. 289. Cf. Watters, *On Yuan Chwang*, II, 13, 14, with some other references, including *Divyāvadāna*.

[3] Beal, S., *Romantic history of Buddha*, p. 52.

[4] Vinson, J., *Légendes bouddhistes et djainas*, Paris, 1900, t. 2, p. 43.

or, to be more exact, recites to it the *mantra* of the Five Namaskāras, whereby it is reborn as a deity, a chief of the Yakṣas; as such it is called Sutañjana and lives in Candrodaya ("Moonrise") on the white Mt. Saṅga. Later, Jīvaka is imprisoned by his enemies; he calls to mind Sutañjana, who immediately experiences a trembling which brings Jīvaka to his mind (cf. the heating or quaking of Indra's throne when good men are in distress), and he hastens to the rescue. He produces a great storm, and under cover of it carries off Jīvaka and takes him to his heavenly palace. Later, he bestows on Jīvaka three great spells (*mantras*) which bestow marvellous beauty, destroy poison, and give the power of shape-shifting, and finally takes him back to earth. There Jīvaka erects and endows a temple and sets up a statue in it.

A detailed story of Yakkhas is given in the *Mahāvaṁsa*, chapters IX, X. It may be summarized as follows:

Prince Gāmaṇi had two attendants, Citta and Kāḷavela, respectively a herdsman and a slave. He fell in love with the Princess Cittā; but it had been prophesied that the latter's son would slay the Prince's uncles, who were then in power. However, the Princess became enceinte, and the marriage was permitted; but it was decided that if a son should be born, he should be put to death, and meanwhile Citta and Kāḷavela were executed for their part in the affair. "They were reborn as Yakkhas, and both kept guard over the child in the mother's womb." The child, a son, was duly born, and was called Paṇḍukābhaya; he was exchanged with the new-born daughter of another woman, and thus brought up in safety away from the court (cf. the story of the infant Kṛṣṇa). When the young prince was once in sudden danger, the two Yakkhas appeared to save him.

Later on, Paṇḍukābhaya captured a Yakkhiṇī mare, described as *vaḷavarūpā* or *vaḷavā-mukha,* "mare-shaped" or "mare-faced" (cf. Assamukhī, discussed below); her name was Cetiyā, and she used to wander about the Dhūmarakkha mountain in the form of a mare, with a white body and red feet. Paṇḍukābhaya bored her nostrils and secured her with a rope; she became his adviser, and he rode her in battle. When at last established on the throne (in Anurādhapura), Paṇḍukābhaya "settled the Yakkha Kāḷavela on the east side of the city, the Yakkha Cittarāja at the lower end of the Abhaya tank. The slave-woman who had helped him in time past (as foster-mother) and was (now) reborn as (or of) a Yakkhiṇī, the thankful (king) settled at the south gate of the city. Within the royal precincts he housed the Yakkhiṇī having the face of a mare. Year by year he had sacrificial offerings made to them and to other (Yakkhas); but on festival days he sat with Cittarāja beside him on a seat of equal height, and having gods and men to dance before him, the king took his pleasure in joyous and merry wise. . . . . With Cittarāja and Kāḷavela who were visible,[1] the prince enjoyed his good fortune, he that had those that had become Yakkhas for friends."[2]

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[1] *I. e.,* were represented by statues.

[2] Alternatively, "had Yakkhas and Bhūtas for friends."

4. SHRINES AND TEMPLES (*CAITYA, AYATANA*)

The haunt or abode (*bhavanam*) of a Yakṣa, often referred to as a *caitya* (Pali, *cetiya,* Prakrit, *cēiya*) or *āyatana* (Prakrit, *āyayaṇa*) may be outside a city, in a grove, on a mountain or at a *ghāṭ* (shrines of Puṇṇabhadda and Moggara-pāṇī; those of the Indra's Peak Yakkha, and the Yakkha Suciloma near Rājagaha mentioned in the *Saṁyutta Nikāya,* Yakkha Suttas (*Kindred Sayings,* I, p. 264); and the Yakṣa shrine and image of *Uttarādhyayana Sūtra,* ch. XII, S. B. E., XLV, p. 50, note), or by a tank (the Yakkha Cittarāja, *Mahāvaṁsa,* ch. X); or at the gates of a city (slave woman reborn as a Yakkhinī, *Mahāvaṁsa,* chapter X, and the tutelary Yakṣa of Vaiśālī mentioned above); or within a city (shrine of Māṇibhadra, *Kathāsaritsāgara,* ch. XIII) or even within the palace precincts (shrine of the Yakkhiṇī Cetiyā, *Mahāvaṁsa,* ch. X). These shrines are constantly spoken of as ancient, magnificent, famous, or world-renowned.

The essential element of a Yakṣa holystead is a stone table or altar (*veyaḍḍi, mañco*) placed beneath the tree sacred to the Yakṣa. The *bhavanam* of the Yakkha Suciloma at Gayā is particularly described as a stone couch (better rendered as dais or altar) by or on which the Buddha rested; the words used are *taṅkita mañco,* explained in the commentary to mean a stone slab resting on four other stones (*Saṁyutta Nikāya,* Yakkha Suttas, ch. X, *Kindred Sayings,* I, p. 264). At the Puṇṇabhadda cēiya described below there were not only altars (and probably an image) in an elaborate temple, but also a decorated altar beneath an aśoka-tree in the grove.

It was just such an altar beneath a sacred tree that served as the Bodhisattva's seat on the night of the Great Enlightenment; Sujātā's maidservant, indeed, mistakes the Bodhisattva for the tree-spirit himself (*Nidānakathā*). It is very evident that the sacred tree and altar represent a combination taken over by Buddhism from older cults, and in the case of the Bodhi-tree we see the transference actually in process.

How often the *bhavanas* of the Yakṣas mentioned in Buddhist and Jaina literature should be regarded as constructed temples it is hard to say. Some, like the Puṇṇabhadda cēiya, were certainly buildings, independent of the altar beneath a sacred tree. In references to constructed temples supposed to have existed in the latter centuries preceding the Christian era there is nothing at all improbable; some of the *āyatanas* and *caityas* of the Epics are certainly buildings, and sometimes contain statues. So, too, in Manu, 4, 39. The Caṇḍāla temple of *Mahābhārata,* 12, 121 (post-epical) has images and bells, and may have been a Yakṣa shrine, or the shrine of a goddess. Structural temple architecture was already far advanced in and before the Kuṣāna period.[1] The existence of images (and Yakṣa images are the oldest known images in India) in every case implies the existence of temples and a cult.

On the other hand it is quite certain that the word *caitya* sometimes means no more than a sacred tree, or a tree with an altar; such are designated *caitya-vṛkṣas* in the Epics, and it is stated in the *Mahābhārata,* Southern Recension, 12, 69, 41 ff., that such holy trees should not be injured inasmuch as they are the resorts of Devas, Yakṣas, Rākṣasas, etc. Even when as so often happens in Buddhist literature, the Buddha is represented as halting or resting at the *bhavanam* of some Yakkha, it does not follow that a building is meant; the *bhavanam* may have been only a tree sacred to a Yakṣa, and such sacred trees are natural resting and meeting places in any village, as at the present day. But in *Saṁyutta Nikāya,* Yakkha Suttas, IV, it is expressly stated that the *bhavanam* of the Yakkha Maṇibhadda was called the Maṇimāla caitya (the Jaina *Sūrya-prajñapti* says that the Maṇibhadda cēiya lay to the northeast of the city of Mithilā). As the shrines of Maṇibhadda and Puṇṇabhadda seem to have been the most famous of all Yakkha shrines, it is most likely that the former as well as the latter was a real temple, and indeed it is described as a temple with doors and an inner chamber in *Kathāsaritsāgara,* chapter XIII. We know, too, that a statue of Maṇibhadda was set up at Pawāyā,[2] and this must have been housed in some kind of structure. Śākyavardhana's shrine, too, in the Tibetan text and in one of the Amarāvatī reliefs, is a temple: so also the *kṛtālaya* of Vajrapāṇi in the Mahāmāyūrī list.

On the whole, then, we may be sure that in many cases Yakṣa shrines, however designated, were structural buildings. What were they like? The passages cited in the present essay tell us of buildings with doors, and arches (*toraṇe,* which may refer either to gateways like the Buddhist *toraṇas,* or, as the text has, "on its doorways," probably to stone or wooden pediments, with which we are familiar from the Maurya period onwards);[3] and of images and altars within

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[1] Cf. HIIA, figs. 41, 43, 45, 62, 69, 70, 142: M. F. A., Bulletin, Nos. 144, 150: Parmentier, *L'Art khmèr primitif,* p. 349, and *Origine commune des architectures dans l'Inde et en Extrême-Orient,* in Études Asiatiques.

[2] See Garde, M. B., in Arch. Surv. India, Ann. Rep. 1914-15, Pt. I, p. 21 and *The site of Padmāvatī, ib.* 1915-16, p. 105 and Pl. LVII. See also p. 28.

[3] Cf. Smith, V. A., *Jaina stupa of Mathurā,* pls. XIX, XX; Coomaraswamy, in M. F. A. Bulletin, No. 150 (August, 1927).

the buildings. Indian styles of architecture, of course, are not sectarian; the style is that of the period. So that to discuss this question fully would involve a discussion of all structural temple architecture from the Maurya to the Kuṣāna period inclusive; which would not be altogether impossible, on the basis of literary references, and representations in reliefs. This would take up too much of the space at present available. But it may be observed that the Gujarātī commentators gloss the word *jakkhāyayaṇa* by *āyat thānak dehro,* a little domed temple.[1] This description would very aptly characterize the little domed pavilions which are represented on Audumbara coins from Kāṅgṛā about the beginning of the Christian era, and on somewhat similar coins from Ceylon,[2] while a more elaborate structure of the same type is seen in the Sudhammā Deva-sabhā in the well-known Bharhut relief (early second century B. C.).[3] Another example of a "little domed temple" is the fire temple of the Sāñcī relief, east *toraṇa,* left pillar, inner face, second panel. Cf. also HIIA, figure 145.

One of the detailed descriptions of a Yakṣa holystead may be quoted in full: this is the famous shrine of the Yakṣa Pūrṇabhadra (Puṇṇabhadda) of which a long account is given in the *Aupapātika Sūtra.*[4]

> Near Campā there was a sanctuary (*cēiya*) named Puṇṇabhadde. It was of ancient origin, told of by men of former days, old, renowned, rich, and well known. It had umbrellas, banners, and bells; it had flags, and flags upon flags to adorn it, and was provided with brushes.[5]

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[1] Barnett, *Antagaḍa Dasāo,* p. 13, n. 5.

[2] Audumbara coins, Smith, V. A., in J. A. S. B., LXVI, pt. I, 1897; Cunningham, *Coins of Ancient India,* pl. IV, 2; HIIA, figs. 116, 117. Ceylon coins, Pieris, P. E., *Nāgadīpa. . . . ,* J. R. A. S., Ceylon Br., XXVII, No. 72, 1919.

[3] Cunningham, *Stupa of Bharhut,* pl. XVI; or HIIA, fig. 43.

[4] Leumann, E., *Das Aupapātika Sūtra, erstes Upanga der Jaina,* Abh. Kunde des Morgenlandes, VIII, 2, 1883. The same account is implied in the *Antagaḍa Dasāo,* the quotation above being taken from Barnett's rendering inserted in his translation of the latter text.

The Jaina canonical works, like the Buddhist, may be regarded as good evidence for the centuries immediately preceding the Christian era.

It may be remarked that Jaina cēiyas are distinguished (from those of Yakkhas) as *ārhat cēiya.*

[5] *Loma-haṭṭha:* it seems to me that the rendering "brushes" may be due to the translator's preoccupation with Jaina ideas.

Pali *loma-haṭṭha* means "with hair erect" (horripilation) in fear, astonishment, or joy. May not the suggestion be here simply "marvellous to behold," rather than the designation of an object? or could yak-tail fly-whisks (*court*), more appropriate in a Yakṣa shrine, have been meant?

It had daises (*veyaḍḍi*)[1] built in it, and was reverentially adorned with a coating of dry cow-dung, and bore figures of the five-fingered hand painted in *gośīrṣa* sandal, fresh red sandal, and Dardara Sandal. There was in it great store of ritual pitchers. On (? beside, or above) its doorways were ritual jars (*vandaraghaḍe*) and well-fashioned arches (*tōraṇē*). Broad rounded long-drooping masses of bunches of fresh sweet-smelling blossoms of the five colours scattered therein. It smelt pleasantly with the shimmering reek of *kālāguru*, fine *kundurukka*, and *turukka* (incenses),[2] and was odorous with sweet-smelling fine scents, a very incense-wafer. It was haunted by actors, dancers, rope-walkers, wrestlers, boxers, jesters, jumpers, reciters, ballad-singers, story-tellers, pole dancers, picture-showmen (*maṅkhē*),[3] pipers, lute-players, and minstrels. . . . . This sanctuary was encompassed round about by a great wood. . . . . In this wood was a broad mid-space. Therein, it is related, was a great and fine Aśoka-tree. It had its roots pure with *kuśa* and *vikuśa* grass. . . . . Underneath this fine Aśoka-tree, somewhat close to its trunk, was, it is related, a large dais of (? resting upon) earthen blocks (*puḍhavīsilā paṭṭae*). It (the dais)

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[1] *Veyaḍḍi:* an earthen or stone slab altar for the reception of offerings is the essential part of a shrine. Sometimes a symbol is placed on it. Later, when images come into general use, it becomes the *āsana* (seat or throne) or *pīṭha* (pedestal) of the figure. Altars are generally plain and smooth; but beautifully ornamented examples are known, particularly one, Jaina, from the Kaṅkālī Tīlā, Mathurā (Smith, *Jaina stupa of Mathura,* pl. XXII), and the outer *vajrāsana,* Buddhist, at Bodhgayā (Cunningham, *Mahābodhi,* pl. XIII), both of pre-Kuṣāna date.

In the *Uvāsagadasāo,* 164 (Hoernle, p. 107) the altar is called a masonry platform (*puḍhavī-silā-paṭṭae* = Sanskrit *pṛthvī-śilā-paṭṭaka* or *paṭṭaya,* cf. the *silā paṭṭaaṁ* of the *Mālavikāgnimitra,* III, 79); Hoernle discusses the terms at some length. *Puḍhavī-silā* might mean laterite. The words *taṅkite-mañco* are used in the Pali *Yakkha Suttas,* and rendered stone couch, but "altar" would be better.

[2] The five fingered hand design is mentioned also elsewhere; *e. g., Mahāvaṁsa,* XXXII, 4 (*pañcāṅgulikā pantikā*). Perhaps a five-foliate palmette would have been thus designated.

[3] Picture-showmen; probably those who exhibited scrolls (*yamapaṭa*) illustrating the rewards of good and bad actions, to be realized in a future life. In the Jaina *Bhagavatī Sūtra,* XV, 1, there is mentioned the heresiarch Gosāle Maṅkhaliputte, whose second name refers to his father's trade as a *maṅkha* (cf. Hoernle, *Uvāsagadasāo,* pp. 108, 121, notes 253, 273 and Appendix, p. 1). Patañjali, *Mahābhāṣya,* III, 2, III, refers to the exhibition of paintings of the Kṛṣṇa Līlā, and to the use of the historical present in verbal explanation of them; see Lüders, Sitz. k. Ak. Wiss., Berlin, 1916, pp. 698 ff.; also Keith, A. B., *The Sanskrit drama* (but Keith's rejection of the spoken explanation is probably mistaken). In Viśākhadatta's *Mudrarākṣasa,* Act. 1, Cāṇakya's spy adopts the disguise of an exhibitor of *yamapaṭa* (Prakrit, *jamapaḍaaṁ*). Cf. the modern Javanese Wayang Bebèr (Groeneveldt, W. P., *Notes on the Malay Archipelago and Malacca, compiled from Chinese sources,* Batavia, 1876; Krom, N. J., in Ars Asiatica, VIII, pl. LIX, and the similar Siamese exhibitions cited by Kramrisch, *Viṣṇudharmottaram,* Calcutta, 1924, p. 5, from the Siamese *Sāratha Pakāsini,* pt. II, p. 398).

was of goodly proportions as to breadth, length, and height; and it was black . . . . smooth and massive, eight-cornered, like the face of a mirror, very delightful, and variously figured with wolves, bulls, horses, men, dolphins, birds, snakes, elves, *ruru*-deer, *sarabha*-deer, yak-oxen, elephants, forest creepers, and *padmaka* creepers. . . . . It was shaped like a throne, and was comforting . . . . comely.

In those days, at that time, there arrived the reverent elder Subhamme. . . . . amidst a company of five hundred friars he travelled on and on, journeying in pleasantness, he came to the city of Campā and the sanctuary Puṇṇabhadde he took a lodging such as was meet, and abode there. People came out from Campā to hear his preaching.

The *Antagaḍa Dasāo,* chapter 6, in connection with the garland-maker Ajjuṇae provides interesting details regarding the cult and shrine of the Jakkha Moggara-pāṇi. The following abstract includes all that is pertinent to our study:[1]

Outside the city of Rāyagihe (Rājagṛha) Ajjuṇae possessed a beautiful flower-garden. Some way from this garden there was a shrine (*jakkhāyayaṇa*) sacred to the Jakkha Moggara-pāṇi; this shrine "had belonged to Ajjuṇae's grandfather, great-grandfather, and great-great-grandfather, and had passed through a line of many men of his race" (by whom it had been supported in past generations). "In it there stood a figure of the Jakkha Moggara-pāṇi holding a great iron mace a thousand *palas* in weight." Every morning, before plying his trade, Ajjuṇae would go to the garden with baskets and cloths to gather flowers; then "with the chiefest and best flowers he would approach the *jakkhāyayaṇa* of the Jakkha Moggara-pāṇi, fall upon his knees, and do reverence." On a certain festival day he took with him his wife Bandhumaī.

Meanwhile a certain gang of roughnecks from Rāyagihe had made their way to the shrine to take their pleasure there; seeing Ajjuṇae and his wife, they plan to bind him and take possession of her. To this end they hid themselves behind the doors; when Ajjuṇae had made his offerings, they seized him as arranged, and worked their will on his wife. Ajjuṇae reflected, "Verily I have been from childhood a worshipper of my lord the Jakkha Moggara-pāṇi; now if the Jakkha Moggara-pāṇi were present here, could he behold me falling into such ill-fortune? Then the Jakkha Moggara-pāṇi is not present here: 'tis plain this is but a log." Moggara-pāṇi, however, became aware of Ajjuṇae's thoughts, and took possession of his body; having done so he seized the iron mace, and smote down the six villains and the woman.

Ajjuṇae, still possessed by the Jakkha, now went about killing six men and a woman everyday. The matter was brought to the king's notice. He proclaimed that people should stay at home, and not go out of doors about their usual tasks. A Jaina ascetic then arrived. Despite the king's orders and the danger, the pious merchant Sudaṁsaṇe cannot be dissuaded from going out to pay his respects to the ascetic. The Jakkha meets and threatens him; but Sudaṁsaṇe, without fear, immediately makes full profession of the monastic vows, and thus, as it were, armed in the Lord, the Jakkha cannot approach him, but comes to a halt, staring

[1] Translation by Barnett, 1907, p. 86. I have restored the original *jakkha* and *jakkhāyayaṇa* in place of Barnett's "fairy" and "fairy-shrine."

fixedly at him; then he abandons the body of Ajjuṇae, and returns to his own place with the mace. Ajjuṇae falls to the ground, but on recovering himself, accompanies Sudaṁsaṇe and likewise takes the vows.

Here we find both the cult, patron-saint, and possession features well displayed; it is also clear that the Jakkha shrine is a building with doors, and it is of interest to note that the statue is of wood, and that it is provided with a club (cf. pl. 12, fig. 3). It is hardly necessary to point out that the statue is not the Jakkha; the latter appears suddenly, and carries off the club with which the statue is provided. The name Moggara-pāṇi signifies, of course, "Club-bearer." The antiquity of the shrine and simple nature of the cult remain, and so, too, the fact that the worshipper regards the Jakkha as his natural protector; but the Jakkha is represented as a fierce creature, without the sense to know when to stop—rather like the giants of European fairy-tales. But he is easily subdued by the new-made Jaina monk; and from the Jaina point of view the story is a highly edifying one.

A characteristic and almost essential feature of Hindu and Buddhist shrines is an enclosing wall or railing (*prākāra, vedikā,* etc.). The following story related in the *Dhammapada Atthakathā* (Burlingame, E. W., *Buddhist legends,* H. O. S., Vol. 28, p. 146) refers to the building of such an enclosure in the case of a tree worshipped with desire for children:

At Sāvatthī, we are told, lived a householder named Great-Wealth Mahā-Suvaṇṇa. He was rich, possessed of great wealth, possessed of ample means of enjoyment, but at the same time he was childless. One day, as he was on his way home from bathing at a ghāṭ, he saw by the roadside a large forest tree with spreading branches. Thought he, "This tree must be tenanted by a powerful tree-spirit." So he caused the ground under the tree to be cleared, the tree itself to be inclosed with a wall (*pākāra*), and sand to be spread within the inclosure. And having decked the tree with flags and banners, he made the following vow: "Should I obtain a son or a daughter, I will pay you great honor." Having so done, he went on his way.

Another story, in the *Kah-gyur* (Schiefner, *Tibetan tales,* IX) relates how

a childless Brahman had recourse to the deity of a great nyagrodha-tree (banyan), near the city called thence Nyagrodhika. He caused the ground around it to be sprinkled, cleansed, and adorned. He then filled the space with perfumes, flowers, and incense, and set up flags and standards. Then, after having entertained eight hundred Brahmans and bestowed upon them material for robes, he prayed to the tree-haunting deity, "Be pleased to bestow on me a son." In case the request were granted, he would continue to offer the like honors for a year, but if not, he would cut down the tree and burn it. The tree deity, who was in favor with the Four Great Kings, betook himself to the Mahārāja Rāṣṭrapāla, Virūḍhaka, Virūpākṣa, and Vaiśravaṇa; and the matter was ultimately arranged by the aid of Śakra and Mahābrahmā.

Another and later instance may be cited in the *Mālavikāgnimitra,* V. 1, where a *bhitti-bandho,* or *bhittivedikābandha* is built round an aśoka-tree.

Elaborate structures built round the Bodhi tree are represented in numerous reliefs from Bharhut, Sāñcī, Mathurā, and Amarāvatī, and there is no reason to suppose that structures of this kind were made for the first time after the Yakkha *bhavanaṁ* (for such it was) at Uruvelā became the Bodhi tree of Gautama.

Yakṣa caityas, etc., are constantly described as places of resort, and suitable halting or resting places for travellers; Buddhist and Jaina saints and monks are frequently introduced as resting or residing at the haunt of such and such a Yakṣa, or in such and such a Yakkha cēiya (Puṇṇabhadda cēiya, *ut supra;* the Buddha, in many of the Yakkha Suttas of the *Saṁyutta Nikāya*). Amongst other caityas or groves mentioned in Buddhist literature, the following may be cited as having been in all probability sacred to the cult of a local divinity: (1) the Cāpāla caitya given to the Buddha by the Vajjians (Licchavis) of Vaisālī (Watters, *On Yuan Chwang,* II, 78) (2) the Supatiṭṭha cetiya in the Yaṭṭhivana or Staffwood, where Buddha stayed on his first visit; it is stated, indeed, that this was the ancient place of abode of Supatiṭṭha, the god of a banyan tree (Watters, *ibid.,* II, 147), (3) the grove of sāl-trees belonging to the Mallas, where the Parinibbāṇa took place. Here the couch (*uttarasīsakaṁ*) on which the Buddha lay must have been a dais or altar originally intended for the reception of offerings. In some reliefs, tree spirits are seen in each of the two trees. (4) The Vajjian (Vaiśāli, Licchavi) caityas referred to by the Buddha (*Mahāparinibbāṇa Suttanta,* and *Aṅguttara Nikāya,* VII, 19) when he repeats the conditions of future welfare for the Vajjians, exhorting them not to allow the "proper offerings and rites as formerly given and performed at the Vajjian cetiyas to fall into desuetude." Buddhaghoṣa (*Sumaṅgala Vilāsinī*) regards these as having been Yakkha cetiya, and it can hardly be doubted that this was so in most or all cases. With reference to the Sāradanda cetiya at Vaiśālī, where the Buddha was staying on the occasion of stating the conditions of Vajjian welfare, he says that "this was a *vihāra* erected on the site of a former shrine of the Yakkha Sāradanda."

In the same way Gujarātī commentators of Jaina texts interpret, no doubt correctly, the cēiyas referred to, as Jakkha shrines. But the Dūipalāsa cēiya N. E. of the Vāniyagāma suburb of Vaiśālī may be separately mentioned. Here, in the *Uvāsaga Dasāo,*[1] § 2f., we find

[1] Hoernle, *Uvāsagadasāo,* II, p. 2.

Mahāvīra[1] in residence. The same cēiya is called a park (*ujjāṇa*) in *Vipāka Sūtra,* lect. 1, § 2, and elsewhere a cēiya of the Nāḷa clan. As Mahāvīra was a son of the chief of this Kṣattriya clan, Hoernle assumes that the cēiya must have been sacred to the previous Jina Pārśvanātha. But even if we regard this Jina as historical, there could have existed no Jaina cult (*pūjā*) in the time of Mahāvīra, and it is much more likely that this was a Jakkha shrine or park. When, further, the son of a pious householder of Vāniyagāma takes the vows of a lay adherent, and renounces willing offerings to " the Devas, or objects of reverence to a heterodox community," it is probable that Jakkha cēiyas are included. But here the commentory cites cēiya as " idol," and mentions Vīrabhadra and Mahākāla.

5. WORSHIP (*PŪJĀ*) IN YAKṢA SHRINES

Offerings to Yakṣas, with a long list of other beings, are referred to in several Gṛhya Sūtras as being made at the close of Vedic studies; the *Śāṅkhāyana Śrauta Sūtra,* I, 11, 6, mentions Māṇibhadra. The *Aśvalayana Gṛhya Sūtra,* I, 12, describes what is called a caitya-offering (*vandana*) by householders. Hillebrandt,[2] followed by Keith, assumes that caityas erected as funeral monuments to teachers and prophets are intended, but it is much more likely that the reference is in the main to Yakṣa caityas.

The *Mahābhārata* mentions that the flowers offered to Yakṣas, Gandharvas, and Nāgas make glad the heart, hence they are called *sumanasas,* eumenides; such flowers being other than the sharp-scented, thorny and red flowers used in magical rites (Hopkins, *Epic Mythology,* p. 68). The incense made from deodar and *Vatica*

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[1] As remarked by Hoernle the terms *cēiya* and *ujjāṇa, vana-saṇḍa, vana-khaṇḍa* = grove or park, are interchangeable.

[2] *Ritual-Literature,* Grundriss, III, 2, p. 86. It is quite possible that Hillebrandt (like the author of the P. T. S. Pali Dictionary) ignores here the common meanings of caitya, other than funeral mound. I cannot help suspecting too that when Keith (*Religion and Philosophy of the Veda,* p. 73) remarks that " Buddhist literature knows . . . . Yakṣas who live in relic mounds," a pre-occupation with the idea of funeral mounds (which are but one kind of caitya) underlies the statement, which seems to be founded only on a misinterpretation of the collocation Yakkha-cetiya.

It is true that the word *caitya* is said to be derived from a root *ci* meaning to build or heap up; but as used in the Epics and early Buddhist and Jaina literature, it means any holystead, altar, shrine, grove, temple, etc. May it not be derived from *cit,* with the sense therefore of an object to be meditated upon or attended to?

The Epic uses the word *eḍūka* when Bauddha cetiyas (stupās) are specifically meant; and in Jaina works, Jaina cēiyas are distinguished as *Arhat cēiya.*

robusta is liked by all deities; but *sallakīya* incense is disliked by the gods and suitable only for the Daityas. Milk and flowers should be offered to the gods, who take only the perfume of the latter. The appearance of flowers is acceptable to Rākṣasas, but the Nāgas use them as food. On the other hand the food of Yakṣas and Rākṣasas is meat and spirituous liquor (Hopkins, *ibid.*, pp. 68, 69). Here again, as is generally the case, the Yakṣas are given a spiritual rank intermediate between that of the gods (Devas) and the lower spirits.

Manu (XI, 96) says that meat and intoxicating drinks are the food of Yakṣas, Rākṣasas and Piśācas. In the Meghadūta, II, 3, Yakṣas are described as drinking wine produced from *kalpa*-trees, in the company of fair damsels: cf. the Bacchanalian Yakṣa groups of Mathurā (pl. 14, fig. 1) and those of the ceiling of Cave I at Ajaṇṭā.

The prospector, before digging for treasure in Northern India, makes offerings of meat, sesamum seeds, and flowers, to Kuvera, Māṇibhadra, etc. (*Mahābhārata*, 14, 65, 11).

In connection with a Yakṣiṇī shrine at Rājagṛha it is mentioned in the *Mahābhārata* (3, 84, 105) that there was a daily service.

A passage omitted from the description of the Puṇṇabhadde cēiya cited above informs us that this sanctuary

> was meet for the prayers and supplications of many prayerful folk; meet for worship, celebration, veneration, offering, largesse, and respect; meet to be waited upon with courtesy as a blessed and auspicious sanctuary of the gods, divine, truth-telling, truth-counselling (or, surely satisfying the desires of its worshippers). Miracles were manifested therein, and it received shares in thousands of sacrifices. Many people came to worship the sanctuary Puṇṇabhadde.

In the *Antagaḍa Dasāo*, loc. cit., pp. 86 ff., the garland-maker Ajjuṇae every day, before practising his trade, repairs to the temple (*jakkhāyayaṇē*) of the Yakkha Moggara-pāṇi, with flower-offerings of great worth, falls upon his knees, and does reverence.

Hariṇegameṣī (see note on p. 12) is represented in the *Antagaḍa Dasāo* (loc. cit., p. 67) as receiving *pūjā:*

> Sulasā was from childhood a worshipper of the god Hariṇegameṣī. She caused to be made an image of H., and every morning she bathed . . . . performed the customary lustratory rites, and with a still moist robe made flower-offerings of great worth, fell upon her knees, did reverence . . . . By the lady Sulasā's devotion, veneration, and obedience the god H. was won over. So in compassion for the lady Sulasā the god H., made both her and thee to become pregnant at the same time.[1]

[1] Here "thee" refers to Queen Devai, whose living children are given to Sulasā. Later, when Queen Devai longs for children of her own, her husband Kaṇhe (Kṛṣṇa) Vāsudeva worships Hariṇegamesī; the latter's throne quakes, he looks down, and sees Vāsudeva whose mind is fixed on him. He appears to Vāsudeva, "clad in robes of the five colours bearing bells," and promises that Devai shall bear a child.

In the beautiful Jaina Tamil classic, the *Jīvaka-cintāmaṇī* (Vinson, J., *Légendes bouddhistes et Djainas,* Paris, 1900, t. 2, p. 43) the grateful Jīvaka erects a temple for the Yakkha Sutañjana, sets up a statue, and dedicates a town (the rents whereof would support the service of the temple) ; then he has prepared a drama relating to the history of the Yakṣa, and most likely we should understand that this drama was presented in the temple on special occasions for the pleasure of the deity.

The tutelary Yakṣa at Vaisāli, as we have seen, was worshipped with oblations, dance and song, and the sound of musical instruments.

Later books appear to show that Yakṣa worship and some particular Yakṣas retained their prestige throughout the medieval period. In these texts we find a cult of the same general character, and can glean some further details. In the *Kathāsaritsāgara,* part I, chapter XIII, we find:

"In our country, within the city, there is the shrine of a powerful Yakṣa named Maṇibhadra, established by our ancestors. The people there come and make petitions at this shrine, offering various gifts, in order to obtain various blessings." Offerings (of food) are referred to, which it was the duty of the officiating priest to receive and eat. The anecdote turns upon the interesting fact that the Yakṣa temple was regularly used as a temporary jail for adulterers.

Numerous other and incidental references to Yakṣas and Yakṣiṇīs will be found in the same work, *passim* (*e. g.,* in ch. XXXIV, story of the Yakṣa Virūpākṣa).

The equally late Pariśiṣṭaparvan of Hemacandra (thirteenth century) Canto 3, has a story of two old women, Buddhi and Siddhi: "Buddhi had for a long time continued to sacrifice to a Yakṣa, Bhola (or Bholaka), when the god, pleased with her devotion, promised her whatever she should ask," etc. A little further on we find a human being, Lalitāṅga, "disguised as a statue of a Yakṣa."[1] The same text, Canto 2, eighth story, describes an ordeal undergone by a woman justly accused of adultery. "Now there was a statue of the Yakṣa Śobhana of such sanctity that no guilty person could pass through between its legs." The lady (like Guinevere in a similar predicament) frames an oath which is literally true but essentially false. "While the puzzled Yakṣa was still at a loss to know how to act," she passed through his legs.

Devendra, in the *Uttarādhyayana ṭīkā* (Jacobi, p. 39, Meyer, *Hindu tales,* p. 140), Story of Domuha, tells of a lady named Guṇamālā

[1] Jacobi, H., *Sthavirāvali Charitra,* Bib. Ind., Calcutta, 1891, pp. 33, 37.

who "was unhappy because she had no daughter. And she vowed an oblation (*uvāiyaṁ*) to the Yakṣa called Mayaṇa . . . . a daughter was born of her. . . . . She gave the oblation to the Yakṣa."

In the *Prabandhacintāmaṇi,* another Jaina story book, about 1419 A. D., we find a Yakṣa by name Kapardin invoked by a Jaina layman, acting on the advice of his Guru.[1] The Yakṣa bestows wealth on his supplicant, and then relates the circumstances to his sons, "in order to manifest in their hearts the power of religion"; the Yakṣa himself is a worshipper of the Jina. It is clear that Jainism and Yakṣa worship could be as closely interrelated as Buddhism and Hinduism have often been.

Rites for attracting Yakṣīs are mentioned in the *Kathāsaritsāgara,* chapter XLIX. These rites are performed in cemeteries, and are evidently Tāntrik. The beautiful Yakṣīs Vidyunmālā, Candralekhā, and Sulocanā are said to be the best among them. A certain Ādityasarman, living in Ujjayinī, obtains the last as his wife, and lives with her in Āḷaka; their son Guṇasarman is sent back to the human world, and becomes a great king.

6. YAKṢA WORSHIP A BHAKTI CULT

The reader cannot fail to have observed that the facts of Yakṣa worship summarized above are almost identical with those characteristic of other and contemporary *Bhakti* (devotional) cults. It is, in fact, a great error to assume that the term *Bhagavat* ("worshipful") applies only to Viṣṇu, and *Bhaktā* ("devout worshipper") only to worshippers of Viṣṇu.[2] The rise, or, as it would be better to say, the coming into prominence of *Bhakti* cults in the centuries immediately preceding the beginning of the Christian era was not an isolated sectarian development, but a general tendency. All forms of belief were involved, Buddhism no less than others.[3]

Not only is Vāsudeva (Viṣṇu) styled Bhagavat, but also the Four Great Kings, the Mahārājas, Regents of the Quarters, amongst whom

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[1] *Prabandhacintāmaṇi,* Trans. by C. H. Tawney, London, 1901, p. 203.

[2] As might be gathered from Bhandarkar, R. G., *Vaiṣṇavism, Saivism, and minor religious systems* (Grundriss indo-arische Ph. und A.).

[3] For the *Bhakti* character of even early Buddhism, see De la Vallée-Poussin, loc. cit. pp. 334 ff. The *Majjhima Nikāya,* 1, 142, has "He who has faith (*śrāddha*) in Me and love (*prema*) for Me will attain to heaven." So too Śaivism, "Even after committing all crimes, men by mental worship of Śiva are freed from sin" (*Mahābhārata,* 13, 18, 65). Both assurances are altogether in the spirit of the *Bhagavad Gītā.*

is Kubera, Regent of the North, himself a Yakṣa [1] (and, as Vaiśravaṇa, frequently styled Bhagavat in the *Mahābhārata*), a Nāga,[2] and the Buddha himself.[3] The Pawāyā image of the great Yakṣa Māṇibhadra has a dedicatory inscription,[4] in which the deity himself is styled Bhagavā and the members of the *goṣṭha* (corporation) for whom the image was set up speak of themselves as *Māṇībhadra-bhaktās*. Nemeṣa, too, is called Bhagavā (Mathurā inscription already cited). Thus, both the designation Bhagavat and the use of the term Bhakti are seen to be common to most, as they probably were to all of the contemporary faiths.[5]

Apart from these questions of terminology it will be evident that the facts of Yakṣa worship correspond almost exactly with those of other Bhakti religions. In fact, the use of images in temples, the practice of prostration, the offering of flowers (the typical gift, constantly mentioned), incense, food, and cloths, the use of bells, the singing of hymns, the presentation of a drama dealing with the Līlā of the deity, all these are characteristic of Hindu worship even at the present day.[6] Only the nature of the food is peculiar, and this may be attributed to the relationship of Yakṣas with Rākṣasas; nor will it be forgotten that animal sacrifices and the use of strong liquors still persists in some Śākta cults. Nothing of this cult type is to be found in the Vedas.

7. YAKṢA SOURCES IN BUDDHIST ICONOGRAPHY

Yakṣas, as we have seen, may be represented by independent cult images, or in connection with other sectarian systems, as attendants,

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[1] Pāṇini, IV, 3, 97, speaks of *Bhakti* directed towards Mahārājas, not in a political sense, but with reference to the Four Great Kings (see Bhusari in Ann. Bhandarkar Inst., VIII, 1926, p. 199). For Māṇibhadra as a Lokapāla see Vogel, *Indian Serpent Lore,* p. 10.

[2] The Nāga Dadhikarṇa, in an inscription at Mathurā, Lüders' list, No. 85.

[3] Already at Bharhut, in the inscription *Bhagavato Saka Munino Bodho,* and on the Piprahwa vase, *Bhagavato sakiyamuni.*

[4] Garde, M. B., *The site of Padumāvatī,* A. S. I., A. R., 1915-16, Gangoly, O. C. in Modern Review, Oct. 1919; Foucher, in J. B. O. R. S.; Chanda, *Four ancient Yakṣa statues.* Text of the Brāhmī inscription: . . . . *gauṣṭhyā Māṇibhadrabhaktāgarbhasukhitāḥ Maṇibhadrasya pratimā pratiṣṭhapayaṁti.* . . . .

[5] For the meaning of *Bhagavat,* "Adorable," "Blessed," "Worshipful," etc., see Grierson, *The translation of the term Bhagavat, J. R. A. S.,* 1910; Schrader, *ibid.,* 1911, p. 194; Hopkins, *Epic use of Bhagavat and bhakti, ibid.,* 1912; Govindacharya Svamin, *ibid.,* p. 483.

[6] For an admirable account of the daily office in a modern temple, see (Burgess, J.), *The ritual of Rāmeśvaram,* Indian Antiquary, XII, 1883.

guardians, and worshippers. But not only have both classes of figures their own intrinsic and aesthetic interest (pl. 1, fig. 1, and pl. 8, for example, are magnificent works), they are also of importance as factors in the development of Indian iconography generally. The force of tradition is strong, and Indian art like other arts has always by preference made use of existing types, rather than invented or adopted wholly new ones. The case is exactly parallel to that of religious development, in which the past always survives. We have to do with a conscious sectarian adaptation, accompanied by an unconscious, or at least unintentional, stylistic evolution.

In early Indian art, so far as cult images are concerned, one iconographic type stands out predominant, that is the standing figure with the right hand raised, the left on the hip. Sometimes the right hand holds a flower, or caurī, or weapon; sometimes the left grasps the robe, or holds a flask, but the position of the arms is constant. We are here, of course, concerned only with two-armed images; those with four or more arms do not appear before the second century A. D., when the fundamentals had already been established. Stylistically, the type is massive and voluminous, and altogether plastically conceived, not bounded by outlines; the essential quality is one of energy, without introspection or spiritual aspiration.

Of this type are the early images of Yakṣas, and Yakṣīs, whether independent or attendant. And it is also this type which provided the model for the cult images of other deities, such as Śiva or Buddha, when the necessities of Bhakti determined the appearance of all deities in visible forms.

Making only a passing reference to the close formal relationship recognizable between the oldest known Śiva image, that of the Guḍimallam liṅgam (pl. 17, fig. 1), and the Yakṣas of Bharhut and Sāñcī, and to the facts that the Nyagrodha, Udambara, or Aśvattha tree may be identified with Viṣṇu, and that Śiva, Śaṁkara, Kārttikeya, etc., are all Yakṣas in the Mahāmayūrī list, I propose to speak here only of the part played by the Yakṣa type in evolution of Buddhist types.

In the case of the Buddha figure, as I have recently treated the subject at length in the Art Bulletin (Vol. IX, pt. 4), I shall only point out the stylistic continuity presented in the series: Pārkham image (pl. 1, fig. 1); one of the Yakṣas from Patna (HIIA, fig. 67); Buddha in the Lucknow Museum (HIIA, fig. 79); Bodhisattva in Philadelphia (Art Bull., *loc. cit.*, fig. 50); Friar Bala's image at Sārnāth (pl. 17, fig. 2); Gupta image in the Mathurā Museum (HIIA, fig. 158). In such a series the relationships are very evident, and there is no room for the insertion of any Hellenistic type.

The Bodhisattvas Padmapāṇi, Vajrapāṇi and Maitreya may be discussed in greater detail.

The earliest Buddha triads are represented, as in plate 9, by a Bodhi-tree supported by two Yakṣas, each with an expanded rose-lotus (*padma*) in hand, or by a symbol (the wheel) between similar Yakṣas with a *caurī* (pl. 10, fig. 1). Yakṣas with a lotus in hand appear as guardian figures (*dvārapālas*) at Sāñcī (pl. 8) and elsewhere (pl. 7). Now, a Yakṣa with a *padma* in hand can only be described adjectivally as *padma-pāṇi;* can it be doubted that the Bodhisattva Padmapāṇi (a form or designation of Avalokiteśvara), whom we find a little later attendant on the Buddha or as an independent Buddhist deity, is the same historically and iconographically, as the *padma-pāṇi* Yakṣa of the earlier sculpture? The *caurī*-bearing Yakṣas (HIIA, figs. 84, and 85 right), too, are the same as those of the earlier compositions, but we cannot as a rule give them a name.

The case of Vajrapāṇi is more involved.[1] The one obvious *vajra-pāṇi* of Indian mythology is Indra, whose weapon is the thunderbolt already in the Vedas. In Buddhist mythology Indra is known as Sakka (San. Śakra), and he plays a conspicuous part in the Buddhist legend visiting or aiding the Buddha on various occasions.[2] Buddhaghoṣa[3] tells us that Vajrapāṇi is the same as Sakka; and Sakka, upon occasion (*Yakkha Suttas, 2*) may be called a Yakkha. But Sakka is never himself a Bodhisattva.

On the other hand Vajrapāṇi, independently of Indra, is called a Yakṣa in the Mahāmāyūrī list, where he is said to be the Yakṣa of Vulture's Peak, Rājagṛha (the work *kṛtālaya* seems to imply that there was a temple). A Tibetan version of the *Vinaya* speaks of a Yakṣa Vajrapāṇi (Gnod-sbyin Lag-na-rdo-rje). And in the *Lalita Vistara,* XV, 66, we have a "benevolent lord of the Guhyakas,

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[1] For Vajrapāṇi in addition to references cited below, see also Vogel, *Le Vajrapāṇi gréco-bouddhique,* B. É. F. E. O. XI, 1911, p. 525, where it is observed that Vajrapāṇi and Indra are not necessarily always one and the same persons. M. Foucher has already fully established the Yakṣa origin of the Bodhisattva Vajrapāṇi (*L'Art gréco-bouddhique . . . .*, II, pp. 48-64). See also Senart, E., *Vajrapāṇi dans les sculptures du gandhāra,* Congr. Int. Orientalistes, 14, Alger, 1905, pp. 111-131.

[2] For a full and valuable discussion of Indra as Sakka, see Mrs. Rhys Davids, Introduction to the *Sakka-pañha Suttanta,* SBB., III., p. 294.

Waddell, *Evolution of the Buddha cult,* p. 118, citing Csoma de Körös, *Analysis of the Dulva,* Asiatic Researches, XX, 64.

[3] Commentary on the *Ambaṭṭha Sutta,* cited SBB, II, 117.

Vajrapāṇi" who appears in the air on the occasion of the Abhiniṣkramaṇa (Going Forth of the Buddha), and who, as remarked by Foucher, "desormais le quittera pas plus que son ombre," becoming, in fact, the Buddha's guardian angel.[1] This Vajrapāṇi is not the same as Sakka, who is independently present on the same occasion.

This Vajrapāṇī is constantly represented in Gandhāran reliefs, and sometimes in those of Mathurā, illustrating scenes from the Life, subsequent to the Going Forth, *e. g.*, Foucher, *loc. cit.*, figs. 191, 195, 197, 199. At his first appearance he is called a "benevolent Lord of the Guhyakas, vajra in hand." Sometimes he holds a *caurī* as well as a *vajra;* moreover, this Vajrapāṇi is generally represented as nude to the waist and without any turban or crown, thus not as a great king, as Indra should be. Moreover, this Vajrapāṇi and Sakka are often present together in one and the same scene (pl. 21, fig. 2).

Perhaps the earliest appearance of a Vajrapāṇi in a Buddha triad may be the example in the Museum of Fine Arts, Boston (HIIA, fig. 85, left); and here we are in doubt whether to call him Yakṣa or Bodhisattva. It may be doubted whether the Bodhisattva Vajrapāṇi had been recognized so early. The only early independent image which may be a representation of the Vajrapāṇi, who is not Indra, is a fragment from Mathurā, illustrated in plate 15, figure 2.[2]

Thus there was actually a Yakṣa Vajrapāṇi, not identical with Indra, but having an independent, pre-Buddhist cult; this Yakṣa became the Buddha's guardian angel and attendant, and finally came to be called the Bodhisattva Vajrapāṇi, who sometimes appears in Buddha triads, and is sometimes the object of separate worship (HIIA, fig. 299).

As regards Maitreya, the earliest of the Bodhisattvas to be designated as such, there is less to say. His characteristic emblem is the *amṛta* ("nectar") flask, held in the left hand. It will perhaps occur to the mind of the reader that there are both Bacchanalian Yakṣas, and Bachhanalian Nāgas, who hold a cup or flask in their hands; and as in verbal imagery nothing is more characteristic of Buddhism than the reinterpretation of an old phrase in the interests of present edification (cf. *Lalita Vistara,* VII, 91, "with the Water of Life (*amṛta*) shalt thou heal the suffering due to the corruption of our mortal nature"), so here, perhaps, we have a literal example of the pouring of new wine into old bottles.

[1] Foucher, *L'Art gréco-bouddhique du Gandhāra,* I, 368: and cf. *ibid.*, II, pp. 48-64.

[2] Vogel, *The Mathura school of sculpture,* A. S. I., A. R., 1909-10, p. 76 and pl. XXVIIIb.

8. WOMAN AND TREE MOTIF

Enough has been said in the course of the present article, or will be found in the accompanying illustrations, to indicate the intimate connection subsisting between spirits and trees.[1] For the rest it will suffice in the present connection to recall the Epic passage, "goddesses born in trees, to be worshipped by those desiring children," such goddesses being designated as dryads (Vṛksakā, Vṛddhikā). There is no motif more fundamentally characteristic of Indian art from first to last than is that of the Woman and Tree. In early sculptures (reliefs on pillars of[2] gateways and railings at Bharhut, Bodhgayā, Sāñcī, and Mathurā) the female figures associated with trees are voluptuous beauties, scantily clothed, and almost nude, but always provided with the broad jewelled belt (*mekhala*) which appears already on the pre-Maurya terra-cotta figures of fertility goddesses,[3] and which the *Atharva Veda* (6, 133) tells us was a long-life (*āyuṣya*) charm. Sometimes these dryads stand on a vehicle (*vāhanam*) such as a Yakṣa (*Guhya*), elephant, or crocodile (*makara*). Sometimes they are adorning themselves with jewels, or using a mirror. Very often they hold with one hand a branch of the tree under which they stand, sometimes one leg is twined round the stem of the tree (an erotic conception, for *latā* is both "creeper" or "vine," and "woman," and cf. *Atharva Veda,* VI, 8, 1, "As the creeper embraces the tree on all sides, so do thou embrace me"). Sometimes one foot is raised and rests against the trunk of the tree. Sometimes there are children, either standing beside the dryad mother, or carried astraddle on her hip. Of the trees represented the

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[1] For pre- and non-Buddhist trees, tree-spirits, and sacred groves generally, see Hopkins, *Epic Mythology,* p. 6 f., and Keith, *Religions and Philosophy of the Veda,* pp. 184, 185. Trees and tree-deities play but an insignificant part in the *Rg Veda* and even in the *Atharva Veda* (Macdonnell, *Vedic Mythology,* p. 154) but even here they are connected with human life and productivity; the beings inhabiting trees being called Gandharvas and Apsarases. The *Atharva Veda,* of course, contains many elements incorporated from aboriginal non-Aryan sources. It is perhaps also significant (in view of possible Sumero-Dravidian connections) that in Babylonian tradition immortality and productiveness are original functions of the tree of Fortune (Ward, *Seal Cylinders of Western Asia,* pp. 233, 237, etc.).

[2] Plate 4, fig. 2; pl. 5; pl. 6, figs. 2, 3; pl. 11, figs. 1, 2, 3; pl. 14, fig. 2; pl. 19; pl. 22, figs. 1, 2.

[3] Also the so-called Earth goddess of Lauriyā-Nandangaṛh (HIIA, fig. 105): this nude goddess, who is represented also in very early terracottas (see M. F. A. Bulletin, No. 152), may not be a Yakṣī.

aśoka and mango are most usual. At first sight, these figures seem to be singularly out of place if regarded with the eyes of a Buddhist or Jaina monk.[1] But by the time that a necessity had arisen for the erection of these great monuments, with their illustration of Buddhist legends and other material constituting a veritable *Biblia Pauperum*, Buddhism and Jainism had passed beyond the circle of monasticism, and become popular religions with a cult. These figures of fertility spirits are present here because the people are here. Women, accustomed to invoke the blessings of a tree spirit, would approach the railing pillar images with similar expectations; these images, like those of Nāgas and Yakṣas often set up on Buddhist and Jaina sites, may be compared to the altars of patron saints which a pious Catholic visits with prayers for material blessings.

From these types of Yakṣī dryads[2] are evidently derived three types iconographically the same, but differently interpreted: the Buddha Nativity, the aśoka-tree *dohada* motif in classical literature, and the so-called river-goddesses of medieval shrines.

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[1] The array of dryads at Mathurā produces on the mind an effect like that of Aśvaghoṣa's description of the beautiful girls in Siddhārtha's palace garden, who "with their souls carried away by love . . . . assailed the prince with all manner of stratagems" (*Buddhacarita*, IV, 40-53).

But it may be said to be characteristic of Indian temples that the exterior displays the world of sensuous experience (cf. Koṇārak), while the interior chambers are plain and severe, or even empty (cf. the air-liṅgam at Cidambaram): and this arrangement, even for a Buddhist shrine, is not without its logic.

I have scarcely mentioned and have not illustrated the many interesting reliefs and paintings in which tree spirits are represented, not by a complete figure beneath a tree, but as half seen amongst the leaves, *patreṣv ardhakāyān abhinirmaya* (*Lalita Vistara*): a face, hand, two hands, or half body emerging from the branches. Representations of this kind occur already at Bharhut, and survive in the eighteenth century Buddhist painting of Ceylon. The spirits thus represented may be male or female as the case requires.

[2] That the Vṛkṣakās of the railing pillars are properly to be described as Yakṣīs is proved by the inscriptions accompanying the similar figures at Bharhut (cf. Vogel, in A. S. I., A. R., 1906-07, p. 146). Vṛkṣakā is, of course, legitimate, but hardly more than a descriptive term. Some with musical instruments should perhaps be described as Gandharvīs, or even Apsarasas, but none are represented as actually dancing, and to call them dancing girls is certainly an error.

Hoyśala bracket figures, however, which preserve the motif of woman and tree, supported by a dwarf Yakṣa, are often in dancing positions, and accompanied by drummers (Smith, *H. F. A.*, fig. 163; others at Palampet and Belūr).

1. The miraculous birth of the Bodhisattva Siddhārtha,[1] as is well-known, took place in the Lumbinī garden near Kapilavastu and on the road between that city and Devadaha. The tree of which the branch, " bending down in response to her need," served Mahāmāyā as support, is variously called a sāl-tree (*Nidānakathā*), mango (*Aśokāvadāna*), *plakṣa* (*Lalita Vistara*)[2] and aśoka-tree (*Divyāvadāna,* and here plate 20). In the *Divyāvadāna* Aśokā himself is represented as visiting the site and conversing with the genius of the tree, who had been a witness to the Nativity; so that the tree had originally been, or at least had come to be regarded as having been the abode of a tree-spirit when Mahāmāyā halted beneath it. It is, no doubt, the spirit of the tree that bent down the branch to meet Mahāmāyā's hand; indeed, in the drawing of a relief almost identical with our plate 20, reproduced in Burgess, *Buddhist stupas of Amaravati and Jaggayyapeta,* plate XXXII, a hand appears visibly from amongst the branches of the Nativity tree. The Buddha himself is sometimes aided in just this way, by a hand put forth from a tree, for example, when he emerges from the waters of Lake Pāṇihata (*Lalita Vistara,* Ch. XVIII), and after crossing the River Nairañjanā (Amarāvatī relief, Vogel, *Indian serpent lore,* pl. VII, a).

We certainly need not and should not regard Mahāmāyā, considered from the point of view of the literature, as having been herself a Vṛkṣakā; but iconographically, as she is represented in Gandhāran

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[1] The Nativity is a stock subject in Buddhist art, Gandhāran, Amarāvatī, and later. Cf. Foucher, *Beginnings of Buddhist Art,* pls. III, IV; *L'Art gréco-bouddhique du Gandhara,* I, pp. 300 ff. and II, pp. 64-72; *L'Iconographie bouddhique de l'Inde,* I, p. 163 and fig. 28: HIIA, fig. 104, upper right hand corner: Krom, *Life of the Buddha,* p. 74 (with complete list of representations).

The Amarāvatī reliefs not only come nearest to the Vṛkṣakā type, but also suggests that the Nativity had been represented in Indian art (without the child) previous to its occurrence in Gandhāra (with the child).

Another version of much interest appears at the back of a Chinese Buddha image of date 457 A. D. (Northern Wei) (Burlington Magazine Monograph on Chinese art, Sculpture, Pl. 4, D). There are two ranges; above we have the tree, female attendant, Māyā standing, the child emerging from her side, and three Devas, one with a cloth, ready to receive it; below, the First Bath and the Seven Steps. As the First Bath is here performed by polycephalous Nāgas, which are rarely met with in Gandhāra, but are highly characteristic for Mathurā, there is a probability of direct dependence on an Indian original.

[2] In the *Lalita Vistara* version, the tree is evidently regarded as a caitya-tree, for it is adorned with coloured cloths and other offerings.

and Amarāvatī reliefs and elsewhere,[1] the step is very easy from a Vṛkṣakā holding the branch of a tree and in the *hanché* ("hip-shot") pose, to that of Mahāmāyā giving birth to the child, who was miraculously born from her side.[2] The addition of attendant deities and later a further complication of the scene by a representation of the Seven Steps, etc., would present no difficulty. The literary versions are probably older that the oldest known sculptures of the Nativity;[3] how far each may be dependent on the other can hardly be determined. In any case, it is certain that the sculptor had ready to hand a composition almost exactly fulfilling the requirements of the text, so far as the principal figure is concerned.

2. The *dohada* motif. The, in India, familiar conceit that the touch of a beautiful woman's foot is needed to bring about the blossoming of the aśoka-tree seems to be equally a form of the Yakṣī-dryad theme; one railing pillar, J 55 in the Mathurā Museum, represents a woman or Yakṣī performing this ceremony[4] (pl. 6, fig. 3) and the motif survives in sculpture to the eighteenth century (pl. 19, fig. 2), if not to the present day. In Kālidāsa's *Meghadūta* the exiled Yakṣa speaks of himself as longing for his wife no less than the aśoka-tree desires the touch of her foot. Even in the *Mālavikāgni-*

[1] The formula was certainly not, as suggested by Foucher, *L'Iconographie bouddhique,* I, 164, created "par l'art superieur des artistes Indogrecs"; it is only possible that they were the first to put in the attendant figures, but we cannot be sure of even this. Even the crossed legs, described by many European writers, grotesquely enough, as a dancing position, are taken over from the Yakṣī-dryads. Le Coq, *Bilder-Atlas,* figs. 153 and 156 not only describes Mahāmāyā as being in "Tänzerinnenstellung," but also a dryad from Bharhut, who with both arms and one leg is clinging to her tree, while her weight is rested on the other foot (pl. 4, fig. 2); to dance under either of these circumstances would not only be a remarkable acrobatic feat, but in direct contradiction to the whole pose. To stand with crossed legs, particularly when leaning against a tree, is in India a position of rest and therefore not inappropriate (as a dancing pose would be) to the representation of a miraculously painless parturition.

The motif has been well discussed (with reference to this and other misunderstandings) by Berstl, *Indo-koptische Kunst,* Jahrb. as. Kunst, I, 1924; where a Western migration of the motif is also recognized.

[2] It is perhaps worth remarking that Cunningham once "erroneously identified" one of the Mathurā railing dryads "with Māyā standing under the *sāl* tree" (Vogel, *Cat. Arch. Mus., Mathura,* p. 6).

[3] The legend of the miraculous birth is found already in the *Acchariyabbhūta Sutta,* No. 123, in the *Majjhima Nikāya,* thus considerably antedating the *Nidānakathā* version (Chalmers, in J. R. A. S., 1894). The Four Devas are mentioned.

[4] Vogel, Catalogue, pp. 44, 153; *La belle et l'arbre aśoka,* B. É. F. E. O., XI, 1911; Cf. [Gangoly, O. C.], *A brass statuette from Mathurā,* Rūpam, 2, 1920.

mitra, where Mālavikā, a mortal woman, is to perform the ceremony, the scene takes place beside a " slab of rock " under the aśoka-tree, and this shows that the tree itself was a sacred tree haunted by a spirit.[1]

The word *dohada* means a pregnancy longing, and the tree is represented as feeling, like a woman, such a longing, nor can its flowers open until it is satisfied. Thus the whole conception, even in its latest form as a mere piece of rhetoric, preserves the old connection between trees and tree spirits, and human life.

3. The River-goddesses.[2] The dryad types with *makara* vehicles (pl. 6, figs. 1 and 2, pl. 14, fig. 2, and pl. 19, figs. 1 and 2) bear an intimate relation, not amounting to identity, with the figures of river-goddesses Gaṅgā and Yamunā, with *makara* and tortoise vehicles placed at the doorways of many northern medieval temples. I propose to discuss this subject more fully elsewhere.

CONCLUSION

The observations collected in the foregoing pages may be summarized as follows:

Kuvera and other Yakṣas are indigenous non-Aryan deities or genii, usually beneficent powers of wealth and fertility. Before Buddhism and Jainism, they with a corresponding cosmology of the Four or Eight Quarters of the Universe, had been accepted as orthodox in Brahmanical theology. Their worship long survived, but in purely sectarian literature they appear only to serve the ends of edification, either as guardians and defenders of the faith, or to be pointed to as horrible examples of depravity.

Yakṣa worship was a Bhakti cult, with images, temples, altars, and offerings, and as the greater deities could all, from a popular point of view, be regarded as Yakṣas, we may safely recognize in the worship of the latter (together with Nāgas and goddesses) the natural source of the Bhakti elements common to the whole sectarian development which was taking place before the beginning of the Kuṣāna period. The designation Yakṣa was originally practically synonymous with Deva or Devatā, and no essential distinction can be made between Yakṣas and Devas; every Hindu deity, and even the Buddha, is spoken

[2] *Mālavikāgnimitra,* Act. III; cf. *Raghuvaṁsa,* VIII, 62.

[2] River-goddesses: Smith, V. A., *History of Fine Art in India and Ceylon,* pp. 160, 161 and figs. 111, 112; Maitra, A. K., *The river-goddess Gaṅgā,* Rūpam, 6, 1921; Vogel, *Gaṅgā et Yamunā dans l'iconographie bouddhique,* Études asiatiques, 1925 (the best discussion); Diez, E., *Zwei unbekannte Werke der indischen Plastik in Ethnographisch Museum, Wien.,* Wiener Beiträge zur Kunst und Kultur Asiens, I, 1926.

of, upon occasion, as a Yakṣa. "Yakṣa" may have been a non-Aryan, at any rate a popular designation equivalent to Deva, and only at a later date restricted to genii of lower rank than that of the greater gods. Certainly the Yakṣa concept has played an important part in the development of Indian mythology, and even more certainly, the early Yakṣa iconography has formed the foundation of later Hindu and Buddhist iconography. It is by no means without significance that the conception of Yakṣattva is so closely bound up with the idea of reincarnation.

Thus the history of Yakṣas, like that of other aspects of non-Aryan Indian animism, is of significance not only in itself and for its own sake, but as throwing light upon the origins of cult and iconography, as well as dogma, in fully evolved sectarian Hinduism and Buddhism. And beyond India, if, as is believed by many, characteristic elements of the Christian cult, such as the use of rosaries, incense, bells and lights, together with many phases of monastic organization, are ultimately of Buddhist origin,[1] we can here, too, push back their history to more ultimate sources in non- and pre-Aryan Indian *pūjās*.

Adherents of some "higher faiths" may be inclined to deprecate or to resent a tracing of their cults, still more of dogmas, to sources associated with the worship of "rude deities and demons" (Jacobi) and "mysterious aboriginal creatures" (Mrs. Rhys Davids). But if the Brāhmans in fact took over and accepted from popular sources the concept of devotion to personal deities, and all that this implied, do we not sufficiently honor these thinkers and organizers of theological systems in recognizing that they knew how to utilize in the service of more intellectual faiths, and to embody in the structure of civilization, not only their own abstract philosophies, but also the "forces brutes mystiques" (De la Vallée-Poussin) of pre-Hindu Hinduism? And if some elements of ancient Hindu cult, perhaps of millennial antiquity, are still preserved in the Christian office, this is no more than evidence of the broad unity that underlies religious tendencies and acts everywhere and always; pagan survivals in all current faiths are signs of fulfillment, rather than of failure. And in India it becomes more than ever clear that thought and culture are due at least in equal measure both to Aryan and indigenous genius.

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[1] See Garbe, *Indien und das Christentum;* Berstl, *Indo-koptische Kunst,* Jahrb. as. Kunst, I, 1924.

EXPLANATION OF PLATES

Plate 1

1. The Yakṣa Kuṇika (the Pārkham image now in the Mathurā Museum): height 8′ 8″. Photo by Johnston and Hoffmann.

The date and identification of this figure have been matters of great controversy.[1] All that can be safely said is that the inscription is in characters generally corresponding to those of the Aśokan and Piprahwa vase inscriptions. Almost the only significant part of the text in the reading of which all students agree is the name Kuṇika. This name has since been found on the so-called statue of Manasā Devī at Mathurā,[2] which is named in the inscription as that of a Yakṣiṇī, sister of Kuṇika. These data appear to confirm the view long held, that the Pārkham image (so-called from the place of its discovery) represents a Yakṣa and dates from the Maurya period. When first discovered, the Pārkham image was being worshipped by the villagers as a Devatā, the Barodā fragment (HIIA, fig. 15) as a Yakheyā. See also Chanda, R., in Mem. A. S. I., vol. 30.

The Pārkham image is of great importance as the oldest known Indian stone sculpture in the round; it establishes a formulae which can be followed through many succeeding centuries. A female statue from Besnagar, now in the Indian Museum, Calcutta, height 7′ 7″, and perhaps representing a Yakṣi, is also contemporary (see HIIA, fig. 8), so too, or but little later, is a colossal female caurī-bearer from Dīdargañj near Patna (HIIA, fig. 17). There is, or was, another Yakṣa (or king) figure at Deoriya, near Allahābād (see reproduction in my *Origin of the Buddha Image,* Art Bulletin, 1927, Pt. 4, fig. 47); here it can be seen clearly that the left hand is placed on the hip; further, the figure wears a turban, and is sheltered by an umbrella. The Deoriya figure must be of about the same (Maurya) date as the Pārkham image.

2. The Yakṣa Bhagavata Māṇibhadra, set up by a guild of Māṇībhadrabhaktās, at Pawāyā, Gwāliar State, now in the Gwāliar Museum, First century B. C. Photograph by the author.

Plate 2

1, 2. The Yakṣa Nandi, and another Yakṣa or king; perhaps the Yakṣi Nandi of Nandinagara, or the pair may be the Yakṣas Nandi and Vardhana of Nandivardhana. Patna, second century B. C., now in the Museum at Patna. A. S. photographs.

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[1] Mr. Jayaswal (J. B. O. R. S., V, 1919) attempted to prove that the inscription included the name of King Kuṇika Ajātaśatru, and he identified and dated it accordingly about 618 B. C. (according to others this Śaiśunāga king died about 459 B. C.). Fatal objections to Mr. Jayaswal's views are raised by Chanda, *Four Ancient Yaksa statues,* in the Journal of the Dept. of Letters, Calcutta University, Vol. IV, 1921, where other references will be found.

[2] For the figure of "Manasā Devī," probably also of Maurya date, see Ann. Rep. Arch. Surv. India, 1920-21, pl. XVIII, and *ibid.,* 1922-23, p. 165.

PLATE 3

1. The Yakṣa Kuvera (*Kupiro Yakho*), Bharhut, second century B. C., now in the Indian Museum, Calcutta. The *vāhanam,* not well seen, is a crouching dwarf demon (Guhyaka?) with pointed ears. India Office photograph.
2. The Yakṣa Supavasu, Bharhut, same date; *vāhanam,* an elephant. Now in the Indian Museum, Calcutta. India Office photograph.

PLATE 4

1. A Yakṣī or Devatā from Bharhut, found at Batanmara: *vāhanam,* a running dwarf. India Office photograph.
2. Culakoka Devatā, from Bharhut: *vāhanam,* an elephant. Now in the Indian Museum, Calcutta. India Office photograph.

PLATE 5

1. Yakṣī or Devatā from Bharhut; *vāhanam,* a horse accompanied by a dwarf with a water-vessel. Now in the Indian Museum, Calcutta.
2. Yakṣī or Devatā: human (?) *vāhanam.* Bodhgayā. India Office photograph.

PLATE 6

1. The Yakṣī Sudarsanā, from Bharhut: *vāhanam,* a *makara.* Now in the Indian Museum, Calcutta. India Office photograph.
2. Yakṣī under aśoka-tree; *vāhanam,* a *makara.* From Mathurā, now B. 51 in the Lucknow Museum. L. Mus. photograph.
3. Yakṣī under aśoka-tree, with one foot pressed against its stem (*dohada* motif). From Mathurā, in the Mathurā Museum. A. S. photograph.

PLATE 7

Yakṣa with *padma* in hand (*padma-pāṇi*); and auspicious pair (*mithuna,* Yakṣa and Yakṣī?). At Amīn, near Thanesar. Second century B. C. A. S. photograph.

PLATE 8

Guardian Yakṣa at the base of a pillar, north *toraṇa, Sāñcī.* The panel above shows the worship of a sacred tree (*caitya-vṛkṣa*) in a grove (the Veṇuvana at Rājagṛha); though the theme is here Buddhist, the relief serves very well to illustrate some of the descriptions of Jakkha cēiē cited above. First half of first century B. C. India Office photograph.

PLATE 9

Part of the north *toraṇa,* Sāñcī. The three uprights of the lower series constitute a Buddha triad, with, in the center, the Buddha represented by the Bodhi-tree, and on each side a *padmapāṇi* Yakṣa (prototype of the Bodhisattva Padmapāṇi). First half of first century B. C. Photograph by Johnston and Hoffmann.

PLATE 10.

1. West *toraṇa,* Sāñcī, showing Yakṣa (Guhya) Atlantes. Two panels of the right hand pillar show the worship of caitya-trees. India Office photograph.

2. Upper part of north *toraṇa,* Sāñcī, with a caurī-bearing Yakṣa; showing also a symbol (often but wrongly styled *vardhamāna*). There was originally a Buddha triad consisting of a Dhamnacakka between two Yakṣas. First half of first century B. C. Photograph by Johnston and Hoffmann.

PLATE 11

1, 2. Front and rear views of a dryad bracket (Vṛkṣakā and mango-tree) east *toraṇa,* Sāñcī; first half of first century B. C. Photographs by the author.
3. Dryad (Yakṣī or Vṛkṣakā) putting on an earring; with banyan (?) tree. Framed in a "caitya-window" niche. Amarāvatī, second century A. D. or earlier. British Mūseum? India Office photograph.
4. Yakṣa bearing a garland, from rail-coping, Amarāvatī, second century A. D. British Museum? India Office photograph.

PLATE 12

1. *Kusapadalamānava Jātaka,* with the Yakṣī Assamukhi. Railing medallion from Pāṭaliputra, early second century B. C., now in the Indian Museum, Calcutta. There are similar medallions at Sāñcī (Stūpa II) and Bodhgayā. Indian Museum photograph.
2. Yakṣa (?) with bell (cf. fig. 29, right). Terracotta, about first century A. D. Museum of Fine Arts, Boston. M. F. A. photograph.
3. Yakṣa (?): held by the right arm, not seen in the photograph, is a broad club; thus the Yakṣa might be described as *mudgara-pāṇi* (cf. the Yakṣa Moggarapāṇi, *supra*). Terracotta, Maurya or earlier? Museum of Fine Arts, Boston. M. F. A. photograph.
4. Yakṣa (?) holding a ram; perhaps a bucolic divinity, a kind of Kṣetrapāla. Terracotta, from Ujjain, probably Kuṣāna, first or second century A. D. Author's collection. M. F. A. photograph.

PLATE 13

1. Yakṣas (Guhyas) as Atlantes, Bharhut, Ca. 175 B. C. Indian Museum, Calcutta. India Office photograph.
2. Winged Yakṣas (Guhyas) as Atlantes; from a railing pillar at Bodhgayā, about 100 B. C. Photograph by Johnston and Hoffmann.
3. Yakṣas as Atlantes, Graeco-Buddhist, from Jamālgarhi. One is winged, and provided with a bell. In Lahore Museum. India Office photograph.

PLATE 14

1. Bacchanalian Kuvera, Kuṣāna, late second century A. D. From Mathurā, in the Mathurā Museum. A. S. photograph.
2. Yakṣī or Vṛkṣakā (so-called river-goddess Ganges) originally one of a pair from a doorway (forming the upper parts of the jambs): *vāhanam,* a *makara;* tree, a mango. Gupta, about 400 A. D. From Besnagar, now Museum of Fine Arts, Boston. M. F. A. photograph.

PLATE 15

1. Pāñcika and Hāritī, the Tutelary Pair, patron deities of wealth and fertility. Graeco-Buddhist, from Sahri-Bahlol, now in the Lahore Museum. Early second century A. D. A. S. photograph.

2. Yakṣa (?) Vajrapāṇi from Mathurā. Kuṣāna; early second century A. D.? Height of the fragment, 1′ 9″. Now E 24 in the Mathurā Museum. A. S. photograph.

Plate 16

1. Yakṣa, on railing to pillar, Kaṅkālī Tīlā, Mathurā. Probably first century A. D.
2. Yakṣa, probably Vaiśravaṇa, with flames, from the Kaṅkālī Ṭīlā, Mathurā, same date. Both after Smith, *Jaina stupa of Mathurā.* Both in the Lucknow Museum.

Plate 17

1. Paraśurāmeśvara liṅgam (Śiva), Guḍimallam, about 100 B. C. For comparison with Yakṣa types from Bharhut, etc. A. S. photograph.
2. Colossal Bodhisattva (Buddha), of Mathurā manufacture, set up by Friar Bala at Sārnāth, 123 A. D. For comparison with Yakṣa types, plate 1, figure 1, and plate 2, figure 1. A. S. photograph.

Plate 18

1. Gaṇeśa, with chain of bells; from Bhumara. Gupta, about fifth century. A. S. photograph.
2. Dvārapāla, a Yakṣa, with chain of bells. South Indian, Coḷa, about the tenth century. Property of C. T. Loo.

Plate 19

1. Yakṣī, on door-jamb at Tāḍpatri; *makara vāhanam.* The tree is now much conventionalized and proceeds from the makara's mouth. The parrot (Kāmadeva's *vāhanam*), perched on the Yakṣī's arm, is a further indication that the *makara* in these associations is rather to be connected with Kāmadeva than regarded as a river-symbol. Parrots or parrokeets are represented already on the shoulders of the voluptuous Yakṣīs from the Bhūteśar side in Mathurā: and in the *Lalita Vistara.* Ch. XXI, some of the apsarasas, Māra's (Kāmadeva's) daughters, tempting the Bodhisattva, are said to have parrokeets or jays perched on their heads or shoulders. Smaller Yakṣa (Guhya) Atlantes on right side (cf. plate 13). A. S. photograph.
2. Yakṣī, on door jamb of the Subrahmaṇiya temple at Tanjore, eighteenth century. *Makara vāhanam;* the tree much conventionalized; the Yakṣī holds a parrot and is pressing one foot against the trunk of the (presumably) aśoka-tree (*dohada* motif). Photograph by the author.

Plate 20

The conception and nativity of Siddhārtha. Upper right, the Dream of Māyā Devī (Mahāmāyā) (Incarnation of the Bodhisattva in the form of a white elephant); one female attendant also sleeping, and the Four Great Kings, the Lokapālas (Kubera, etc.), occupying the four corners of the chamber, on guard. Upper left, The Interpretation of the Dream; Māyā Devī seated, King Suddhodana enthroned, two Brahman soothsayers seated below. Lower right, the Nativity; Māyā Devī under the aśoka-tree, supporting herself by one hand (woman and tree, or yakṣī motif), with one attendant; to her proper right, the Four Great Kings holding a cloth on which the presence of the infant, miraculously born from her right side, is indicated by two small feet. The stool represents the First Bath. Lower left, Presentation at the Shrine of the Yakṣa Śākyavardhana, as related in the Tibetan Dulva; Mahāprajāpatī, aunt of the child, holding the infant in the cloth, where its presence is again indicated by the two small feet; two female attendants, one with an umbrella. The shrine of the tutelary Yakṣa consists of a tree and altar, the Yakṣa visibly emerging from the altar and bowing to the child. From Amarāvatī, late second century A. D.; now in the British Museum.

Another representation of the same subject, also from Amarāvatī, is illustrated in Fergusson, J., *Tree and Serpent Worship,* Pl. LXIX; here the Yakṣa is leaning forward from a sort of booth which may be called a temple, and bowing to the child. A third example (Burgess, *Buddhist stupas of Amaravati and jagayyapeta,* frontispiece, detail) resembles that of our Plate 20. A fourth, *ib.* Pl. XXXII, 2, differs from our Plate 20 only in minute details.

Plate 21

1. Māyā Devī's dream, Descent of the Bodhisattva, in the form of a white elephant. The elephant is seen in a pavilion, supported by four Yakṣas. Amarāvatī, late second century A. D. India Office photograph.
2. The visit of Indra. On the right, the Yakṣa Vajrapāṇi above, Indra standing below. Kuṣāna, second century A. D., Mathurā. Property of L. Rosenberg, Paris.

3, 4. Pāñcika and Hāritī, from door jambs. Kuṣāna, Mathurā, first or second century A. D.

5. Pāñcika and Hāritī. Kuṣāna, Mathurā, first or second century A. D.
6. Scene from the Buddha's life: the Buddha, nimbate, in center, the Bodhi tree above him; on the proper right, four women, of whom two at least are represented as tree spirits. I cannot identify the scene. Amarāvatī, late second century A. D. British Museum? India Office photograph.

Plate 22.

1. Yakṣī (*vṛksakā,* dryad) bracket, from the Kaṅkālī Ṭīlā, Mathurā. Kuṣāna, first century A. D. Lucknow Museum. L. Mus. photograph.
2. Yakṣī, Madura, seventeenth century. Photograph by Dr. Denman W. Ross.
3. *Nārī-latā,* ivory, Ceylon, eighteenth century. Colombo Museum. Author's photograph.
4. Yakṣa, probably Kubera; now C 18 in the Mathurā Museum. Author's photograph.

Plate 23

1, 2. Yakṣa (gaṇa) garland-bearers. One with an elephant's head, suggesting Gaṇeśa. Amarāvatī, late second century A. D. Madras Museum? India Office photographs.

3. Palace of Kāmadeva, a dance of Yakṣas. Central architrave, back face of north *toraṇa,* Sāñcī, about 100 B. C. India Office photograph.

APPENDIX

I

I owe to Professor Walter Eugene Clark the following tale of a Yakṣa, found in the *Divyāvadāna,* 275, *et seq.* A certain man was the keeper of a *śulka-śālā* or toll-house. When he died, he was reborn among the Vyāḍa-Yakṣas. He appeared to his sons in a dream and told them to make a *yakṣasthāna* and attach a bell. He said that the bell would ring if anyone tried to smuggle merchandise past without paying toll. A man tried to smuggle in a *yamalī* of fine cloth concealed in the stick of his umbrella. The bell kept ringing and the merchants were detained till he confessed.

This is very like the Vaiśāli story cited above, pp. 14, 15. The *yakṣasthāna* may have been a separate shrine, or more likely a shrine made within the toll-house: presumably there was an image, and the bell was hung round its neck.

II

The well-known Besnagar *kalpa-druma* capital, representing a banyan having below its branches three money bags, and a conch, lotus, and jar, from which square coins are welling up, probably represents Kubera in his capacity of Dhanada, "Wealth-giver." The banyan-tree is mentioned in *Mahāvaṁsa,* X, 89 as specifically his abode. Śaṅkha and Padma personified as lords of wealth are amongst the eight treasures of Kubera (*Harivaṁśa,* 2467 and 6004, and *Viṣṇudharmottara,* III, 53). The conch with coins or vegetation rising from it occurs as a symbol elsewhere.

III

Page 2, note 1, add: It is perhaps significant of the orthodox Vedic Brahmanical attitude towards the Yakṣa cult that in *Baudhāyana Dharmaśāstra,* I, 5, 9 *caitya-vṛkṣas* are mentioned in a list of objects of which the touch causes defilement requiring purification.

IV

Yakṣa of the *Kīratārjunīya* story (p. 14): The Yakṣa, described as a follower of Kubera, appears in Bharavi's drama *Kīratārjunīya,* guiding Arjuna to the Indrakīla (see H. O. S., Vol. 15).

V

The shrine of Kāmadeva in *Mṛcchakaṭika,* I, 32, is situated in a grove (*Kāmadevā adaṇaujjāṇa = Kāmadeva ayatana udhyāna*).

1

2

Yakṣas, from Pārkham and Pawāyā.

(For explanation, see pages 7, 29, 38)

1

2

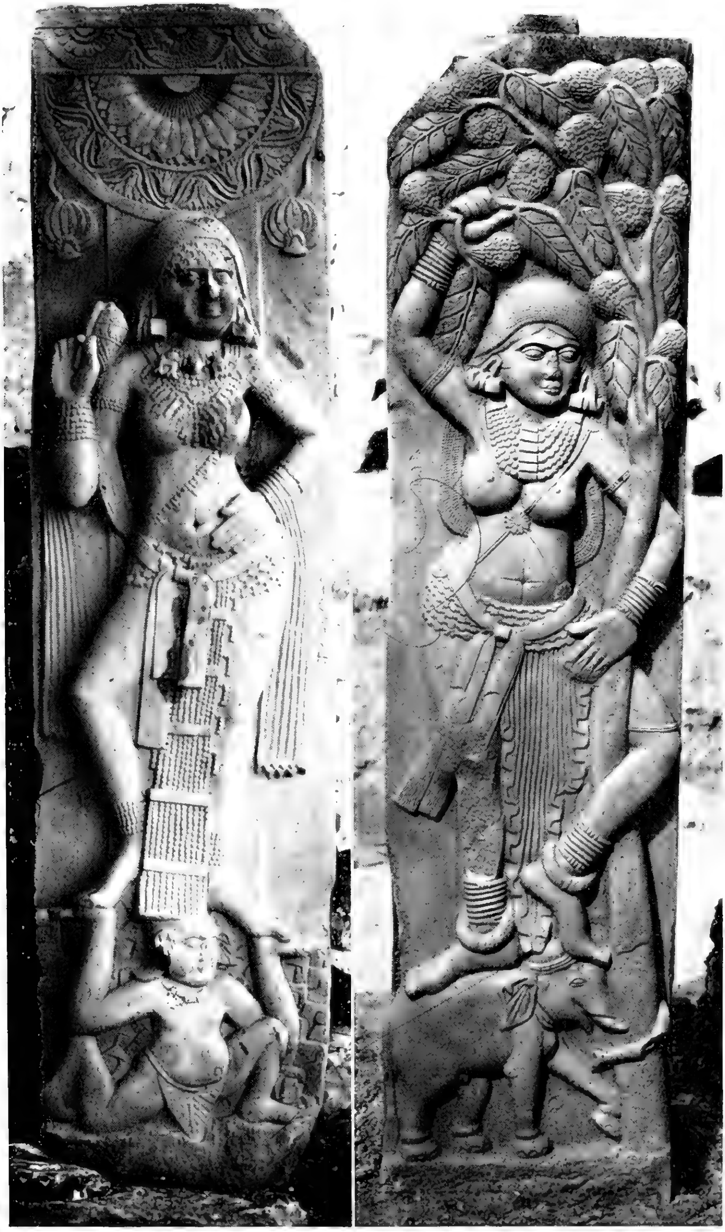
Yakṣas, from Patna.

(For explanation, see pages 12, 38)

1 2

Yakṣas, from Bharhut.

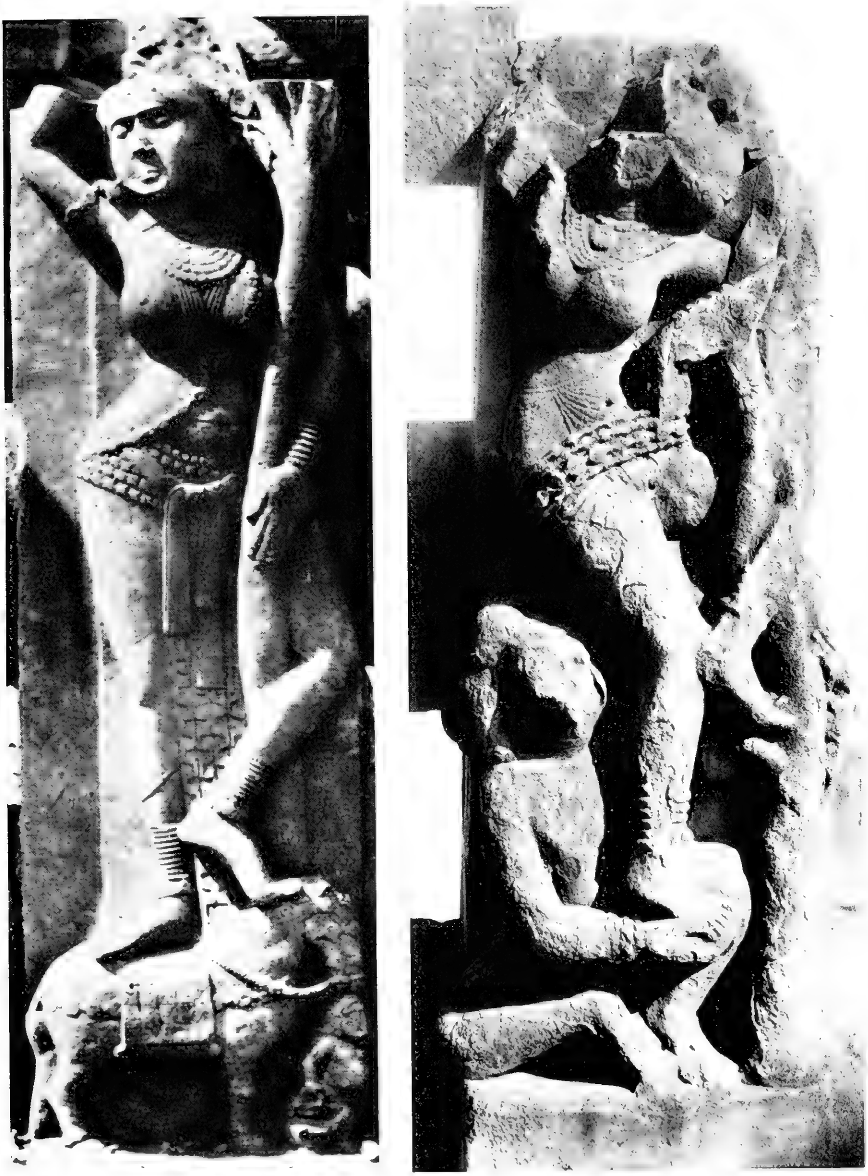
(For explanation, see pages 8, 39)



1 2

Yakṣīs or Devatās, from Bharhut.

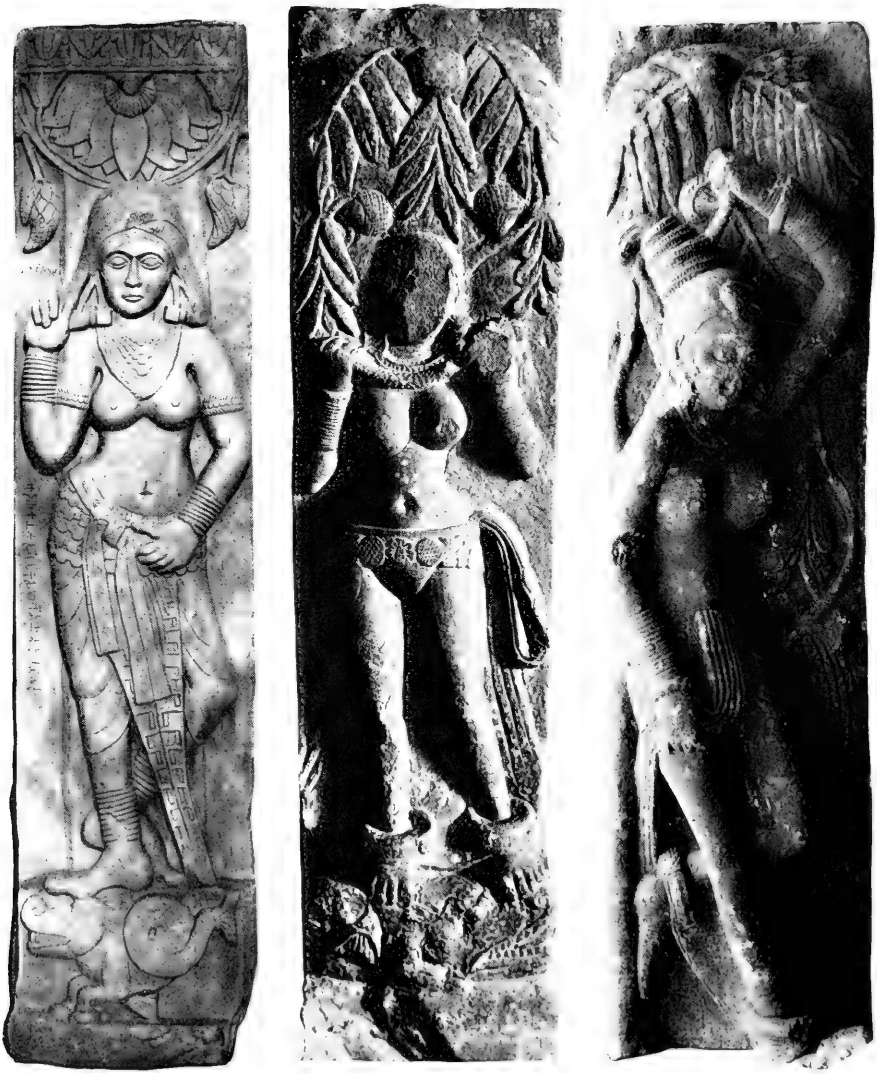
(For explanation, see pages 32, 35, 39)



1 2

Yakṣīs or Devatās, from Bharhut and Bodhgayā.

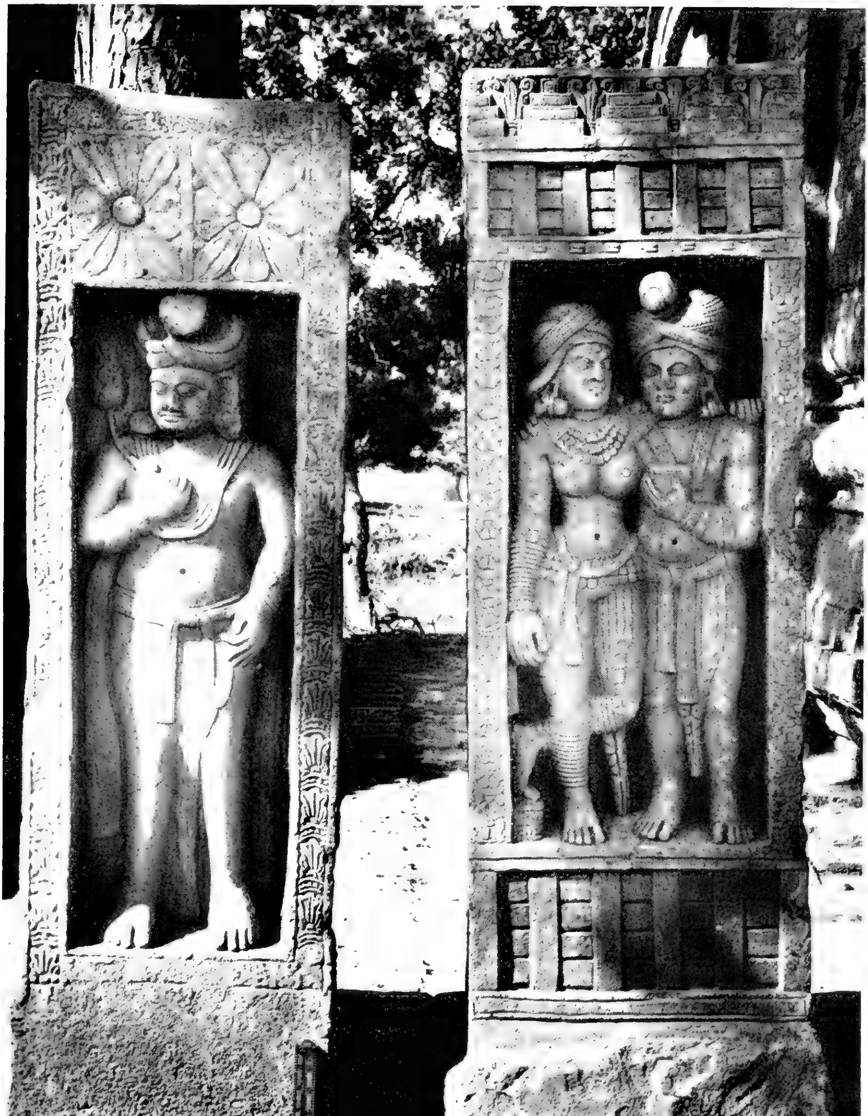
(For explanation, see pages 32, 39)



1 2 3

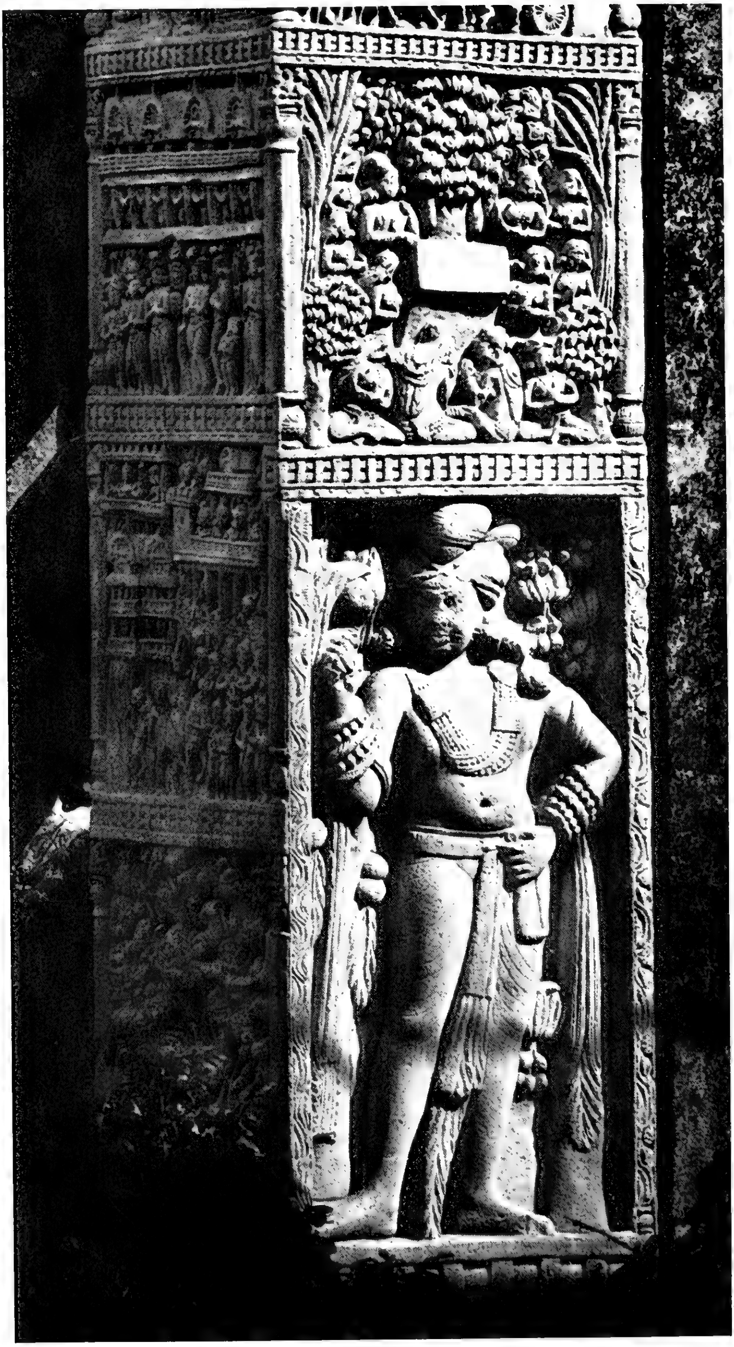
Yakṣīs, from Bharhut and Mathurā.

(For explanation, see pages 32, 39)



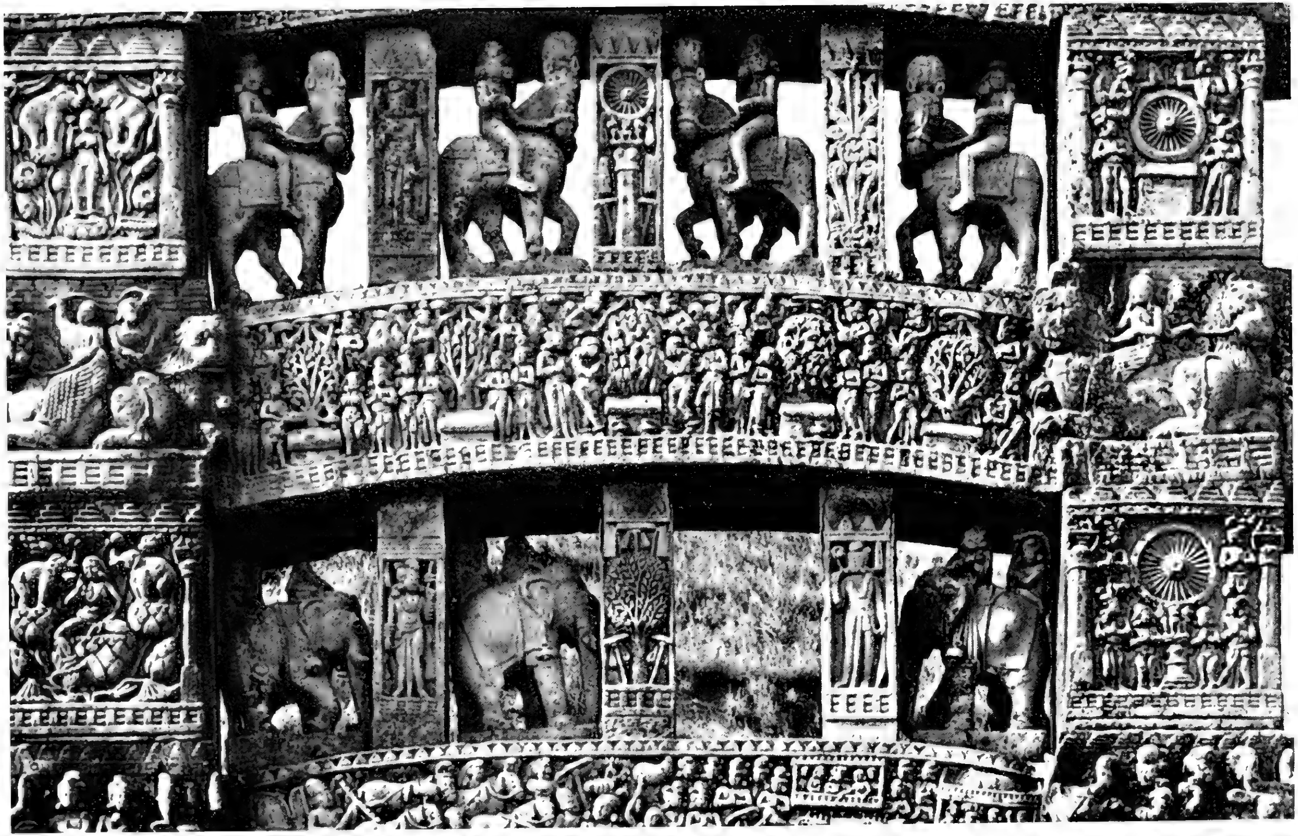
Yakṣa and *mithuna*, from Amīn.

(For explanation, see pages 30, 39)



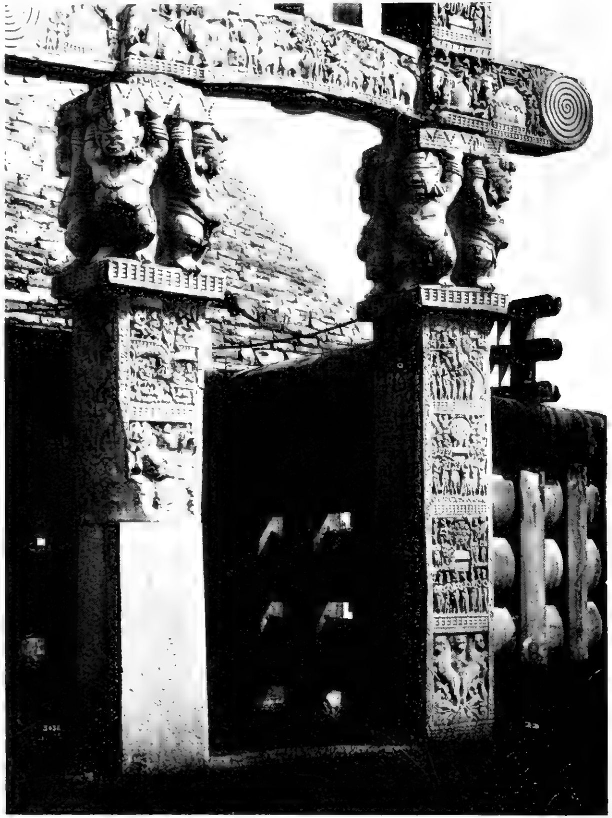
Yakṣa, at Sāñcī.

(For explanation, see pages 29, 30, 39)



Yakṣas and Bodhi-tree, at Sāñci.

(For explanation, see pages 30, 39)



1

Toraṇa, at Sāñcī, with Yakṣa caryatides.

2

Yakṣa and Buddhist symbol, *toraṇa*, Sāñcī.

(For explanation, see pages 39, 40)

1

2

Yakṣī bracket, West *toraṇa*, Sāñcī.

3

Yakṣī, Amarāvatī.

4

Yakṣa, Amarāvatī.

(For explanation, see pages 32, 40)

1
The Yakṣī Assamukhi.

2
Yakṣa with bell.

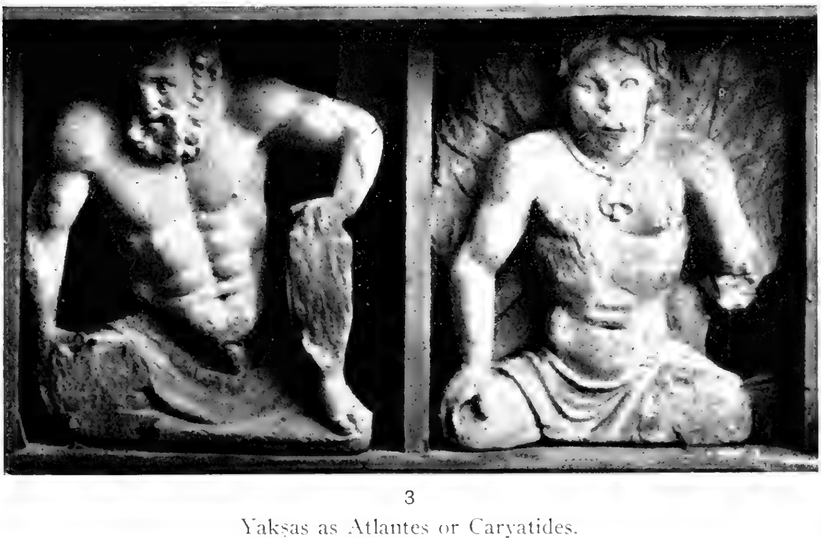
3
Yakṣa.

4
Yakṣa.

(For explanation, see pages 10, 15, 22, 40)

1

2



3

Yakṣas as Atlantes or Caryatides.

1, Bharhut. 2, Bodhgayā. 3, Jamālgarhi.

(For explanation, see pages 8, 40)

1

Bacchanalian Kubera; Mathurā.

2

Yakṣī, from Besnagar.

(For explanation, see pages 25, 32, 36, 40)

1
Pāñcika and Hārītī; Sahri-Bahlol.

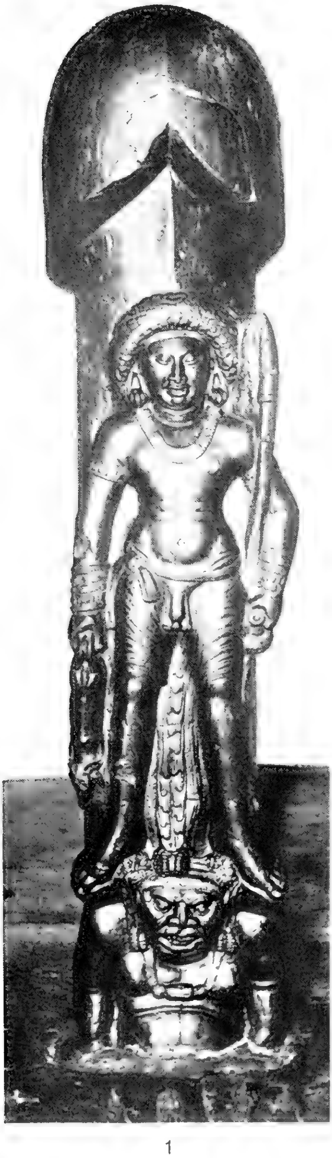
2
Vajrapāṇi; Mathurā.

(For explanation, see pages 9, 10, 31, 40, 41)

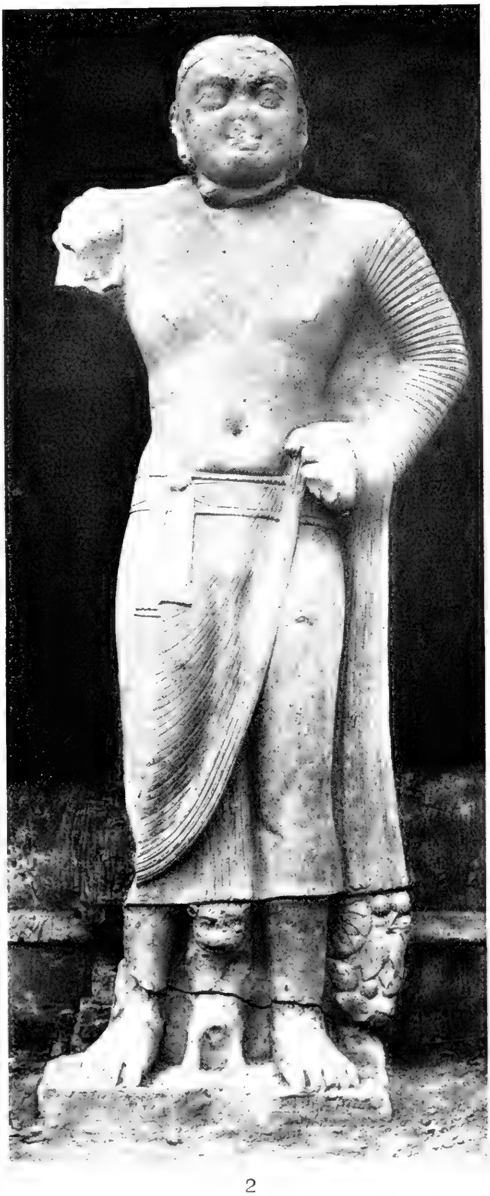
1 2

Yakṣas from Mathurā

(For explanation, see pages 7, 41)



1
Śiva-liṅgam; Guḍimallam.



2
Bodhisattva (Buddha), from Mathurā, at Sārnāth.

(For explanation, see pages 8, 29, 41)

1

Gaṇeśa; Bhumara.

2

Yakṣa dvārapāla, S. Indian.

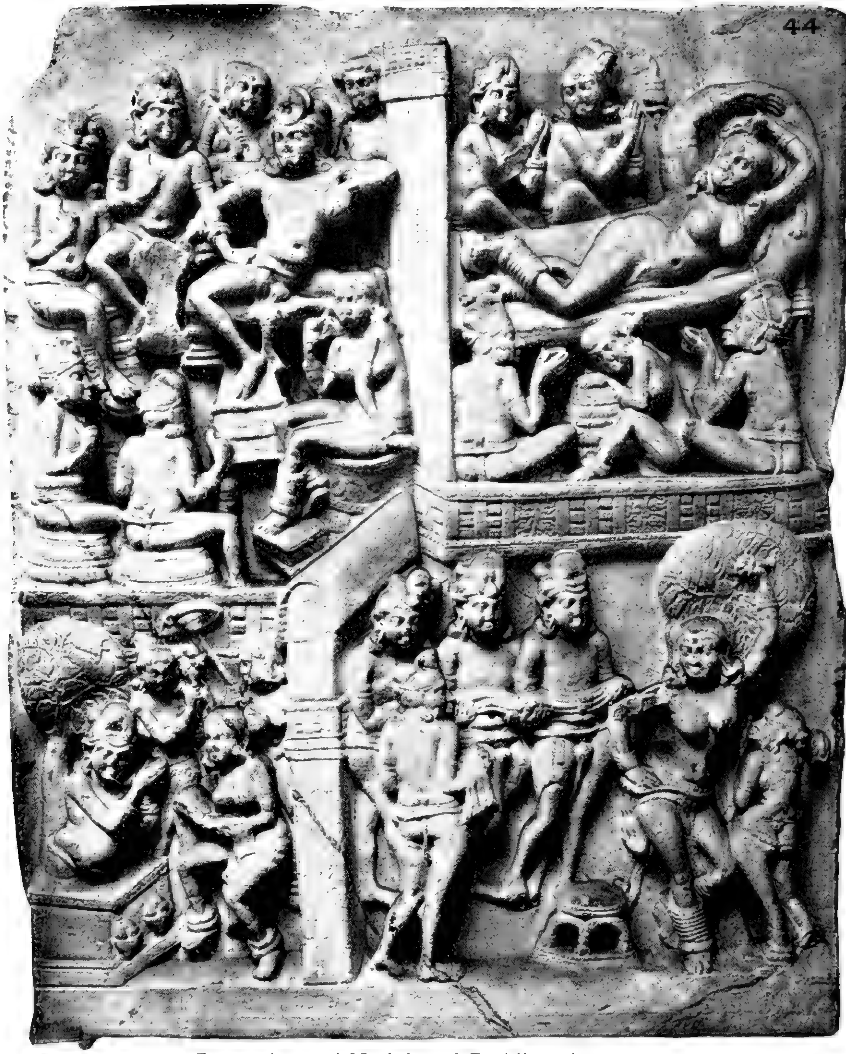
(For explanation, see pages 7, 15, 41)

1

2

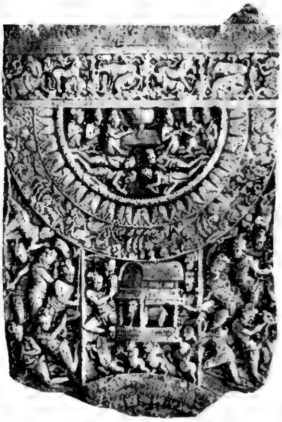
Yakṣīs, from Tāḍpatri and Tanjore.

(For explanation, see pages 32, 36, 41)



Conception and Nativity of Buddha; Amarāvatī.

(For explanation, see pages 32, 34, 41, 42)



1

Descent of the Bodhisattva. Amarāvatī.

2

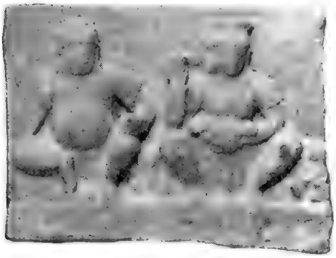
Visit of Indra: Vajrapāṇi above: Mathurā.

3

Kubera: Mathurā.

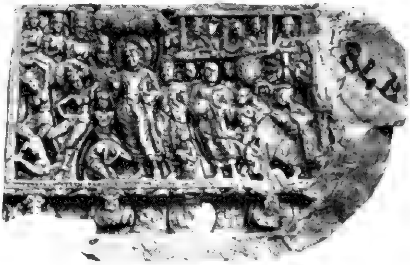
4

Hāritī: Mathurā.



5

Kubera and Hāritī: Mathurā.



6

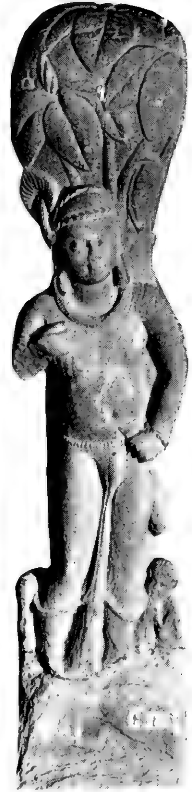
Scene from Buddha's life: Amarāvatī.

(For explanation, see pages 8, 9, 10, 31, 42)

1
Yakṣī *toraṇa* bracket; Mathurā.

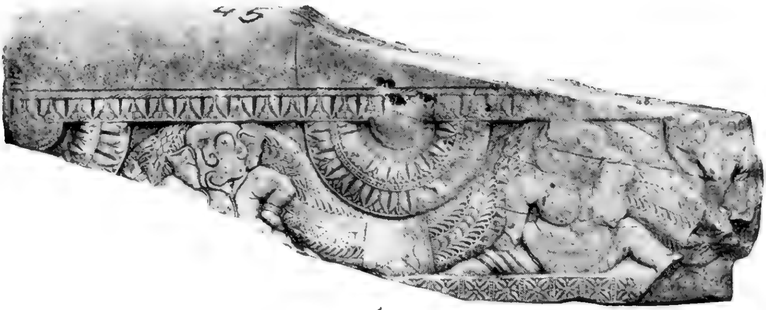
2
Yakṣī; Madura.

3
Nārī-latā; Ceylon.



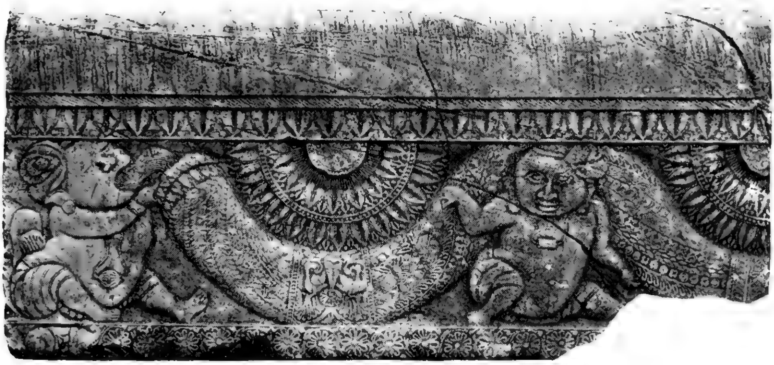
4
Yakṣa; Mathurā.

(For explanation, see pages 6, 32, 42)



1

Gaṇa garland-bearers; Amarāvatī.



2

Gaṇa garland-bearers; Amarāvatī.

3

Māra in darbār, with a dance of Yakṣas; Sāñcī.

(For explanation, see pages 7, 8, 13, 42)

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THE ABORIGINAL POPULATION OF AMERICA NORTH OF MEXICO

BY
JAMES MOONEY

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THE ABORIGINAL POPULATION OF AMERICA NORTH OF MEXICO

By JAMES MOONEY

PREFACE

BY JOHN R. SWANTON

When the Handbook of American Indians (Bull. 30, Bur. Amer. Ethnol.) was in course of preparation, the article on "Population" was assigned to Mr. James Mooney, and he entered upon the investigation of this problem in his accustomed serious and thorough manner. Soon, however, he found that the task grew to unexpected proportions, his interest growing with it, and finally it was decided to prepare a short article for the Handbook, embodying the main results of his researches, and to publish a more complete statement in the form of a bulletin. Mr. Mooney's untimely death in 1921 prevented the completion of this latter project, but he had made provisional detailed estimates which, fortunately, have been preserved.

The region covered by this projected bulletin was naturally that which the Handbook had undertaken to treat, all of America north of the Mexican boundary. Mr. Mooney planned to divide this into a certain number of natural sections, discuss the population of each in turn, first generally and then tribally, and conclude with a detailed table giving figures at the period when disturbances from European sources began and again at the period of writing or some nearby date for which census figures were available. The discussion of the first two sections then contemplated by him, the New England area, and the territory covered by New York, New Jersey and Pennsylvania, was completed and typewritten, as was the table to accompany the study of the former, but at this point Mr. Mooney's work seems to have been interrupted and all that remains of the other sections of the more comprehensive undertaking is contained in loose notes, with which practically nothing can be done.

But, whether for use in the Handbook or for some other urgent purpose, Mr. Mooney decided to prepare (1908-9), a briefer statement of the Indian population embodying the principal results of his investigation. The general plan of this was the same but the number of sections seems to have been reduced since New England, New York, New Jersey, and Pennsylvania were put together as the region of the North Atlantic States. The preliminary discussion of each was reduced to two or three pages, but the tables of figures, which, after all, constitute the most important element in the undertaking, were given in full.

To his discussion of the 14 areas into which he finally decided to divide the territory under consideration, Mr. Mooney evidently intended to supplement a chapter on the causes of the decline of Indian population as indicated by his figures, including such factors as war, spirituous liquors, and disease. He attached the greatest importance to the last mentioned, particularly contagious diseases introduced by the whites.

The accompanying bibliography, reproduced from Mr. Mooney's manuscript, will indicate in some measure the extent of his reading in connection with the present work. It is known that, in some cases, he carried his investigations back to the original census rolls.

Mr. Mooney would have been the last to maintain that his figures are final; modifications will from time to time be found necessary. Indeed, there is a considerable difference between his own earlier and later estimates of the aboriginal population of New England, the former being 32,700 and the latter 25,100, but it is impossible to say whether this represents a general modification of his position or not. Isolated investigations of others seem to indicate that his figures, though conservative as compared with most earlier undertakings of the kind, are still somewhat high.

Mr. Mooney's work does, however, supply a want long felt by students of the American Indian: a set of detailed figures that give an approximate understanding of the relative strength of the several tribes, an understanding of the Indian population of the region taken as a whole, and the approximate losses and gains of both. In justice to the author it must be remembered that it represents the advance results of a more extensive but never completed enterprise.

POPULATION

NORTH ATLANTIC STATES

In this section we include New England, New Jersey, New York, and Pennsylvania—excepting the western portions of the two latter states formerly held by the Neutrals and the Erie, but including that portion of Quebec Province lying between New York and the St. Lawrence. The period of disturbance and colonization for this region began about the year 1600, at which time the Indian population was probably about 55,000, reduced now to about 22,000 or about 40 per cent in the United States and Canada. Of the latter the Iroquois make up nearly 18,000, largely of mixed blood, while the rest consist of Abnaki, also much mixed, and mongrel remnants of the coast tribes, hardly deserving the name of Indians.

The original Indian population of New England was probably about 25,000 or about one-half what the historian Palfrey makes it. The first great cause of decrease noted here was the epidemic—apparently some previously unknown fever—which swept the whole southern New England coast in 1617, almost depopulating eastern Massachusetts. Then followed the Pequot war of 1637, the terribly destructive King Philip's war of 1675-6, and the later border wars of Maine, each with its accompaniment of enslavement and head or scalp bounties. In 1632-3, only 19 years after the fever, smallpox ravaged southern New England, killing, as is said, 700 of the Narraganset tribe alone, and destroying all of the Massachuset that had survived from 1617. With the subjection of the tribes began an era of dissipation which continued almost unchecked until the tribes had lost all importance and survived only as half-negro mongrels. The single exception is the Abnaki tribe, which still keeps an independent existence with fairly healthy blood, owing to the watchful care of devoted missionaries.

In New York the Iroquois, from being rather a small confederacy, as compared with other noted historic groups, rapidly grew in strength from earlier possession of firearms and singular compactness of organization, until by successful, aggressive warfare and wholesale incorporation of aliens, chiefly of cognate stock, they had doubled their number within a century and are now probably three times as many as in 1600. This increase, however, has been at the expense of the tribes which they have destroyed—Hurons, Neutrals, Erie and Conestoga—and has been aided also by intermixture with the whites. Smallpox epidemics in 1637-8, 1663, 1717, 1755 and later, only temporarily checked the general advance.

The Conestoga, formerly the dominant southern tribes of the region, after steady decrease by Iroquois invasion and smallpox were finally destroyed as a people by the Iroquois about 1675, the survivors being mostly incorporated with the conquerors. The power of the

Mahican, Wappinger, Munsee and Montauk tribes and their associates of the Hudson River and Long Island, was broken in the wars with the Dutch in 1640 and 1664, by local epidemics, and by the utter demoralization which came upon them with the completion of the conquest. On Long Island in 1658 an epidemic visitation destroyed one-half of the Montauk and a proportion of the smaller tribes. The Delaware (Lenapé) bands of New Jersey had become almost extinct from the use of spirituous liquors and general dissipation before 1720, while the main body of the tribe has steadily decreased from wars, removals, and the same dissipation, until less than one-fourth remain.

	1600	1907
New England		
Abnaki tribes (including Passamaquoddy)	3,000	1,400
Pennacook	2,000	Extinct
Massachuset	3,000	Extinct
Nipmuc, independent	500	Extinct
Pocomtuc, etc. (central Mass.)	1,200	Extinct
Wampanoag, etc.	2,400	Extinct
Nauset	1,200	50 (?) mixt
Nantucket	1,500	Extinct
Marthas Vineyard	1,500	50 (?) mixt
Narraganset, etc., and E. Niantic	4,000	30 (?) mixt
Pequot	2,200	25 mixt
Mohegan	600	75 (?) mixt
Niantic, Western	250	Extinct
Podunk (E. Windsor, E. Hartford)	300	Extinct
Quinnipiac (New Haven)	250	Extinct
Paugusset and Wepawaug (Milford, Bridgeport)	400	Extinct
Tunxis (Farmington)	400	Extinct
Wongunk (Wethersfield, Middletown)	400	Extinct
New York		
Iroquois confederacy (excluding Tuscarora)	5,500	17,630
Mahican (?)	3,000	760
Wappinger tribes (excluding Conn.) (?)	3,000	Extinct
Montauk, Canarsee, etc., of Long Island	6,000	30 (?)
New Jersey and Pennsylvania		
Delaware and Munsee (?)	8,000	1,850
Conestoga (?)	5,000	Extinct
	55,600	21,900

SOUTH ATLANTIC STATES

In this section we include most of Delaware, Maryland, Virginia, West Virginia and the Carolinas, with the exception of the Cherokee territory. At the beginning of the colonizing period, say about 1600, this region was well populated with numerous tribes which dwindled rapidly by wars, disease, dissipation, and dispossession, so that, with the exception of the Tuscarora, there exist of them today not 20 fullbloods keeping their own language, although a thousand or more of mixed Indian, white and negro blood, still claim the name. All of the so-called "Croatan Indians" of North Carolina worthy of serious ethnologic consideration are included within this number.

Leaving out of account the early Spanish expeditions and slave raids along the Carolina coast, we may date the beginning of the decline with the founding of the Virginia colony in 1607. The ensuing wars with the Powhatan and other Virginia tribes were of such an exterminating character that already in 1645 it was reported that they were "so routed and dispersed that they are no longer a nation," and by 1705 they were reduced to about one-seventh of their original strength. Some mixed blood bands keep the name. The interior Virginia tribes disappeared unnoticed. The unceasing attacks of the well-armed northern Iroquois constantly weakened the southern tribes, while systematic slave captures throughout the whole region had also much to do with their extinction.

The Charleston colony (S. C.) was founded in 1670 and the Albemarle settlement (N. C.) a few years later. Here, smallpox and gross dissipation, introduced by degenerate whites, so rapidly thinned the native population that Lawson, writing about 1710, said that through these means there was not left within reach of the frontier one-sixth the number of 50 years before. The Piedmont region was still populous, with small towns thickly scattered. He speaks of earlier repeated visitations of smallpox, of none of which record seems to have been preserved, excepting for 1696, when it swept the Albemarle region. In 1738, 1759 and 1776, the same disease again ravaged Carolina. The Tuscarora war of 1711-2 and the Yamasee war of 1715-6 nearly completed the destruction of the Carolina tribes, which, with the exception of the Cherokee, are represented today only by about 700 Tuscarora and less than 100 mixed blood Catawba, with a few scattered mongrels in the eastern counties.

North of the Potomac the chief causes of decrease were smallpox and other introduced diseases, and dissipation, which prevailed to such an extent that not a single fullblood survives. The decrease for the whole South Atlantic region has been at least 96 per cent, even including the surviving mongrel claimants.

	1600	1907
MARYLAND and DELAWARE		
Conoy or Piscataway, Patuxent, etc.	2,000	Extinct
Tocwogh and Ozinies	700	Extinct
Nanticoke, etc.	1,600	80 (?) mixt
Wicomoco	400	20 (?) mixt
VIRGINIA (West Virginia probably not occupied[1])		
Powhatan confederacy	9,000	500 (?) mixt
Monacan confederacy } later Saponi and Tutelo	1,200	Extinct
Manahoac confederacy } later Saponi and Tutelo	1,500	Extinct
Nottoway (Mangoac of 1585)	1,500	Extinct
Occaneechi	1,200	Extinct
Meherrin	700	Extinct
NORTH CAROLINA		
Yeopim, Pasquotank, etc. (Weapemeoc of 1585)	800	Extinct
Chowanoc	1,500	80 (?) mixt
Machapunga, etc. (Wingandacoa of 1585)	1,200	Extinct
Pamptico and Bear River (Pomouik of 1855)	1,000	Extinct
Neus and Coree (Nusiok and Cawruuock of 1585)	1,000	Extinct
Tuscarora (now in N. Y. and Ontario)	5,000	700 about
Woccon	600	Extinct
Sara (Xuala, 1590; Cheraw)	1,200	Extinct
Keyauwee	500 }	
Eno, Shoccoree and Adshusheer	1,500 }	
Sissipahaw (Sauxpa 1579)	800 }	500 (?) mixt
Cape Fear Indians	1,000 }	
Waxhaw and Sugeree	1,200 }	
SOUTH CAROLINA		
Catawba (Issa 1579; Ushery 1670; Esaw 1700)	5,000	90 (?)
Pedee	600 }	
Waccamaw } Winyaw, Hook, etc. }	900 }	200 (?) mixt
Sewee	800 }	
Santee	1,000 }	
Congaree	800	Extinct
Wateree (Guatari 1579)	1,000	Extinct
Etiwaw	600	Extinct
Edisto (Audusta 1562; Orista 1570)	1,000	Extinct
Westo } Stono }	1,600	Extinct
Cusso (Couexi 1562; Coçao 1569; Casor 1675)	600	Extinct
Cusabo tribes (Corsaboy 1715)	1,200	Extinct
	52,200	2,170

[1] There seems to have been one very small tribe called Moneton on Kanawha River in the latter part of the 17th century.—J. R. S.

GULF STATES

In this section we include Georgia, Florida, Alabama, and Mississippi, most of Louisiana, Arkansas and Tennessee, with some outlying territory, and the whole Cherokee country.

In the Gulf States the Indian population seems to have decreased by nearly one-half since the beginning of regular white colonization. If the percentage of alien blood in the survivors could be segregated a much greater decrease would be apparent, the great majority now existing being mixed bloods. The chief causes of decrease have been smallpox, dissipation, wars, slave raids, and removals. The destruction accomplished by De Soto and other Spanish adventurers is of too early a date to be estimated, and the tribes had probably recovered from its effects before the beginning of regular occupation by the whites, about the end of the seventeenth century for most of the region, excepting east Florida where it began a full century earlier. For convenience of treatment, however, we have made one date for the whole region. A great smallpox epidemic in 1698 is on record as having destroyed the larger part of the Quapaw and about the same proportion of the Tunica, lower down the river, and the Biloxi and others about Biloxi Bay. It probably swept the whole lower Mississippi River. During the same period, or about 1690-1720, slave raids organized by the English of Carolina were very destructive of Indian life, the Chickasaw and Creeks, armed with guns furnished for the purpose, being the principal agents in the destruction. In 1702 the Chickasaw admitted to Iberville that in 12 years they had killed or captured for slave traders 2,300 Choctaw at a cost to themselves of over 800 men. Moore's expedition against the Apalachee missions in 1703 was practically a slave raid, 200 Apalachee being killed and 1,400 carried off into slavery. In one raid in 1723 the Choctaw killed or brought back for sale to the French 400 Chickasaw. After the final defeat of the Natchez, in 1731, 500 were sold by the French into West Indian slavery. The populous tribes of Florida seem to have dwindled rapidly under Spanish rule, and their destruction was completed in the eighteenth century by irruptions of the Creeks, who were armed with guns by the English of Carolina, while the Spanish government refused firearms to its own Indian dependents. They long since became entirely extinct. Several destructive smallpox visitations are recorded for Carolina and the adjacent region before the Revolution, while intoxicating beverages and general dissipation were constant demoralizing forces. Over

1,600 Creeks were slaughtered within a few months in the Creek war of 1813-4, besides those who must have died from starvation and hardship. It is claimed that the Cherokee removal in 1839 cost the lives of 4,000 Indians, while the disturbances in the Indian Territory during the Civil War cost thousands more. The apparent increase in the five civilized tribes of Indian Territory since then is almost entirely from white intermixture. The ordinary figures for these five tribes cannot be taken as ethnologically correct, as they include as " Indians " fully 10,000 claimants with so little, if any, of Indian blood as to have been repudiated by the Indian tribal courts while those courts were still in existence. Other thousands are still clamoring for admission to land and money privileges. Over 7,000 of these repudiated claimants are now upon the Cherokee roll together with some 1,600 adopted Shawnee and Delawares not separately noted. Nevertheless, there can be no doubt but that both Cherokee and Choctaw have increased within the historic period, although, as has been said, this is due largely to white intermixture, as also to absorption of remnant tribes.

	1650	1907
GEORGIA, ALABAMA, TENNESSEE		
Cherokee	22,000	25,000
Yuchi	1,500	700
Creek confederacy }	18,000	11,000
Seminole (later offshoot from Creeks) }		2,200
Yamasee	2,000	Extinct
Mobile }	2,000	Extinct
Tohome }		
FLORIDA		
Apalachee, etc.	7,000	Extinct
Potano	3,000	Extinct
Yustaga	1,000	Extinct
Timucua, etc.	8,000	Extinct
Tocobaga	1,000	Extinct
Caloosa	3,000	Extinct
Ais, Tegesta, etc.	1,000	Extinct
MISSISSIPPI		
Chickasaw	8,000	5,000
Choctaw	15,000	18,000
Natchez	4,500	25 (?)
Tunica } Lower Yazoo River	2,000	50 (?)
Yazoo }		Extinct
Koroa }		Extinct
Ofogoula }		Extinct
Amount carried forward	99,000	61,975

Mississippi—*Continued*	1650	1907
Amount brought forward	99,000	61,975
Chakchiuma, Ibitoupa, Taposa, Tiou } Upper Yazoo River	1,200	Extinct
Biloxi, Pascagoula, Moctobi	1,000	Extinct
Arkansas		
Quapaw or Arkansa	2,500	290
Louisiana (excluding Caddo tribes)		
Houma [1]	1,000	350
Chitimacha	3,000	60 (?)
Atakapa	1,500	25 (?)
Acolapissa (including Tangipahoa)	1,500	Extinct
Bayogoula, Mugulasha, Quinipissa	1,500	Extinct
Chawasha, Washa, Opelousa } (" les Gens de la Fourche ")[2]	1,400	Extinct
Taensa, etc.	800	Extinct
	114,400	62,700

NOTE

In Bulletins 43 and 73 (Bur. Amer. Ethnol., 1911, 1922) I gave the following estimates of population of tribes considered by Mooney in this section, the supposed date being near 1700, or about fifty years later than that selected by Mooney. For purposes of comparison I repeat Mooney's estimates in the second column.

	Swanton	Mooney
Creek Confederacy	7,000	18,000
Mobile and Tohome	1,225	2,000
Chickasaw	3,000–3,500	8,000
Choctaw	15,000	15,000
Natchez	3,500	4,500
Tunica, Yazoo, Koroa, and Ofogoula	2,450	2,000
Chakchiuma, Ibitoupa, and Taposa (Mooney places the Tiou here but I put it with the Natchez)	750	1,200
Amount carried forward	32,925–33,425	50,700

[1] Houma: The so-called Houma of today include remnants of most of the Louisiana coast tribes, in all degrees of mixture, Indian, white and negro. The state census recognizes about 350 as Indian. They claim over 800 of all mixtures and intermarriages.—J. R. S.

[2] There has been a confusion here between two tribes, one called Okelousa, which was in fact one of " les Gens de la Fourche," the other the Opelousa living farther west. Both were, however, comparatively insignificant.—J. R. S.

	Swanton	Mooney
Amount brought forward	32,925–33,425	50,700
Biloxi, Pascagoula, and Moctobi	875	1,000
Houma	1,225	1,000
Chitimacha	2,625	3,000
Atakapa (subtracting the population of the Texas tribes from my original estimate)	2,000	1,500
Acolapissa	1,050	1,500
Bayogoula, Mugulasha, and Quinipissa	875	1,500
Washa, Chawasha, and Okelousa (Mooney gives Opelousa erroneously for Okelousa)	700	1,400
Opelousa	455	
Taensa, and Avoyel	1,155	800
	43,885–44,385	62,400

While the discrepancy between the totals seems to be considerable, it will be noticed that it is due almost entirely to the rather wide differences in the estimates for the Creeks and Chickasaw. The numbers of Chickasaw appear to have varied greatly owing to their constant wars, while those of the Creeks were affected by this cause and by the adoption from time to time of independent tribes. I was mainly influenced by a particularly careful estimate made under the auspices of the colony of South Carolina in 1715, but it is quite possible that it was too low. It did not include the Yuchi, Natchez, Shawnee, and probably some other tribes which came to be parts of the Confederation. If we omit the figures for these two tribes the estimates fall very close to each other.—J. R. S.

CENTRAL STATES

In this group we include the native tribes of the Ohio Valley and lake region from the Alleghenies to the Mississippi, together with the territory held by the Ojibwa in Canada, north of the Great Lakes. The Ottawa and Wyandot (Hurons), long identified with this region, entered it within the historic period from eastern Canada and are considered under that section, while the equally prominent Delawares came from east of the mountains and are treated under the North Atlantic section. The Shawnee, although part of them lived for some time in South Carolina and Alabama, had their principal early residence within the Central region.

The best calculation possible seems to make the native population of this section in 1650, the period of first disturbance, about 75,000 as against about 46,000 existing today in and out of their original territory, a decrease of about 39 per cent. The French statements ascribing to the ancient Erie a population of from 7,000 to 10,000 souls are evidently based upon insufficient acquaintance with the tribe. It is impossible to arrive at very close figures for the present population for the reason that probably one-half of the great Ojibwa tribe is not officially differentiated from intermingled Ottawa and Cree.

On the whole the Central tribes have held their own comparatively well. The chief causes of decline have been: The Iroquois invasions of the seventeenth century by which the Erie were destroyed and the Illinois, Miami, and Mascouten greatly reduced; the war waged by the Foxes and their allies against the French from about 1712 to 1740, by which the Foxes were nearly destroyed; liquor and wholesale dissipation introduced by the French garrisons and traders and continued through the later treaty and removal period, the prime cause of the extinction of the Illinois and Miami; the almost continuous border wars from 1774 to 1815; local epidemics and removals. No widespread epidemic visitations are on record, although smallpox has several times visited particular tribes, notably the Mascouten, Ottawa, and Ojibwa. The great smallpox visitation of 1781-2 ravaged the Ojibwa territory as far east as Lake Superior. There have been no great losses from mission confinement, as in Texas, from blood-poisoning as on the Columbia, or from wholesale massacre as in California. Several tribes have recruited their number by intermarriage with the whites, particularly the Ojibwa, who appear to be more numerous now than at any earlier period.

	1650	1907
Erie	4,000	Extinct
Fox (now represented by a band in Iowa)	3,000 [1]	345
Illinois confederates (now about 1/6 of Peoria, etc., in Oklahoma)	8,000	50
Kickapoo (including perhaps 350 or more in Mexico in 1907)	2,000	830
Mascouten	1,500 [1]	Extinct
Menomini	3,000	1,375
Miami (including Wea and Piankashaw)	4,500	530
Ojibwa (United States and Canada)	35,000	36,000 (?)
Potawatomi (including 180 in Canada)	4,000	2,555
Sauk	3,500 [1]	608
Shawnee	3,000	1,500 (?)
Winnebago	3,800	2,333
	75,300	46,126

[1] Michelson (Journ. Wash. Acad. Sci., Vol. 9, No. 16, Oct. 4, 1919, pp. 489-494) tells us that the most reliable early estimates of the population of the Foxes and the Sauk are those of Lewis and Clark which would make the numbers of the former 1,200 and of the latter 2,000 in the year 1806. Allowing for the losses which the two tribes suffered between 1650, the date taken by Mooney for his first estimates, and the time of Lewis and Clark, there would still seem to be a discrepancy of perhaps a thousand in each case between Mooney's figures and the figures indicated by Michelson's researches. Dr. Michelson also considers it certain that the "Mascouten" of Mooney were identical with the Peoria.—J. R. S.

THE PLAINS

At the beginning of regular white occupancy the Plains territory, from the Canadian border to the Gulf, with some overlapping on the east into the timber land, was held by some 32 tribes, confederacies or tribal groups. For convenience these may be classified as Northern and Southern; the first including all those south of the Red River of the North within territory dominated in the early period by French and English influence, while the second includes those of Texas and adjacent regions formerly subject chiefly to Spanish influence. In the southern area the breakdown of aboriginal conditions may be considered to have begun about 1690. In the north it began nearly a century later, when many of the southern tribes were already practically extinct.

A detailed study for each tribe and group shows an aggregate original population for the whole region of about 142,000 souls as against the present official enumeration of about 53,000 souls, a decrease of some 89,000 or about 60 per cent. The Sioux alone have not only held their own, but have largely increased, by reason of their greater resisting power and the adoption of numerous captives from weaker tribes. Leaving them out of both calculations we should have for the others an original aggregate of about 117,000 souls as against about 25,000 souls today, a decrease of nearly 80 per cent. It must be remembered that the original Indians were all full-bloods, while whole tribes of today have a large percentage of white blood.

The chief causes of decrease have been smallpox or other epidemics of white origin; removals, and restraints of mission and reservation conditions; liquor and general demoralization from contact with civilization, and wars with the whites. The largest factor has been smallpox, while the actual destruction by warfare seems of minor importance, as the hostility of the warlike tribes saved them from the demoralizing influences of intimate contact with the whites.

The great epidemics in Plains history are as follows:

1691. Epidemic of unknown character throughout east Texas and adjacent Louisiana, officially reported to have killed 3,000 of the southern Caddo alone.

1778. Smallpox ravaged same territory and nearly destroyed several small tribes.

1781-2. Smallpox over whole upper Missouri, Saskatchewan, Columbia and Great Slave Lake region, paralyzing the fur trade for two years.

1801. Smallpox swept the whole Plains, together with Louisiana from the Gulf to Dakota, with especial destruction in Texas and among the Omaha (see Sibley, and Lewis and Clark).

1837-8. Smallpox swept whole Plains from Saskatchewan to Red River or further; practically exterminated the Mandan.
1849. Cholera in central Plains; killed about one-fourth of the Pawnee.
1870-1. Smallpox very destructive among Assiniboin, Blackfeet and Cree.

PLAINS (NORTHERN)

	1780	1907
Arapaho	3,000	1,774
Arikara	3,000	389
Assiniboin	10,000	2,080
Atsina	3,000	553
Blackfoot	15,000	4,560
Cheyenne, etc.	3,500	3,351
Crow	4,000	1,787
Hidatsa, etc.	2,500	468
Iowa	1,200	339
Kansa	3,000	196
Kiowa	2,000	1,220
Kiowa-Apache	300	156
Mandan	3,600	263
Missouri	1,000	Extinct
Omaha	2,800	1,246
Osage	6,200	2,156
Oto	900	390
Pawnee	10,000	644
Ponca	800	845
Sioux	25,000	28,060
	100,800	50,477

PLAINS (SOUTHERN)

	1690	1907
Akokisa	500	Extinct
Aranama	200	Extinct
Bidai	500	Extinct
Caddo (incl. Hasinai), etc.	8,500	555
Comanche	7,000	1,430
Karankawa, etc.	2,800	Extinct
Kichai	500	30
Lipan	500	25
Mescalero	700	466
Coahuiltecan Tribes	15,000	Extinct
Tonkawa, etc.	1,600	45
Wichita, etc.	3,200	310
	41,000	2,861

THE COLUMBIA REGION

Under this heading we may include Washington, most of Oregon excepting the southern part, north and central Idaho, and northwest Montana; embracing all of the Salishan, Chinookan, Shahaptian, Lutuamian, north-central Athapascan and neighboring small stocks, within the present United States but excluding the Shoshonean and Shastan peoples. The population of this section was probably at its highest about the year 1780, when it may have numbered nearly 90,000 souls as against about 15,000 at present. About 1782-3 the whole region was swept by the great smallpox epidemic which had started on the Missouri a year earlier and extended from Lake Superior to the Pacific and northward to Great Slave Lake (see *Plains Region*). From all accounts it destroyed from one-third to one-half of the Indians within its area. Lewis and Clark in 1806 noted its effects at the Willamette mouth and on the coast, and it is apparent from their statements that the tribes were still far from having recovered their losses. Their estimates for the principal groups at that period seem very nearly correct as compared with later statements of the Hudson Bay Company officers, Hale and others. They give the Shahaptian tribes 17,960; Chinookan tribes 16,640; the Kalapuyan tribes 2,000; Yakonan 5,700; the Kusan 1,500; etc., each of which was probably from one-fourth to one-third less than the corresponding number before the epidemic of 1782-3.

The beginning of regular trade with ocean vessels at the mouth of the Columbia in 1788 marked the introduction of sexual diseases from sailors and traders which soon poisoned the blood of practically all the Indians west of the Cascades, resulting in a constant and rapid decay even without the agency of epidemics or wars. Liquor, introduced in large quantities by Russian traders, despite the efforts of the Hudson Bay Company officers to prevent it, is also said to have been a potent destroyer along the coast and the Columbia (Farnham). In 1823 (Hale; others make it as late as 1829) an epidemic of fever, said to have been due to plowing operations by the whites at Fort Vancouver, spread along the whole Columbia region below the Dalles, the whole Willamette Valley, and apparently also the coast and central region as far south as California. Over much of this area, according to Hale, it destroyed four-fifths of the natives, practically exterminating the Chinookan tribes, leaving only about 1,300 out of the thousands found by Lewis and Clark. The Kalapuya and Oregon coast tribes seem to have suffered in nearly the same proportion, but the Salishan and Shahaptian tribes of Washington, eastern Oregon, and Idaho appear to have escaped. In 1846 the Columbia tribes, including the Nez Percés, suffered another visitation of smallpox. In 1847 a measles epidemic, also originating with the whites, spread over much of the same territory, being particularly fatal to the Cayuse and associated tribes in eastern Oregon. In 1852-3 smallpox, introduced from San Francisco among the Makah, spread with its usual destructive effect among nearly all the tribes of Washington and northern Idaho, wiping out whole villages in some tribes. The Indian wars and conflicts with new settlers from 1840 to 1855 contributed also to a large decrease in the tribes concerned, while the removal to reservations about the latter date proved in many cases more fatal even than smallpox, the small tribes of western Oregon especially losing over half their number within a few years. The decrease continued until they are now almost extinct. The larger tribes of eastern Washington, northern Idaho and western Montana, having been less exposed and of healthier blood, have suffered less.

and perhaps in some few cases may actually have increased through improved food resources and protection from outside enemies.

	1780	1907
WASHINGTON, WEST		
Wakashan		
Makah (Quinnechant)	2,000	438
Chimmesyan		
Chimakum	400	Extinct
Quileute and Hoh	500	295
Salishan		
Clallam	2,000	327
Quinaielt and Quaitso	1,500	196
Chehalis, Cowlitz, etc. (including Humptulip)	1,000	170
Lummi, Samish and Nooksak	1,000	614 (?)
Skagit, Swinomish, etc.	1,200	273
Snohomish, Snoqualmu, Tulalip, etc.	1,200	200 (?)
Suquamish, Dwamish, etc. (Port Madison, etc.)	1,200	210 (?)
Nisqually, Puyallup, etc. (including Muckleshoot reservation)	1,200	780
Skokomish, Toanho, Squaxon	1,000	290
Chinookan		
Echeloot (Tlaqluit, Wishram)	1,500	
Chilûktkwa (Chilluckittequaw) and Smackshop	3,000	
Shahala, Skilloot } partly in *Oregon, q. v.*	...	
Shoto	600	
Quathlapotle	1,300	150 (?)
Callamaks (Kalama)	250	
Wahkiakum	300	
Chinook	600	
Killaxthokle (Shoalwater Bay)	200	
Athapascan		
Kwalhioqua	200	Extinct
Shahaptian		
Klikitat and Taitinapam { probably included with "Sokulk" of Lewis and Clark; now with "Yakima," q. v. from whom they had branched off. }	600	Extinct
WASHINGTON, EAST		
Salishan		
Lake or Senijextee	500	268
Colville (Wheelpoo, Shwoyelpi)	1,000	334
Sanpoil (Hihighenimo) and Nespelim	800	358
Spokan (Lartielo; part on Flathead reservation, Montana)	1,400	769
Amount carried forward	26,450	5,672

Washington, east—*Continued*	1780	1907
Amount brought forward	26,450	5.672
Okinagan, etc. (Lahanna) (not including those in British Columbia)	1,000	348
Methow and Isle de Pierre (Columbias, Moses' band)	800	324
Piskwau, etc. {including Wenatchi, Kititas (Shanwappom), Skautal (Skaddal), Wshanatu (Shallatoo), (Skwanana ? (Squannaroo), Kahmiltpah, Siapkat (Seapcat).}	1,400	2,002 (Piskwau to Atanum)
Shahaptian		
Palus (Pelloatpallah)	1,800	
Wanapum (Sokulk, see Klikitat)	1,800	
Chamnapum (Chimnahpum)	1,800	
Yakima proper (Pishquitpah, Cutsahnim ?)	3,000	
Tapanash (Eneeshur) {including Kowassayee, Skinpah, Uchichol, Hahaupum (Wabowpum), Tapanash.}	2,200 (Tapanash and Atanum)	
Atanum		
Montana, west, and Idaho, north		
Salishan		
Salish or Flathead	600	623
Kalispel or Pend d'Oreille (Coospellas)	1,200	943
Skitswish or Coeur d'Alêne (Skeetsomish)	1,000	506
Shahaptian		
Nez Percé (Chopunnish)	4,000	1,563
Oregon, west		
Chinookan		
Skilloot (Calooit, Kreluit, Cooniac; partly in Washington)	3,000	Extinct
Clatsop	300	Extinct
Cathlamet	450	Extinct
Wappatoo Indians (including later Namanamin, Namoit, Wakamuck, Wapeto):	3,600 (Wappatoo Indians, a–i)	10
a Nechacokee		
b Multnomah		
c Clannahquah		
d Nemalquinner		
e Cathlahcommahtup		
f Cathlannahquiah		
g Claninnata		
h Cathlahcumup		
i Clannaminnamun (Namanamin)		
Clackamas (Clarkamus)	2,500	18
Charcowah (Clowwewalla, Willamette, Willamette Tumwater)	300	Extinct
Amount carried forward	57,200	12,009

Oregon, west—*Continued*	1780	1907
Amount brought forward	57,200	12,009
Cushook (probably included later with Willamette Tumwater)	900	Extinct
Shahala {partly in Washington; including later Wattlala, Cathlakaheckit, Kigaltwalla, Kwikwûlit or Dog River, Cascade, Wasco, Wahlala, Tumwater, etc. Wasco {Dalles band of Wasco, Dalles Indians, Wascopam, probably in 1780 included with Shahala on Washington side.	3,200	170 (?)
Salishan		
Tillamook, Nestucca, Salmon River, Siletz, etc.	1,500	Extinct
Waiilatpuan		
Molalla (probably in 1780 with Cayuse)	....	Extinct
Athapascan		
Tlatskanai	1,600	Extinct
Yakonan		
Luckton, Yaquina (Youickcone, Yakone), Alsea (Ulseah), Siuslaw (Sheastuckle)	6,000	100 (?)
Kusan		
Coos (Cookkoo-oose), Mulluk (Lower Coquille of Siletz agency)	2,000	50 (?)
Takelma		
Takelma (Rogue River), Latgawa (Upper Rogue River	500	Extinct
Athapascan		
Chocreleatan (Upper Coquille), Quatomi (Six, Flores creek, Sucquachatany), Cosuthenten (Port Orford, Kusochatany), Euquachee (Euchre, Uka), Yahshute (Joshua, Lower Rogue River of Siletz agency), Chetléssentun (Pistol River), Wishtenátin (Naltunatunne, Nultnatna ?), Chetco (Cheattee, Chata), Tototin (Tootootena), Mackanotin (Mecanotany, Rogue River of Siletz agency), Shistakoostee (Shishequittany, Chasta Costa, Illinois River)	5,600	250 (?)
Umpqua (Upper Umpqua of Grande Ronde Agency), Nahankhuotané (Cow Creek), Taltushtuntudé (Talhushtany, Galice Creek), Dakubetedé (Upper Rogue River, Applegate Creek)	3,200	100 (?)
Amount carried forward	81,700	12,679

Oregon, west—*Continued*	1780	1907
Amount brought forward	81,700	12,679
Kalapooian		
Atfalati		
Calapooya		
Lakmiut		
Mary's River	3,000	49
Santiam		
Yamhill		
Yonkalla		
Shahaptian		
Wallawalla, Umatilla	1,500	612
Tenino		
Tilqûni (Warmspring)		
Tai-aq (Taigh, Upper Des Chute Wallawallas)		
Tûkspûsh (Dockspus, John Day River)	1,400	750 (?)
Waiam (Wayyampa, Lower Des Chutes Wallawallas)		
Waiilatpuan		
Cayuse	500	405 (?)
Lutuamian		
Klamath	800	665
Modoc (partly in California)	400	271
Shasta (mainly in California, q. v.)	....	....
	89,300	15,431

CALIFORNIA

In treating California we include the border tribes, Shasta and Yuma, but exclude as extra-limital the Modoc (Ore.), northeastern border Paiute (Nev.), Chemehuevi and Yavapai (Ariz.). Throughout most of California tribal organization was so loose, and the bands so many and their names so little known, that it is almost impossible to differentiate by tribes, and we are forced to deal with linguistic stocks or territorial groups. The population cannot be tabulated by tribes, but there can be no question that it was several times larger than in any other area north of Mexico and that the destruction has been correspondingly greater. The period of disturbance may be said to begin in 1769, the date of the beginning of Spanish occupation and the establishment of the first mission.

Estimates of the original population for the whole state have been made by Powers (Tribes of California, Contr. N. Amer. Ethnol. III, 1877), Merriam (Indian Population of California, Amer. Anthrop. (n. s.) VII, Oct. 1905), Kroeber (Inds. of Calif., in Handbook I, 1907) and S. A. Barrett (personal letter, Feb. 5, 1908). Powers, who had extended opportunity for observation, but little scientific training or knowledge of earlier history, estimated it from 500,000 to 700,000 stoutly refusing to lower his figures when challenged. Merriam, after close investigation of every section of the state, both from the ethnologic and the biologic or subsistence standpoint, makes it 260,000 in 1800, at which time, however, 18 of the 22 missions were already in operation, resulting in a steady thinning out of the natives within their jurisdiction. Kroeber makes the original number "perhaps 150,000." Barrett, basing his opinion upon close study of the Pomo region, is "inclined to support Merriam's view" and estimates it at "upwards of 200,000." In view of Merriam's opportunities and detailed investigation we may take his figures (beginning with 1800) as the best approximation for the whole region, although the known decrease among the Mission Indians, almost from the start, would seem to make even his figures conservative.

In 1853 the Indian population of the state was officially estimated at 100,000; in 1856 at 48,100; in 1864 at not more than 30,000; and in 1906, exclusive of 200 Paiute in the northeastern corner, and less than a dozen Shasta in Oregon, at 19,014, a decrease of nearly 93 per cent.

Among the principal causes of decrease may be noted: evil effects of unaccustomed confinement, and a number of epidemics including smallpox, together with widely prevalent infanticide, among the Mission Indians from 1769 to 1834; a great fever epidemic throughout the whole central region in 1833, officially estimated to have killed 70,000 Indians and reported to have come from the "English settlements" (*i. e.,* Hudson's Bay Co. posts) in the north, and possibly connected with the great fever epidemic of Oregon in 1823 and later; dispersal and starvation of surviving Mission Indians after confiscation of missions in 1834; wholesale massacres, clearances, and robberies of food stores by American miners and settlers from 1849 to the close of the Modoc war in 1873, together with the general demoralization consequent upon association of the two races. For details and special instances see Powers, Merriam, and Bancroft.

	1769	1907
Total of state, Merriam estimate for 1800..............	260,000[1]	18,797

[1]A careful and very detailed estimate of the Indian population of California in 1770 has been made more recently by Professor Kroeber and incorporated in his Handbook of the Indians of California (Bull. 78, Bur. Amer. Ethnol., 1925, p. 883). This is only a year later than the date selected by Merriam for his earliest estimate, the one which Mooney adopts, but the figure which Kroeber fixes upon, 133,000 is scarcely more than half of Merriam's.

CENTRAL MOUNTAIN REGION

Under this designation we include all of Nevada and Utah, with western Colorado and Wyoming beyond the main divide, southern Idaho, southeast Oregon and southwest Montana, with small portions of New Mexico and Arizona, being the central territory of the Shoshonean tribes, together with the Washo and Jicarilla.

The aboriginal period for this region may be considered to culminate in 1845. Previous to this time there seems to be no record of any epidemic or other destroying agency but by the opening of two emigrant trails—to Oregon and California—within the next five years, and the subsequent opening of the Southern Pacific railroad, each crossing the territory from east to west, the seeds of disease were scattered broadcast, murders and larger massacres became common, starvation resulted in consequence of eviction from old homes, and a chronic and wasting warfare, involving most of the bands, was inaugurated, lasting until 1868. In one notable fight, at Bear River in 1863, the Indians engaged lost 308. The short Bannock war in 1877-8 destroyed at least 200. In 1853 a smallpox epidemic, possibly the same which ravaged the upper Columbia about the same time, spread among the Shoshoni and Bannock, and is said to have "more than decimated" the latter tribe. The official reports still show a steady decline. On the whole, however, the Indians of this region, have suffered less than those of any other large section of the United States, the rough and desert character of the country having served as a protection from disturbance.

	1845	1907
Bannock	1,000	530
Shoshoni and Sheepeater	4,500	2,265
Ute (including Gosiute and Pahvant)	4,500	2,068
Paiute (including Paviotso and "Snake" Oregon)	7,500	5,605
Washo	1,000	300
Jicarilla	800	776
	19,300	11,544

NEW MEXICO AND ARIZONA

In this group we include the tribes of these two States, with the exception of the border tribes, Yuma, Paiute, Jicarilla and Mescalero, credited to adjoining sections. The Cocopa are omitted as extra-limital, but some 1,000 Papago in Sonora are included with the Indians of Arizona.

The first invasion of this section, by Coronado in 1540-1, resulted in the destruction of perhaps a thousand Indians, chiefly of the Tigua tribe, but as it was not followed up by permanent occupation on a large scale until nearly a century later, we may assume that the Indians recovered from the blow and continued to increase, without special loss through mission establishment, until the general upheaval of the great Pueblo revolt and reconquest, 1680-1692. This struggle practically wiped out the two largest Pueblo tribes, reducing the Pueblos by at least one-third, and inaugurating a decline which has steadily continued to the present day. The Yuman and Piman tribes were not affected, the former wasting chiefly through tribal wars or perhaps also by unrecorded epidemics, while the Pima and Papago apparently continued to increase until the American occupation about 1850, since when there has been a sharp decline among nearly all the tribes, due to introduced diseases and dissipation, and starvation consequent upon deprivation of water rights. Epidemics, especially of smallpox, have been almost periodical for nearly a century, the last notable outbreak among the Pueblos in 1898-9 resulting in the death of over 500. Our Pueblo figures are largely based upon the investigations of Mr. F. W. Hodge.

The cognate Navaho and Apache seem to be an exception to the general rule, due to the fact that they have kept themselves free from blood contamination and excesses, and, like the Iroquois, have recruited their war losses by wholesale incorporation of captives and broken tribes. For 50 years, beginning about 1835, the Apache were in constant warfare with either Mexico or the United States, or both, standing bounties being paid by Mexico for Apache scalps during most of that period, resulting in a total recorded loss of at least 2,000 killed. They were probably at their highest point about 1850, when they may have numbered 5,500 or even 6,000. The Navaho have suffered much less in proportion in warfare, and very little from other causes, and by reason of healthy blood and incorporation of aliens, have probably increased steadily from the beginning of the historic period. Their present number is given officially as 26,626, but 8,000 of this is reported as "a mere estimate." It is a mistake to suppose, as has been claimed, that they have reached this number from a total of less than 9,000 when released from military confinement in 1868, as evidence shows that only about half the tribe had surrendered.

	1680	1907	
Shoshonean			
Chemehuevi	....	144	
Yuman			
Havasupai (Suppai, Cohonino)	300	172	
Yavapai (Mohave Apache)	600	655	
Walapai	700	525	
Mohave	3,000	1,309	
Maricopa	2,000	383	
Quigyuma (Jalliquamay)	2,000	Extinct	
Cajuenche (Cawina)	3,000	Extinct	
Alchedoma	3,000	Extinct	
Piman			
Sobaipuri	600	Extinct	
Pima	4,000	4,037	
Papago	6,000	5,800	
Athapascan			
Apache proper	5,000	4,500	
Navaho	8,000	25,000	(?)
Pueblo			
Hopi "province" (incl. Awátobi; but excl. Hano)	2,800	1,970	
Zuñi "province" (modern Zuñi)	2,500	1,682	
Tano "province"	4,000	Extinct	
Piros "province" (modern Senecú, Mex.)	9,000	60	(?)
Tewa "province" (modern Nambe, San Ildefonso, San Juan, Santa Clara, Tesuque, Hano of Hopi group)	2,500	1,215	
Tigua "province" (modern Isleta, Sandía, and Isleta, Tex.)	3,000	1,108	
Taos "province" (modern Taos, Picurís)	1,500	590	
Pecos "province"	2,000	Extinct	
Jemez "province" (modern Jemez)	2,500	521	
Keres "province" (modern Cochiti, San Felipe, Santa Ana, Santo Domingo, Sia)	2,500	1,971	
Acoma "province" (modern Acoma, Laguna)	1,500	2,190	
	72,000	53,832	

GREENLAND

Greenland was originally colonized by Scandinavians, about the year 1000, but the colony dwindled and became extinct shortly before 1500, owing chiefly to the inroads of the Eskimo. The existing Danish colony was established in 1721.

The aborigines are all of Eskimo stock and number altogether about 11,000, including a very large proportion of mixed-bloods, who, as a rule, adhere to Eskimo custom and language. This number seems to be considerably higher than in 1721, but the difference is largely, if not entirely, to be accounted for by the increase of the mixed-blood stock from European intermarriage. In addition the Danish government and the resident missionaries have been particularly careful and successful in shielding the natives from outrage, liquor, and other destructive agencies so common elsewhere in the contact of the savage with civilization. According to Rink, the Eskimo of the Danish districts, during the eighteenth century—the colonizing period—seem to have greatly decreased, then " for a long period " again increased, and again since 1855 to his writing, in 1875, had remained almost stationary at between 9,400 and 9,700 souls. As those outside the Danish district number about 800, there seems to have been an increase since then.

	1721	1907
Eskimo	10,000	11,000

EASTERN CANADA

In this section we include Newfoundland, Labrador and the Ungava district, Prince Edward Island, Nova Scotia, New Brunswick, Quebec, Ontario north and east of the watershed of Lake Superior, Keewatin east of the Severn River watershed and a small extension into western New York, formerly a part of the Neutral Nation territory.[1] The shores of Lake Superior, Rainy Lake, etc., held by the Ojibwa, are treated in connection with the *Central States* (U. S.).

Throughout a large part of this region tribal organization is so loose and dialectic variation so slight, that it is impossible to make close tribal distinctions. With the Monsoni, classed indifferently with the Ojibwa or the Cree, we have included all the bands of the Canadian Treaty No. 9 (1905-6) in southeastern Keewatin and northern Ontario, together with those of southwestern Ungava. Under Algonkin and Ottawa we include all the former and present bands of the Ottawa and St. Maurice River basins, most of these being now resident in the United States under the name of Ottawa. Under Montagnais and Nascapee we have included the bands thus officially designated in eastern Quebec, including the Saguenay River and the St. John Lake basin, together with those of the interior of Ungava. The standing official estimate for Ungava district comprising all of Labrador excepting the Atlantic coast strip, has been kept for some years past at 5,060, with no differentiation of tribes, comprising, according to Turner, Eskimo, Nascapee, Montagnais and Monsoni. The proportion here made is therefore as arbitrary as the official estimate.

[1] Since this paper was written the Ungava district has been incorporated in the Province of Quebec, Ontario expanded toward the northwest, and Manitoba, Saskatchewan, and Alberta extended northward to the 60th parallel of latitude. Athabaska and Franklin districts have been effaced and Keewatin greatly curtailed.—J. R. S.

but is based upon a study of probabilities. The Indian and Eskimo population of Newfoundland and the eastern Labrador coast is not noted in the Canadian report. The original population for the whole section was probably about 54,000, which has been reduced about one-half.

The period of first disturbance for Eastern Canada may be considered to begin shortly after 1600, although an active fishing business began along the coast nearly a century earlier. The first great destruction in this region was accomplished by the Iroquois, who, having procured guns before their neighbors, proceeded to exterminate or drive out all the surrounding tribes, and between 1648 and 1675 successively destroyed or reduced to refugee remnants the Hurons, Tionontati, Neutrals, Erie, Algonkin, Montagnais and Conestoga, several of which tribes at the start outnumbered their destroyers, but lacked firearms. Next in destructive importance comes smallpox, of which the principal early visitations were in 1636-9 among the Hurons, Neutrals, Algonkin, etc., and again in 1670 among the Algonkin and Montagnais, when it was said that it destroyed almost all of those who remained after the Iroquois wars. Later local smallpox epidemics were in 1702-3 in Quebec and in 1799 among the Ottawa of lower Michigan, killing about one-half of those at their main settlement of Arbre Croche. Liquor and general dissipation have also been responsible for a part of the decrease, though not to the same extent as in some other sections. The Eskimo tribes have probably remained about stationary, while the Micmac and Malecite show a credible increase, chiefly, however, of the mixed-blood element. The Algonkin of Canada have increased rapidly also in recent years, and with the Ottawa of the United States have probably more than made up their earlier losses. The small Beothuk tribe was practically exterminated by the Micmac early in the last century.

	1600	1906
Eskimo—*a.* Labrador coast, Newfoundland	1,800	1,500 (?)
b. Ungava district, Canada proper	1,800	1,250 (?)
Monsoni, etc. (Ungava, Keewatin, Ont., Que.)	5,000	4,800 (?)
Montagnais and Nascapee bands (Quebec, Ungava)	5,500	5,400 (?)
Beothuk	500 (?)	Extinct
Micmac	3,500	4,500 (?)
Malecite	800	900
Algonkin and Ottawa bands (incl. Ottawa in U. S.)	6,000	7,000 (?)
Huron confederates	10,000	840 (Huron confederates and Tionontati together)
Tionontati {confederated remnant known as Huron in Can. and Wyandot in U. S.	8,000	
Neutral Nation	10,000	Extinct
Missisauga	1,300	810
	54,200	27,000

CENTRAL CANADA

In this section we include the " Northwest Territories " of Canada and other Canadian territories of the great central region between Ontario on the east and British Columbia and Alaska on the west, together with the Arctic shores and rivers, but excluding small portions of Keewatin and Manitoba (*Canada, Eastern,* and *Central States*) and larger portions of Alberta and Saskatchewan (*Plains*).[1] The several jurisdictions are officially designated as Manitoba, Alberta, and Saskatchewan provinces, Keewatin, Athabaska, Mackenzie, and Franklin districts, and Yukon territory. The original population may have been about 51,000. It is now about 28,000, of which one-half belong to the Cree tribe; about 5,500 are Eskimo and the rest are of Athapascan stock. The period of first disturbance may be conveniently put at 1670, the date of the charter of the Hudson Bay Co., which until recently controlled the whole vast region. Along the Eskimo coast in the Mackenzie region, however, there was no essential change until after 1800.

For lack of data it is impossible to make any close reliable estimate for the earlier period, but reasoning from the known to the unknown there appears to have been a decrease over the whole region, greatest among the Eskimo and among the southern Athapascan tribes. The destruction of the Eskimo has been accomplished chiefly through new diseases and dissipation introduced by the whalers and by starvation consequent upon the dwindling of the food supply through the same agency. In the lower Mackenzie region an epidemic of scarlatina in 1865 is estimated to have killed about one-fourth of the population. Further south the Athapascan tribes were greatly reduced early in the eighteenth century by destructive wars waged against them by the Cree, who were the first to procure guns from the Hudson Bay Co. traders. In 1781-2 the great smallpox epidemic already noted in treating of the northern Plains, swept over the whole central Canada region as far as the Great Slave Lake and across the mountains into British Columbia. The Cree and Chipewyan were among the chief sufferers. In 1837-8 the Cree and perhaps others lost heavily by the same smallpox epidemic which nearly destroyed the Mandan, and again to some extent in 1870-1. As in the cases of some others of our largest tribes, the Cree seem to have made up their losses and are now probably as numerous as ever before in their history. A part of their recovery is due to intermarriage with whites. The Sarsi who

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[1] See footnote, page 23.

branched off from the Beaver tribe some time before 1790 have declined rapidly almost since first known.

	1670	1906
Eskimo—*a.* Baffin Land, Franklin District	6,000	1,100
b. Western Franklin District	6,000	1,400
c. Yukon Territory	2,200	1,000
d. Mackenzie District	4,800	1,300
e. Northern Keewatin District	3,000	700
f. Southampton Island, Keewatin Dist.	300	Extinct
Kutchin tribes—*a.* Yukon Territory (Voen K., Tukkuth K., Tutcone K.)	2,200	1,700
b. Mackenzie D. (Thetlet K., Nakotco-ondjig K., Kwitqak K.)	800	600
Sheep (Esbathaotinne), Mackenzie Dist., etc.	300	200
Mountain Inds., Mauvais Monde (Etquaotinne) Mackenzie Dist., etc.	400	250
Nehane tribes of Yukon Ter., etc. (excl. those of British Columbia)	800	600
Hare } Mackenzie District	750	450
Dogrib } Mackenzie District	1,250	850
Slave } Mackenzie District	1,250	850
Yellow-knife } Mackenzie District	430	250
Beaver, Athabaska Dist. and B. C.	1,250	700
Chipewyan, etc., Athabaska and Mackenzie Dist., etc.	2,250	1,520
Caribou-eaters, Athabaska and Keewatin Dist.	1,250	900
Sarsi, Alberta Prov.	700	200
Cree & Muskegon (Swampy Cree) { Saskatchewan 5,300; Manitoba 4,000; Alberta 1,680; Athabaska 1,220; Keewatin 2,000. }	15,000	14,200
	50,950	28,770

BRITISH COLUMBIA

The present population of British Columbia, including Vancouver Island, is about 25,000, as compared with an original population of about 86,000, at the period of earliest disturbance shortly after 1780, being a decrease of about 70 per cent. This is a very conservative estimate, authorities generally putting the original population much higher, and Hill-Tout estimating it as at least 125,000. The estimate of the Hudson Bay Company officers makes it approximately 41,000 in 1857, exclusive of the Nootka tribes of Vancouver Island, which would probably make about 6,000 more, or a total of about 47,000 some 50 years ago.

The first great disturbing influence was the great smallpox epidemic of 1781-2, which swept over the whole country from Lake Superior to the Pacific (see Plains). There is traditional and archeologic evidence that this epidemic was very destructive throughout British Columbia, but the tribes may be assumed to have nearly made up the losses from this cause in the 70 years or more that elapsed thereafter before the permanent occupation of the country by the whites. The coast trade, inaugurated about 1785, marks the beginning of steady decline, which proceeded rapidly to almost complete extinction of the coast tribes after the advent of the miners about 1858, and the consequent wholesale demoralization of the natives. The interior tribes have suffered much less in proportion from this cause, but these, however, have been greatly reduced by repeated visitations of smallpox and other epidemics, of which the most destructive was the smallpox epidemic which swept the Fraser River country and northward along the coast in 1862. In 1852-3 the Nootka tribes of Vancouver Island also lost heavily by this disease. Famine and intertribal wars have also been important factors in the decrease, although the tribes of this section have almost entirely escaped the evils of removal and war with the whites.

	1780	1906
Athapascan		
Nahane tribes, excl. of those of Yukon Territory, etc. { "Naanees," and "Tahltans" of Babine and Cassiar agencies. }	2,000	374
Strongbow	500	350
Beaver—see Canada, Central		
Sekani tribes (only 212 attached to an agency, *i. e.*,		
Haida (Masset & Skidegate tribes of Queen Charlotte		500 (?)
Babine tribes	3,500	600
Carrier tribes	5,000	876
Chilcotin	2,500	400
Tsetsaut (Nahane tribe, Iskoot River & Portland canal)	350(?)	Extinct
Stuwihamuq (of Nicola valley)	150	Extinct
Kitunahan		
Kutenai	1,200	1,122[1]
Skittagetan		
Haida (Masset & Skidegate) tribes of Queen Charlotte Islands, B. C.)	8,000	599
Haida (Kaigani) of Prince of Wales Island, Alaska	1,800	200 (?)
Amount carried forward	28,200	5,021

[1] Of these 573 were in Montana, U. S., and 549 in British Columbia.

	1780	1906
Amount brought forward	28,200	5,021
Chimmesyan		
Tsimshian—*a.* Kitsun or Kitksan tribes, Babine and Upper Skeena River Agency	1,500	1,130
b. Tsimshian proper tribes of B. C., Northwest Coast agency, Port Simpson, Metlakatla, Kitkatla, Kikatla, Kitkaata or Hartley Bay, Port Essington, Kitsumkalum, Kitselas.	5,500	1,383
c. Tsimshian of New Metlakatla, Alaska.		400 (?)
d. Niska or Nishgar tribes, Northwest Coast agency, B. C. (Kincolith, Kittex, Andegulay, Lackalsap, Kitwintshilth, Aiyansh, Kitlacdamax.)		814
Wakashan		
Heiltsuk tribes (incl. China Hat, part; Kitlope, Kitimat, Bellabella, Oweekayno or Wikeno, of Northwest Coast Agency)	2,700	852
Kwakiutl tribes—*a.* On Vancouver Island, Kwakewlth agency (incl. Koskimo, Kwatsino, Kwawkewlth or Kwakiutl proper, Nimkish, Nuwitti).		376
b. On Mainland, Kwakewlth agency (incl. Klawitsis, Kwawshela, Kwiahkah, Mamalillikulla, Newakta, Tanakteuk, Tsawantiano, Wawalitsum, Wiwaiaikum, Wiwaiaikai).	4,500	881
Aht or Nootka tribes of Vancouver Island (West Coast Agency, 18 tribes, besides others extinct)	6,000	2,159
Salishan		
Songish tribes of Vancouver Island (Cowichan agency, incl. Sooke, Cheerno, Esquimalt, Songhees, Tsehum, Panquechin, Tsartlip, Tsawout, Mayne Island, Discovery Island). (See also Semiahmoo)	2,700	488
Puntlatsh tribes of Vancouver Island (Cowichan agency, incl. now only Qualicum, others extinct)	300	13
Comox tribes of Vancouver Island (Cowichan agency, incl. only Comox). (See also Comox tribes of mainland)	400	59
Cowichan tribes of Vancouver Island (Cowichan agency, incl. Malahut, Kilpanlus, Comeakin, Clemclemaluts, Khenipsin, Koksilah, Quamichan, Somenos, Hellelt, Siccameen, Kulleets, Lyacksum, Lilmalche, Penelakut, Tsussie, Nanaimo, Snonowas, Galiano Is.) (See also Cowichan tribes of mainland)	5,500	1,298
Amount carried forward	57,300	14,874

Salishan—*Continued*	1780	1906
Amount brought forward	57,300	14,874
Cowichan tribes of mainland, Fraser River mouth, etc. (Fraser River Agency incl. Coquitlam, Katsey, Langley, Matsqui, Musqueam, New Westminster, Nicomen, Skweahm, Sumass, Tsawwassen or Sewathen, Wharnock, Langley and Wharnock-Kwantlen)	2,600	516
Cowichan tribes: Chilliwack dialect of mainland (Fraser River agency, incl. Aitchelitz, Kwawkwawapilt, Skwah, Skway, Squiahla, Skulkayu, Soowalie, Tzeachten, Yukkwekwioose)	1,300	315
Cowichan tribes: Tait group of mainland (Fraser River agency, incl. Cheam, Chehalis, Ewawoos, Hope, Ohamil, Popkum, Scowlitz, Squawtits, Texas Lake, Skwawalooks, Yale)	3,200	620
Semiahmoo tribe (Fraser River agency: Songish lang. See also Songish tribes of Vancouver Island)	300	34
Comox tribes of mainland (Fraser River Agency incl. Homalko, Klahoose, Sliammon; see also Comox tribes of Vancouver Island)	1,400	265
Sechelt tribe (Fraser River Agency)	1,000	230
Squawmish tribes (Fraser River Agency, incl. Burrard Inlet No. 3, Kapilano, Skwamish or Howe Sound, Seymour Creek, Mission or Burrard Inlet, False Creek)	1,800	387
Okanagan tribes (Kamloops-Okanagan agency; incl. Okanagan, Osoyoos or Nkamip, Penticton, Upper and Lower Similkameen. (See also *Columbia Region* for those in U. S. = 348)	1,200	634
Shuswap tribes (incl. Adams Lake, Ashcroft, Bonaparte, Deadman's Creek, Kamloops, Neskainlith or Halant, North Thompson, Little Shuswap Lake, Spallumcheen of Kamloops-Okanagan agency; Alkali Lake, Canoe Creek, Clinton, Dog Creek, High Bar, Pavilion, Soda Creek, Williams Lake, of Williams Lake Agency; Kinbasket of Kootenay Agency)	5,300	2,109
Thompson River or Ntlakyapamuq (Kamloops-Okanagan agency; incl. Ashcroft, Boothroyd, Boston Bar, Coldwater, Cooks Ferry, Kanaka Bar, Lytton, Nicomen, Lower Nicola, Oregon Jack Creek, Siska Flat, Skuppa, Spuzzum)	5,000	1,938
Bellacoola tribes (incl. Bellacoola, Kinisquit, Tallion, of Northwest Coast Agency)	1,400	288
Amount carried forward	81,800	22,210

Salishan—*Continued*	1780	1906
Amount brought forward	81,800	22,210
Lillooet or Stlatlumq (incl. Anderson Lake, Bridge River, Cayoosh Creek Nos. 1 and 2, Fountain, Kenim Lake, Lillooet Nos. 1 and 2, Seton Lake (Mission, Enias, Schloss, Necait), of Williams Lake Agency, Douglas, Pemberton Meadows, Skookumchuck, Samahquam, of Fraser River Agency)	4,000	1,228
Nomadic Indians, "about 3280," unclassified, probably includes nearly 1200 Sikani, Nahane, Chilcotin and Strongbow, already noted. Deducting these leaves unclassified and unattached about		2,150
	85,800	25,588

ALASKA

Alaska was discovered by the Russians under Fedorov in 1732 and the first permanent settlement was made in 1745, which may be taken as the date of the earliest disturbance of the coast population. Through the cruelties of the soldiers and irresponsible Russian traders it was estimated that within about 20 years of the Russian advent the Aleuts had been reduced at least one-half, and when the Russian government interfered for the protection of the natives about 1795-1800 it was said, although probably with exaggeration, that the Aleuts had then been reduced to one-tenth of the original number. Dall thinks they may have numbered originally 25,000. The same causes tended, in less degree, to reduce the Tlingit.

The Eskimo tribes, farther north, were not greatly disturbed until about 1848 when whalers began to frequent the arctic coasts, introducing whisky and disease, and destroying the native food supply. In the winter of 1878-9, some 400 natives of St. Lawrence Island starved to death in consequence of the introduction of a cargo of whisky in the preceding summer, causing them to neglect their hunting through continuous drunkenness.

The interior (Athapascan) tribes have probably suffered less in proportion, but have been reduced by epidemics of smallpox and fever, usually entering from the coast. The first recorded smallpox visitation occurred in 1775 among the Tlingit. It is not known whether the great epidemic of 1781-2, which ravaged the Plains and Columbian region, reached Alaska. In 1836 or 1837, and continuing four years, smallpox introduced from the south ravaged the whole coast northward to include the Aleutian Islands and spread eastward among the interior tribes, everywhere with desolating effect. It is said to have killed from 3,000 to 4,000 of the Tlingit and to have been of almost equally fatal consequence along the Eskimo coast and in the interior. Between 1855 and 1860 scarlet fever also wasted the Yukon tribes, entirely wiping out several small bands. In 1843-4 the Aleut were again visited by smallpox and about 1900 by a destructive epidemic of grip, so that they number now only about 2,000, nearly one-half of whom are mixt-bloods.

The latest Alaskan census of tribes is that of 1890, which takes separate account also of mixt-bloods. The census of 1900 gives only the total by districts, without distinction of tribes, and there are no official figures of later date.[1] In some districts there appears to be a considerable increase of late years, owing to improved living conditions, but a large part of this increase is of the mixt-blood element. The original population of at least 72,000, and possibly much more, is now reduced to about 28,000, or about 40 per cent.

Eskimo	1740	1900
Arctic Coast to Norton Sound		
Kangmaligmiut, etc.		490
Nuwukmiut		165
Utkeagvik		230
Sidaru or Sezarok		70
Utuka and Kukpaurungmiut		130
Tigeramiut or Tikera		350
Nunatogmiut	8,000	60
Kuangmiut (= Kowagmut and Selawigmut of Dall)		110
Mahlemiut		720
Kingegan or Kingigumiut (incl. Little Diomede Island = part Okeeogmiut 90 in all)		730
Kaviagmut		490
Umudjek (St. Lawrence Island; Kikhtogamut of Dall)		315
Ukivokmiut (King Island; part of Okeogmut of Dall)		240
Norton Sound to Bristol Bay		
Unaligmiut		140
Chnagmiut		720
Kwikhpagmiut or Ikogmiut (Ekogmut of Dall)		210
Magemiut, incl. Kaialigmiut		2,620
Nunivagmiut (Nunivak Island, etc.)	17,000	810
Kuskwogmiut		4,000
Togiagmiut		230
Nushagagmiut or Tahlekukmiut		210
Kiatagmiut		250
Amount carried forward	25,000	13,290

[1] The 1910 census gave 12,636 Eskimo, 1,451 Aleut, 3,916 Athapascans, and 4,426 Tlingit, but the stock of 1,640 individuals was not reported.—J. R. S.

	1740	1900
Eskimo—*Continued*		
Amount brought forward	25,000	13,290
South of Bristol Bay		
Aglemiut (Ogulmut of Dall)	15,000 (Aglemiut to Kaniagmut, etc.)	870
Kaniagmiut (incl. Kadiak Island)		1,280
Chugachigmiut		410
Ugalakmiut or Ugalentz		200
Kaniagmut, etc., mixt-bloods, separately noted		800
Aleut or Unangan tribes	16,000	1,060
Aleut mixt-bloods, separately noted	....	830
Athapascan		
Kaiyuhkhotana or Ingalik	1,800	930
Koyukukhotana	1,000	580
Unakhotana or Kuilchana	500	360
Knaiakhotana (Kenaitz, Tehanin-Kutchin)	1,200	890
Ahtena or Atna	500	170
Mixt-Boods, separately noted	....	160
Tennuth-Kutchin	100	Extinct
Tatsah-Kutchin	100	Extinct
Kutcha-Kutchin	500	675 (Kutcha-, Natsit- and Han-Kutchin)
Natsit-Kutchin	200	
Han-Kutchin	200	
Tenan-Kutchin	500(?)	370
Tlingit tribes		
Yaktag	10,000 (Yaktag to Mixt-bloods)	100
Yakutat		420
Chilkat		930
Huna		680
Auk		335
Taku and Sumdum		270
Hutsnuwu		490
Sitka		925
Kake & Kuiu		285
Stikine		285
Tongass and Sanya		285
Hanega or Henya		285
Mixt-bloods, separately noted, about		145
Kaigani and New Metlakatla (Tsimshian) See *British Columbia*		
Total	72,600	28,310

SUMMARY OF RESULTS

The totals for the several areas are brought together in the following table:

	Early figure	Late figure
North Atlantic States	55,600	21,900
South Atlantic States	52,200	2,170
Gulf States	114,400	62,700
Central States	75,300	46,126
The Plains		
Northern	100,800	50,477
Southern	41,000	2,861
The Columbia Region	88,800	15,431
California	260,000	18,797
Central Mountain Region	19,300	11,544
New Mexico and Arizona	72,000	53,832
Greenland	10,000	11,000
Eastern Canada	54,200	27,000
Central Canada	50,950	28,770
British Columbia	85,800	25,588
Alaska	72,600	28,310
	1,152,950	406,506

Allowing for overlappings between the United States and Canada, the following estimates of population in the several political divisions concerned may be given:[1]

	Early figure	Late figure
United States Proper	849,000	266,000
British America	221,000	101,000
Alaska	73,000	28,000
Greenland	10,000	11,000
	1,153,000	406,000

The figures in the second columns of these two tables are of approximately the same date, usually 1907. Those of the first column apply to very different dates but agree in that they are intended to represent the population just before it suffered the first disturbance from Europeans.

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[1] This summary was provided for by Mr. Mooney but before printing a considerable alteration was found necessary.—J. R. S.

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Numerous private letters from ethnologists in various parts of the country are also noted.

This sheet to be inserted in Smithsonian Miscellaneous Collections, Volume 80, Number 7, The Aboriginal Population of America North of Mexico, by James Mooney (Publ. No. 2955).

Erratum

Page 27, 7th line in table, reading:

Haida (Masset & Skidegate tribes of Queen Charlotte		500	(?)

should read:

Babine)	3,200	500	(?)

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 8

FOSSIL FOOTPRINTS FROM THE GRAND CANYON: THIRD CONTRIBUTION

(With Five Plates)

BY
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Curator of Vertebrate Paleontology,
United States National Museum

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INTRODUCTION

A third visit to the Grand Canyon in the late spring of 1927 enabled me to collect additional fossil footprints, some of which are undescribed species. Since there is no immediate prospect of acquiring further specimens, it seems important that these, together with a specimen presented to the Museum by Mr. G. E. Sturdevant, naturalist of Grand Canyon National Park, should be described, in order to perfect as far as possible the record of the ichnites of this region. While the above mentioned specimens from the Hermit and Supai formations form the basis of the present paper, attention is also given to a fourth ichnite fauna recently found in the Tapeats sandstone of the Bright Angel section. These materials are fragmentary and do not warrant systematic description. All are trails of invertebrate animals, probably trilobites, a conclusion reached by the late Dr. Charles D. Walcott from his study of similar trails from this same formation in other parts of the Grand Canyon.

I wish here to express to Dr. John C. Merriam and his associates of the Grand Canyon Exhibit Committee of the National Academy of Sciences my appreciation for the financial assistance which made this third trip possible. I also wish to acknowledge again the help given by various members of the Park organization. Superintendent M. R. Tillotson furnished equipment and assistance of personnel; Mr. James Brooks, chief ranger, detailed ranger assistants; and Mr. G. E. Sturdevant, Park naturalist, as on previous visits, contributed freely of his time and energy to the successful outcome of the work in hand.

NEW OBSERVATIONS ON THE GEOGRAPHICAL DISTRIBUTION OF TRACKS IN THE GRAND CANYON

The geographical range of fossil tracks in the Grand Canyon was considerably extended through the opportunity offered of exploring new localities. It would seem that on the south rim of the Grand

Canyon, tracks can be found in the Coconino, Hermit, and Supai formations wherever local conditions permit of search being made for them.

In the Coconino, footprints were found in débris at the base of the Coconino cliff on the west side of the Bright Angel Trail, and were also noticed by Dr. E. F. Miller of the Marlin Oil Company, on the Grand View Trail where he was engaged in measuring the geological section. Their presence here is further substantiated by a specimen (No. 2367, U. S. N. M.) collected in this same locality in 1903 by the late Dr. Charles D. Walcott. This is some 20 miles east of the nearest known fossil footprint locality, and thus considerably extends their previously recorded range.

Accompanied by Dr. David White and Mr. G. E. Sturdevant, I visited the Dripping Springs locality at the head of Hermit Gorge and, although only a short time was spent there, we observed tracks in great abundance on the sloping ledges immediately to the north and east of the spring, thus fully verifying earlier reports of their occurrence.

Considerable time was spent in searching the track-bearing horizon in the Coconino formation where it is crossed by the Yaki Trail, and although numerous tracks and trails were found, with one exception their preservation was so poor that none was thought to be of sufficient value to collect.

In the Hermit formation, Dr. David White discovered tracks of extinct animals in association with fossil plants in two distinct and widely separated localities—on the Bright Angel Trail and on the Yaki Trail. In both of these localities the preservation of the plants was far superior to that of plants found in Hermit Basin, but the animal tracks were inferior in that only a few imprints were found, never a trackway of any extent. Neither of these places, therefore, seems to be a promising locality for further work, their chief interest being in extending the known geographical distribution of the Hermit ichnites.

In the Supai formation Mr. Sturdevant, as previously mentioned, found a slab of well preserved tracks on the Bright Angel Trail, and numerous footprints were observed by us on blocks that had fallen down from the more or less perpendicular face of the track-bearing bed of sandstone on the point which projects into the Canyon immediately below Yavapai Point.

Several days prospecting in the Supai formation along the western side of O'Neill Butte on the Yaki Trail disclosed a considerable abundance and variety of tracks. Those found were on blocks lying on the hillside, though a few were preserved *in situ*. That this formation has a large undescribed ichnite fauna is plainly evident, but it is difficult to obtain specimens for study because of the inaccessibility of the perpendicular track-bearing cliffs, and because the tracks usually occur in massive blocks of sandstone that do not readily cleave into layers. If adequate study specimens are to be secured, specially trained stone workers with proper equipment must be employed.

In the Coconino on the south rim of the Grand Canyon, tracks are now known at Dripping Springs on the west, and on the Grand View Trail to the east, an extent of about 29 miles. In the Hermit and Supai, tracks have been found from Hermit Basin on the west to the Yaki Trail on the east, a distance of about 11 miles. That further exploration will greatly extend these ranges is now plainly evident. Tracks have not yet been found in the rocks of the north rim of the Canyon, but it is confidently expected that their discovery there will be one of the early announcements.[1]

SYSTEMATIC DESCRIPTION OF GENERA AND SPECIES

Under this heading are included notes and new observations on described genera and species as well as descriptions of a few that are new to the ichnite faunas of the Grand Canyon. They are discussed in the same order as in the preceding papers on this subject, commencing with those from the Coconino formation and following successively with the Hermit, Supai, and Tapeats footprints.

ICHNITES FROM THE COCONINO FORMATION

Genus LAOPORUS Lull

Mention was made in my previous paper[2] of the similarity existing between the tracks of *Laoporus* and those figured by Hickling[3] from the British Permian. Further study and comparison deepens my conviction that these tracks are congeneric. Their close similarity in size, number, relative lengths and arrangement of the digits is clearly indicated in the illustrations (compare figs. 1 and 2). The

[1] Under date of Dec. 14, 1927, a letter from Mr. G. E. Sturdevant announces the discovery by him of fossil tracks in both the Supai and Coconino formations on the north rim of the Grand Canyon.

[2] Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 17, footnote.

[3] Manchester Lit. and Philos. Soc., Memoirs, Vol. 53, 1909, Art. 22, pl. 2, figs. 10 and 11.

British tracks are referred by Hickling to *Chelichnus ambiguus* Jardine, but examination of Jardine's original figures of this species[1] leaves much doubt as to the correctness of this assignment. If correct, it is of interest to note Hickling's observation that in Jardine's

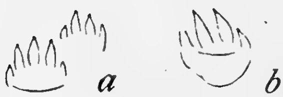


FIG. 1.—Footprints from the British Permian which can be properly referred to the genus *Laoporus*. *A*, fore and hind tracks; *B*, manus. All after Hickling. About ½ natural size.

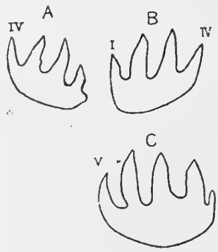


FIG. 2.—*Laoporus noblei* Lull. *A*, outline of manus track. Paratype. No. 8422, U. S. N. M. *B*, *C*, manus and pes track of No. 11,122, U. S. N. M. All about ½ natural size.

specimen, "the fifth digit is nowhere shown," and it is a condition often observed in the trackways of the American *Laoporus*.

OCTOPODICHNUS DIDACTYLUS Gilmore

Octopodichnus didactylus Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 31, pl. 10, fig. 2, text fig. 13.

Recently in bringing together all of the miscellaneous fossil footprint materials in the U. S. National Museum, the accumulation of many years, a small slab (No. 2367) was found on whose surface there was a trackway that is clearly referable to the genus *Octopodichnus* and provisionally to the species *O. didactylus* Gilmore. The specimen is of interest as being the third recognizable specimen found of this species and also from the fact of its coming from a new locality for tracks, thus greatly extending their known geographical range.

The specimen was collected by the late Dr. Charles D. Walcott from the Coconino sandstone on the Grand View Trail, Grand Canyon National Park, Arizona, in 1903. This discovery antedates by 12 years the finding of quadruped tracks in the Grand Canyon by Schuchert and by nearly a quarter of a century the discovery of the type specimen (No. 11,501 U. S. N. M.) on which the above genus and species was established.

The considerably smaller size of the trackway and slight differences noted in some of the individual imprints suggest the possibility of

[1] Ichnites of Annandale, 1853, pls. 6 and 11.

the specimen representing a distinct species, but more perfectly preserved material is needed to determine that point. The trackway shows two parallel lines of imprints arranged as in the type in groups of four, the groups of the two sides alternating. These groups have the usual arrangement of a row of three regularly spaced tracks with the fourth offset inward.

After a study of the type specimen, it was my conclusion that the trackway was probably made by some Permian crustacean. In confirmation of the probable correctness of that conclusion, Mr. Remington Kellogg, of the U. S. Biological Survey, calls my attention to a considerable similarity between these tracks and trails made by the living sand crab *Ocypoda albicans,* recently observed by him in the sands on Hatteras Island, North Carolina.

ICHNITES FROM THE HERMIT FORMATION

Genus HYLOIDICHNUS Gilmore

Hyloidichnus Gilmore, Charles W., Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 51.

Generic characters.—Quadrupedal, semi-digitigrade. Both manus and pes have five digits. Manus smaller than pes and placed in front of hindfoot. Toes either terminated with pellets or having bifurcated ends.

HYLOIDICHNUS WHITEI, new species

Plate 3, fig. 1

Type.—Catalogue number 11,692, U. S. N. M. Consists of a small slab on which are four imprints. Collected by Dr. David White, June, 1927.

Type locality.—Yaki Trail (" Cedar Ridge " 500 feet west of trail), Grand Canyon National Park, Arizona.

Geological occurrence.—Hermit shale, 30 feet above Hermit-Supai contact, Permian.

Description.—Stride estimated to be about 106 mm., width of trackway about 45 mm. Forefoot slightly smaller than hind and placed almost directly in front of it. *Hindfoot:* Length about 24 mm., width about 22 mm. Five toes. The toes are long and especially slender, fourth longest, others growing progressively shorter toward the inside of the foot. First only faintly impressed, but apparently about the same length as the fifth. Digits II to V having terminations slightly enlarged, the first apparently having bifurcated ends. The toes have the following lengths: I=7.5 mm., II=11.1 mm., III = 13 mm., IV = 16 mm., V = 8 mm. Sole not sufficiently impressed to show its outline; it seems to be short and broadly rounded behind. *Forefoot:* Length about 18.5 mm., width from tip of first to tip of fifth digit 17 mm. Five digits which increase in length from first to fourth. Fifth about one-half as long as the fourth, but longer than first. First and fifth directed strongly forward and outward respectively from the median digits. Digits I and II terminated by pellets; III

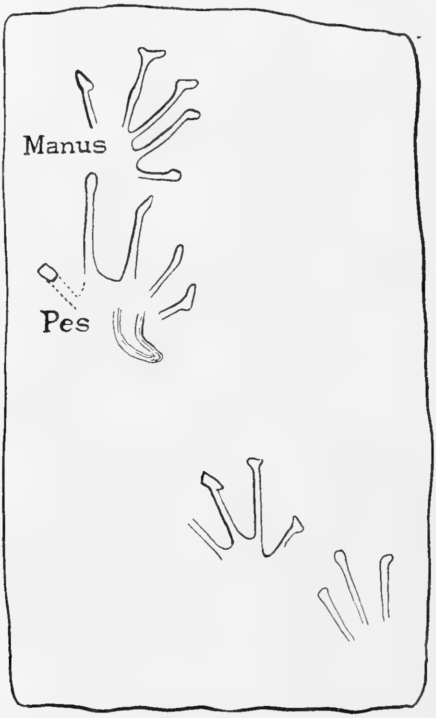


FIG. 3.—*Hyloidichnus whitei,* new species. Type. No. 11,692, U. S. N. M. Diagram of trackway. About natural size.

and IV by asymmetrically bifurcated ends resembling those of the pes in *H. bifurcatus.* All toes especially slender. The digits have the following measurements: I = 6 mm., II = 12 mm., III = 13 mm., of the manus. *Forefoot:* Length about 30 mm., width about 30 mm. IV = 13.5 mm., V = 5 mm. The palm failed to leave a distinct impression and thus its size and contour are unknown.

The general resemblance of the foot plan, the same relative length of toes, and the presence of both bifurcated and pellet toe terminations as in the feet of *Hyloidichnus bifurcatus* Gilmore from this same formation, indicates that its affinities fall within that genus. Its specific distinctness, however, is shown by its much smaller size, in having the bifurcated toes on the manus, and the more slender form of the toes as a whole.

The species is named in honor of Dr. David White who collected the type specimen.

PARABAROPUS COLORADENSIS (Lull)

Plate I

Megapezia ? coloradensis Lull, R. S., Amer. Journ. Sci., Vol. 45, 1918, p. 341.
Parabaropus coloradensis (Lull), Gilmore, C. W., Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 53.

On the track covered surface of a large slab (No. 11,707, U. S. N. M.) of impure Hermit sandstone of the collection of 1927, obtained from the fossil track locality one-fourth mile west of the sign "Red Top" on the Hermit Trail, is a trackway identified as *Parabaropus coloradensis* (Lull). This trail, the most perfect yet discovered, shows the trackway to have a width of about 190 mm.

On this same slab are numerous trails of *Holopus hermitanus* and a single trackway of *Collettosaurus,* probably *C. pentadactylus.* The large size of this slab, with its undulating surface covered with footprints, presents an interesting section of the old mud flat over which these animals walked and which has preserved a plain record of their ramblings. A view of this specimen is given in plate I.

The stride of the *Parabaropus* tracks varies from 260 to 340 mm., whereas in specimen No. 11,598, described in my previous paper,[1] the stride is about 240 mm., and it is quite apparent from the measurements of the foot impressions that the two animals were of about the same size.

In the specimen now before me, the pes impressions lack the elongated sole which is such a distinctive feature of the hindfoot in the tracks previously referred to.[2] The difference noted is due, as is clearly apparent from a comparison of specimens, to the difference in depth to which the feet impressed themselves into the mud. In the specimen under discussion, the posterior part of the heel did not register, whereas in the trackway previously described, the whole foot sank deeply into the muddy surface. The proportions of the feet, number of toes, their form and close similarity of arrangement, leave no

[1] Fossil footprints from the Grand Canyon, Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 57.

[2] *Op. cit.,* p. 56, fig. 27.

doubt as to their being cospecific. The differences noted in a comparison of these two specimens illustrates the need of an abundance of material in the study of fossil tracks if an investigator is not to be led astray by differences that are more apparent than real.

In the normal relationships of the tracks, the forefoot is placed in front of the hind, but in the trackway now before me the forefoot is occasionally found in the rear of the hindfoot.

COLLETTOSAURUS PENTADACTYLUS Gilmore

Plate 1

Collettosaurus pentadactylus Gilmore, C. W., Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 60, text fig. 32, pl. 19, fig. 1.

A trackway 1300 mm. in length, on slab No. 11,707, U. S. National Museum (see pl. 1) seems to be clearly referable to the above genus and species. While this specimen adds nothing to our knowledge of the feet impressions, the presence of a deep, continuous, but slightly undulating, tail drag is of interest, since the type specimen (No. 11,527, U. S. N. M.) showed none. A second specimen (No. 11,710, U. S. N. M.) identified as pertaining to the same species, although 530 mm. in length, gives no evidence of a dragging tail. Study of these three specimens confirms my previous conviction that the presence or absence of a tail drag has but little significance as a diagnostic character for distinguishing fossil tracks.

ICHNITES FROM THE SUPAI FORMATION

Genus AMMOBATRACHUS, new genus

Generic characters.—Quadrupedal. Five digits in pes, four in manus. Forefoot smaller than hind, with the latter placed in front of the former. Digits of both manus and pes widely separated, outer toes of both much reduced in size, fifth of pes widely divergent.

Genotype.—*Ammobatrachus turbatans,* new species.

AMMOBATRACHUS TURBATANS, new species

Plate 2

Type.—Catalogue number 11,691, U. S. N. M. Consists of a slab of sandstone 380 mm. long having a trail traversing its entire length. Collected by G. E. Sturdevant, 1927.

Type locality.—Bright Angel Trail, Grand Canyon National Park, Arizona.

Geological occurrence.—Supai formation, Pennsylvanian.

Description.—Stride about 80 mm., width of trackway about 115 mm. *Hindfoot:* Length about 40 mm., width about 40 mm. Five digits. The first toe is short. Third slightly the longest while second and fourth are subequal. All three acuminate. The second and third curved slightly outward. Fifth toe, short, stout, with bluntly rounded

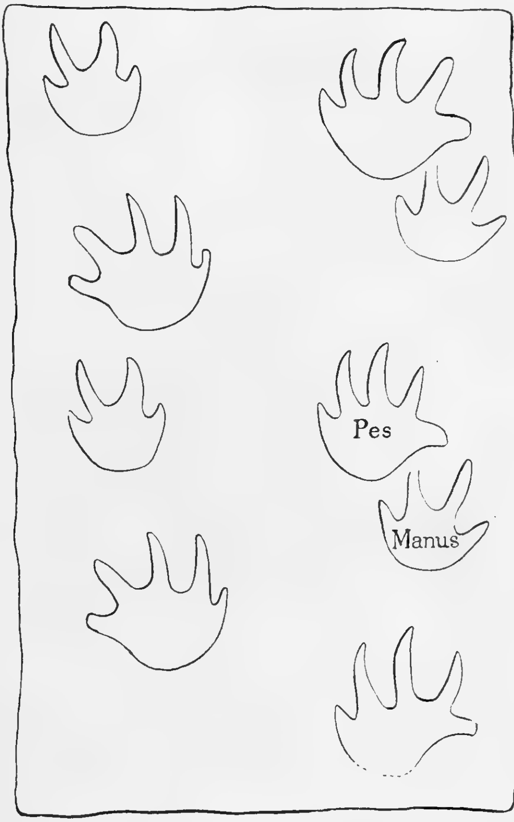


FIG. 4.—*Ammobatrachus turbatans,* new genus and species. Type. No. 11,691, U. S. N. M. Diagram of trackway. About ½ natural size.

extremity. This digit is directed strongly outward, its longer axis standing nearly at right angles to those of the other toes. In the imprints of the pes on the left side the fifth toe is longer, more slender, and directed more forward than on the right side. The imprint of the second toe is lacking in most of the tracks of the left side. The sole of the foot is relatively long, exceeding the length of the toes, is rounded behind, and had palmar pads. The toes have the following lengths: II = 15 mm., III = 17.5 mm., IV = 15 mm., V = 7.5 mm. Hind-foot regularly placed in front of fore, but usually clear of the toes of the manus. *Forefoot:* Length about 30 mm., width about 30 mm. Four toes. Toes lengthening toward the outside of foot, the outer and inner being short and subequal in length. The outer toe originates well backward on the side of the palm, and is directed forward and outward. Median toes widely separated and divergent anteriorly. All of the digits of the manus have subacute terminations (see fig. 4). The foot as a whole is much smaller than the pes. Sole relatively short, being broader than long and broadly but regularly rounded posteriorly. Length of toes as follows: II = 7.5 mm., III = 12.5 mm., IV = 14.5 mm., V = 7.5 mm. The digital formula of five and four at once distinguishes this genus from all described forms of the Supai ichnite fauna. *Batrachichnus* of the Hermit, *Laoporus* and *Agostopus* of the Coconino, have a similar number of toes, but here their resemblance to *Ammobatrachus* largely ends. The intermediate size of the footprints under discussion, the wide spreading of the toes, and differences in length and other proportions effectually distinguish these from all other Grand Canyon tracks.

Hickling [1] figures a pes track from the Permian of Corncockle Muir, Scotland, which bears certain resemblances to the pes, but his details of foot plan are uncertain and thus a closer comparison is of little importance.

INVERTEBRATE TRAILS FROM THE SUPAI FORMATION

During the field work of 1927, a considerable number of trails evidently made by invertebrate animals, were observed in the track-bearing horizons of the Supai formation. Owing to the lack of proper facilities, only a few of these were collected. Although many of them clearly show that the impressions were made by animate creatures, their details are not sufficiently clear to depict their principal characteristics, and on that account they seem unworthy of generic and specific designation, but in order to advance our knowledge of the Supai ichnite fauna as far as is consistent with the character of available materials, a few of these specimens are briefly described and illustrated.

In figure 1, plate 4, is illustrated a trail (No. 11,740, U. S. N. M.) found lying on the slope west of O'Neill Butte. A second specimen found later on a massive block of sandstone at the base of the track-

[1] Manchester Lit. and Philos. Soc., Memoirs and Proc., Vol. 53, 1909, Art. 22, pp. 6 and 7, pl. 3, fig. 20.

bearing sandstone in the middle Supai appears to be identical, but the extreme hardness of the sandstone resisted all attempts to collect it. These were the only trails of this particular kind observed in many days of prospecting in this formation. The trail illustrated (see fig. 5) is impressed on the surface of a pinkish sandstone and has a length of approximately 370 mm. The specimen, which is the positive slab,

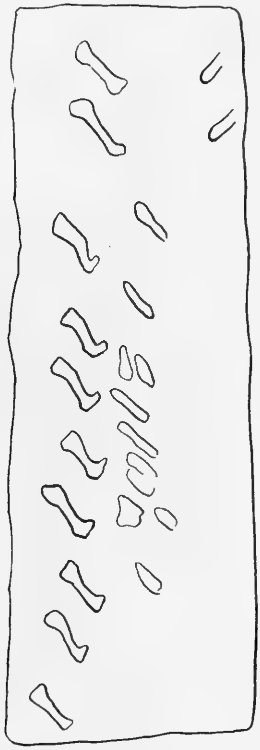


FIG. 5.—Invertebrate trail from Supai formation. No. 11,740, U. S. N. M. About ½ natural size.

has been cast, and the replica affords all the evidence of the original. The trackway as a whole is asymmetrical, brought about, it would seem, by the failure of the appendages of the right side to leave their imprints. Two faint impressions on the right side near the midlength lend support to this view. (See pl. 4, fig. 1.) These are elongated depressions set diagonally to the line of movement, and in nearly every way conform to those forming the outer row on the left side of the trackway. If this supposition is correct, the normal trail would have a width of about 46 mm. The longitudinal row of tracks of the left side consists of a uniform series of elongated depressions that stand diagonally to the line of direction. These are quite regularly spaced, averaging about 15 mm. apart. The outer ends of the diagonal tracks are somewhat enlarged backward, whereas the inner end gives off a sharp spur that is directed forward and inward. Over all, these diagonal impressions have an average length of about 27 mm. A second, and supposedly median row of elongated impressions, but less clearly registered, parallels those just described. They also have a diagonal trend, paralleling in direction but usually alternating with those of the outer row.

This trail seems to be undescribed and when more perfect examples are found, there will be little difficulty in fully characterizing it. The character of the trackway points clearly to its invertebrate origin, though at this time I have no suggestion to offer as to the particular group of animal life to which it may be attributed.

A second trail, No. 11,693, U. S. N. M. (see pl. 4, fig. 2), collected by Mr. G. E. Sturdevant in 1927, from the uppermost track-bearing horizon of the Supai formation, on the west side of O'Neill Butte, represents another undescribed trackway of peculiar kind, the details of which, as in the preceding, are not altogether clear. This trackway has a total length of 330 mm.; width about 65 mm.; length of stride about 25 mm. It consists of two parallel rows of curved, pointed, finger-like markings, between which are irregularly shaped, subround impressions of spasmodic occurrence. The tracks of opposite sides seem to alternate, although in some few instances they are opposite. The finger-like impressions stand diagonally to the line of movement and seem to be directed forward, though from this specimen alone one cannot be sure of the direction of movement. The irregularity of the impressions (see fig. 6), especially of the two rows, does not permit of a satisfactory diagnosis, and for that reason I refrain from naming it, though it undoubtedly represents a form new to this ichnite fauna.

In plate 3, figure 2, is illustrated a kind of track that has been observed on numerous occasions in the Supai formation, but which has not yet been found in the form of a definite trackway. While this type of track may be easily recognized, none of the examples found gives any idea of a continuous trail, the individual tracks being placed here and there and apparently without rhyme or reason. Occasionally two and three will be found, one placed behind the other.

Some of the imprints are tridactyle, others didactyle. The toes are usually sharply pointed and widely divergent. These tracks vary from 14 to 16 mm. in length and from 9 to 12 mm. in width. They

FIG. 6.—Invertebrate trail from Supai formation. No. 11,693, U. S. N. M. About ½ natural size.

give every evidence of having been made by an invertebrate animal to whose identity we have no clue at this time. It is anticipated that sooner or later well-defined trails of this animal will be discovered.

ICHNITES FROM TAPEATS SANDSTONE

Plate 5, figs. 1, 2, 3, and 4

In a previous paper[1] mention was made in a footnote of the discovery by Mrs. G. E. Sturdevant on the Bright Angel Trail of a small section of a trackway which at that time was thought to come from the Bright Angel shale. More extended search of this locality by Messrs. G. E. Sturdevant and Edwin D. McKee has brought to light several additional specimens, and Mr. Sturdevant writes me that all of these specimens, including the one previously found by Mrs. Sturdevant, are from the Tapeats sandstone.

The correctness of his observation is fully confirmed by comparison of the specimens with trails figured by the late Dr. Charles D. Walcott[2] from the Tapeats sandstone of other parts of the Grand

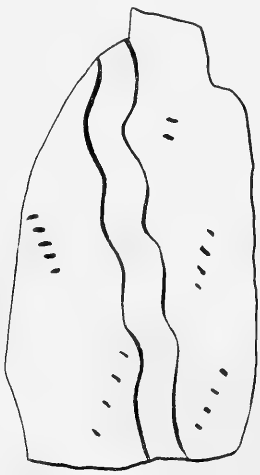


FIG. 7.—Trilobite ? trail from Middle Cambrian; Tapeats sandstone on Bright Angel Trail. About ½ natural size.

Canyon, several of which are identical in character. That there was an extended ichnite fauna in this formation is abundantly shown by the many different kinds of trails figured by Walcott, and by the specimens more recently collected.

Walcott attributes all of the various kinds of trails illustrated by him as being made by trilobites. He points out that the known genera and species of trilobites from the Middle Cambrian give a wide varia-

[1] Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 9.
[2] Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, pls. 37 to 42.

tion in size, and in ventral appendages, quite sufficient perhaps to account for most of the trails found.[1]

While I have no intention of giving a detailed description of these recently discovered trails, a few of the more characteristic specimens are illustrated here, especially those that differ from the trails published by Walcott, and these figures tell the story of the kinds found.

The discovery of these trails in the Tapeats of the Bright Angel section is especially interesting as recording a fourth track-bearing horizon in this one geological section.

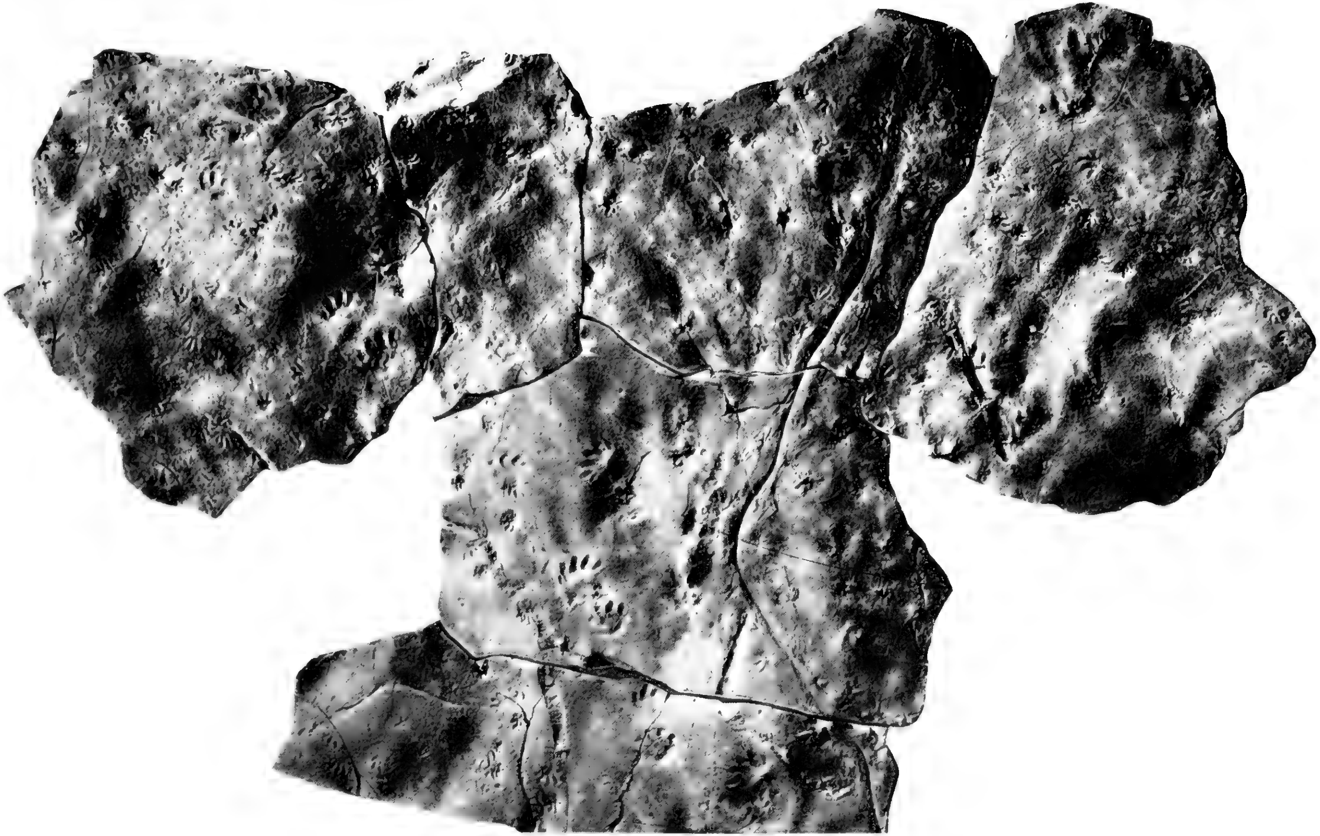
A CORRECTION

In the faunal list of the Coconino, Smithsonian Misc. Coll., Vol. 80, No. 3, 1927, p. 4, a third species of *Agostopus*, *A. robustus* is listed. This name was inadvertently included, but it has no standing and should therefore be dropped from further consideration, as a *nomen nudum*.

Attention is also called to the misspelling of the species *Hylopus hermitanus* in the same publication. In the list of Hermit ichnites, page 7, *H. hermitus*, and on page 78, *H. hermitensis* both should be *Hylopus hermitanus* Gilmore.

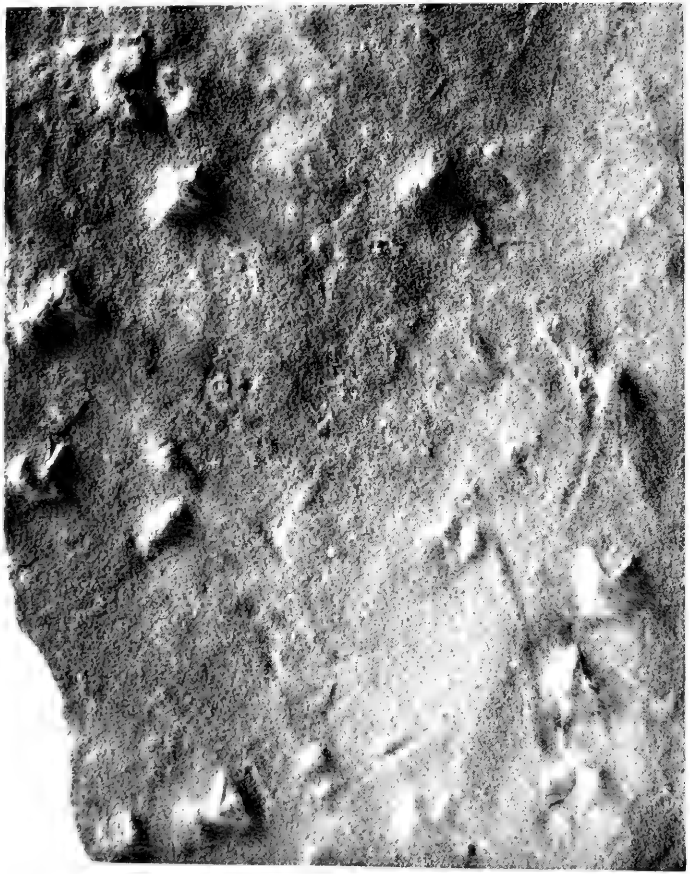
[1] *Idem*, p. 175.

EXPLANATION OF PLATES



Fossil footprints from Hermit formation.
(For explanation, see page 16)

Fossil footprints from Supai formation.
(For explanation, see page 16)



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Fossil tracks from the Grand Canyon.

(For explanation, see page 16)

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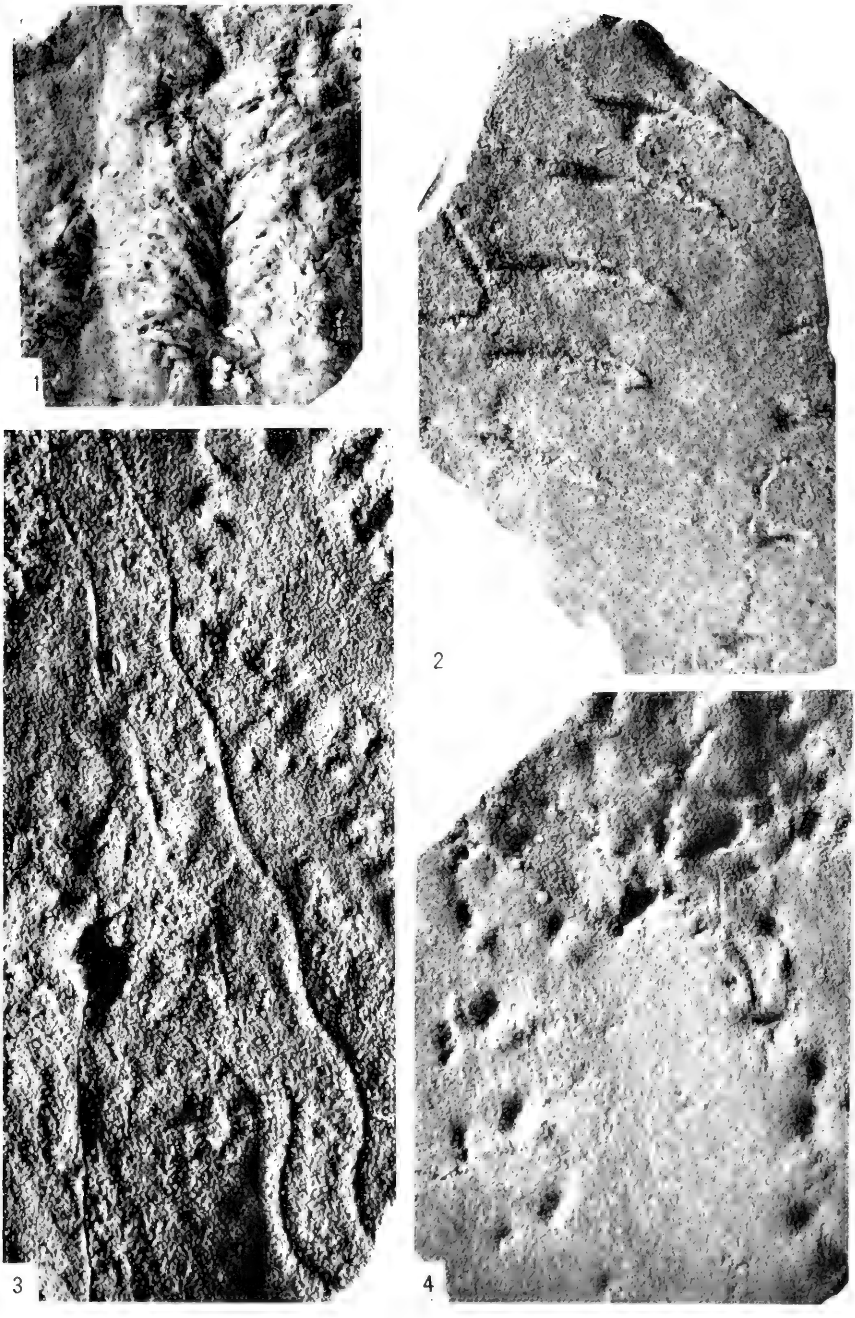
Fossil invertebrate trails from Supai formation.

(For explanation, see page 16)



Trilobite tracks and trails, Tapeats formation.

(For explanation, see page 16)

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 9

ABORIGINAL WOODEN OBJECTS FROM SOUTHERN FLORIDA

(With Three Plates)

BY
J. WALTER FEWKES
Chief, Bureau of American Ethnology

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ABORIGINAL WOODEN OBJECTS FROM SOUTHERN FLORIDA

By J. WALTER FEWKES
CHIEF, BUREAU OF AMERICAN ETHNOLOGY

(With Three Plates)

In 1895 the late Mr. F. H. Cushing, for many years connected with the Bureau of American Ethnology, made some very remarkable discoveries of aboriginal remains at Key Marco, on one of the chain of islands that fringe the southwest coast of Florida, forming the coastal border of the Florida Everglades on the Gulf of Mexico. Cushing described and illustrated in a preliminary report on his work some of the most important objects found at that time.[1] Among the characteristic artifacts obtained by him were several wooden objects so radically different from any found elsewhere in Florida shell heaps that he regarded them as typical of an aboriginal culture theretofore unrecorded. He thereby opened up a new chapter of archeological research in Florida.

The author has desired for several years to obtain more specimens of this work in wood and although he has not been successful in his search for them in the field, a few have come to light in other ways. Through the kindness of Dr. Walter Hough, Head Curator of Anthropology of the U. S. National Museum, he is able to present figures of two "altar slabs" and a wooden "idol" found near Fort Myer and Lake Okeechobee. There is good reason to believe that as exploration in southern Florida progresses other wooden images will be brought to light.

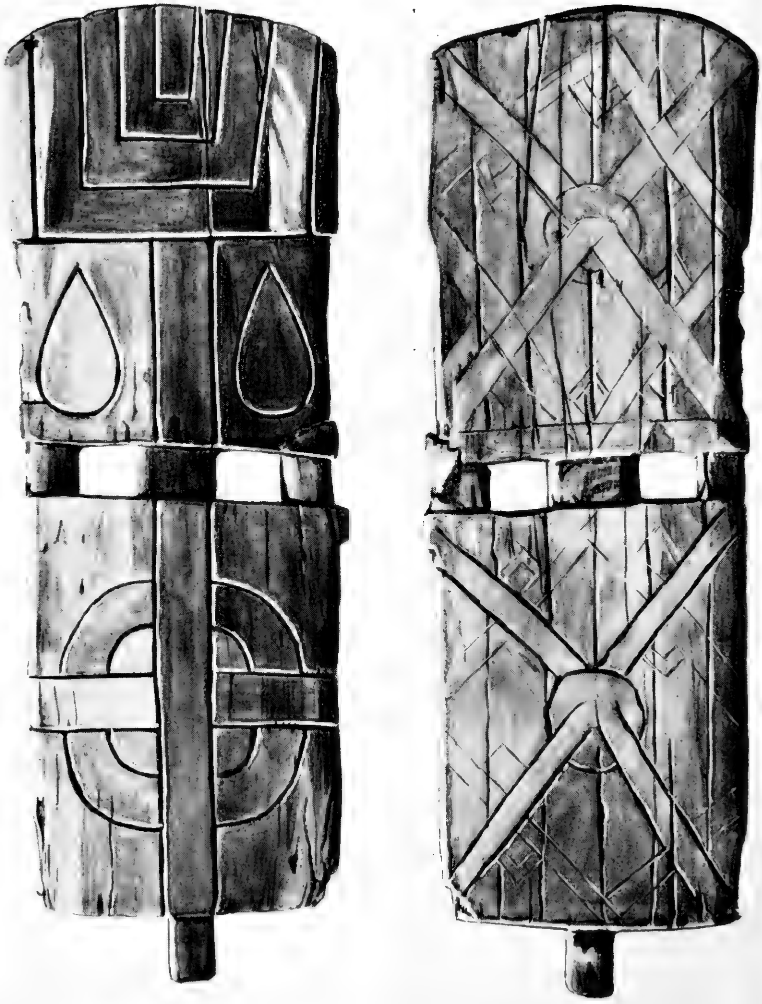
The idol (pl. 1, Cat. No. 316254, U. S. N. M.) is cut out of lignum vitae. It is said to have been plowed up on the north shore of Lake Okeechobee and was shipped to the U. S. National Museum by Mr. M. A. Miller, artesian and deep-well constructor of that vicinity. The De Soto County News of March 25, 1921, published an account of it by Mr. Miller in which he states that "where Mr. Miller plowed up the idol, Lake Okeechobee waters formerly stood six feet deep. The

[1] Proc. Amer. Phil. Soc., Vol. XXXV, No. 133.

land is muck that has been reclaimed by drainage." The account continues: "Additional strength is lent to the theory that some race antedating the Indians lived along the shores of the lake by the finding of fragments of pottery in the same vicinity as that in which the idol was plowed up. It is also stated that there is a large shell mound in the vicinity of Lakeport which is believed to have been thrown up by the vanished race." The form and technique of this idol would seem to leave little doubt of its having been made by Indians, although a similar wooden idol found in Cuba is regarded by some ethnologists as African. The latter, now in the Museum of the Havana University at the Verdado, has been figured by Dr. Montone and also by M. R. Harrington of the Museum of the American Indian. The two specimens differ in form and in the position of the legs, that from Cuba resembling a sitting figure, with the legs bent at the knee, while in the Florida specimen the figure is squatting. The hair of the latter is cut in such a way as to remind one of the Muskhogean stone idols. Both seem to have been made of the same kind of wood and they are weathered to the same color.

Cushing associated certain wooden slabs that he discovered in the muck at Key Marco with altars and suggested that they were used in worship. The two specimens here illustrated (pls. 2 and 3) are made of soft wood (cypress or pine). They were presented to the U. S. National Museum by Mr. George Kinzie. One of them (pl. 2) is incised on the surface with a circle and cross, as if to represent the sun and a cosmic direction symbol. The form of the other (pl. 3) is different from that of any known wooden object from the region, but it is likewise decorated with an incised cross and straight and curved lines.

Front and side views of Wooden Idol, North Shore Lake Okeechobee, Florida.
Cat. No. 316,254, U. S. National Museum.



Front and back of Wooden Ceremonial Slab from Florida. Cat. No. 329,599, U. S. National Museum.

Wooden Ceremonial Slab from Florida. Cat. No. 329,598.
U. S. National Museum.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 10

DRAWINGS BY JOHN WEBBER OF NATIVES OF THE NORTHWEST COAST OF AMERICA, 1778

(WITH 12 PLATES)

BY
DAVID I. BUSHNELL, Jr.

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By DAVID I. BUSHNELL, JR.

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The third and last expedition commanded by Captain James Cook was one of the most remarkable voyages of discovery in the history of the world.

Early in the year 1776 the two ships—the *Resolution* and the *Discovery*—were, as Captain Cook wrote: "in the dock at Deptford, under the hands of shipwrights; being ordered to be equipped to make farther discoveries in the Pacific Ocean, under my direction." Everything was supplied and furnished that was believed essential or that would, in any way, aid in the fulfillment of the great undertaking. When all was ready they sailed from England about the middle of July, 1776. Captain Cook was on the *Resolution* which carried a crew, officers and men, of 112. The *Discovery*, a sloop of 300 tons, had 80 men on board and was commanded by Captain Charles Clerke. After many eventful experiences the two ships returned safely and arrived at the Nore, October 4, 1780.

Very extensive and valuable collections of ethnographical material were made during the voyage, and many of the objects are now to be seen in the various European museums. Thirty-four specimens are in the Anthropological Museum, Florence, Italy. Twenty-three of these were secured at Nootka and include garments, ornaments, weapons, and ceremonial pieces. The remaining 11 examples were gathered at Prince William Sound, Oonalashka, and Norton Sound. All were described, and many figured, by Giglioli in 1895.

Doctor Anderson, surgeon on the *Resolution,* who had attended Captain Cook on a previous voyage, probably collected many specimens; he likewise made several vocabularies, one being of the natives of Nootka. After a lingering illness Anderson died August 3, 1778. His death proved a great loss to the expedition.

To quote again from Captain Cook's own narrative: "And, that we might go out with every help that could serve to make the result of our voyage entertaining to the generality of readers, as well as instructive to the sailor and scholar, Mr. Webber was pitched upon, and engaged to embark with me, for the express purpose of supplying the unavoidable imperfections of written accounts, by enabling us to preserve, and to bring home, such drawings of the most memorable scenes of our transactions, as could only be executed by a professed and skillful artist." This tends to prove with what great interest the drawings were accepted, how very important they were considered, and how skillfully and accurately they must have been prepared.

John Webber, to whom the preceding notes refer, was born in London in 1752. His father was a Swiss sculptor whose name, Weber, became Anglicized to the form used by the son. When quite young John Webber was sent to Paris where he studied under J. G. Wille. He also went to Berne, Switzerland, and there became a student under J. L. Aberli. After an absence of about five years he returned to be with his family in London. He then became a student of the Royal Academy, and the next year, 1776, through the influence of Doctor Solander, was appointed draftsman to accompany Captain Cook on his last voyage. The expedition returned in 1780, and Webber then superintended the engraving of the collection of drawings and sketches which he had made for the Admiralty. The majority of his original sketches were quite large and it became necessary for him to make replicas, reduced to the proper size for the engravers. These were "engraved by the most eminent Artists" and appeared in 1784 to illustrate the narrative of the expedition, entitled: A Voyage to the Pacific Ocean, undertaken by the Command of His Majesty, for making Discoveries in the Northern Hemisphere. . . . . Published by Order of the Lords Commissioners of the Admiralty. It was issued in three volumes, the first two having been prepared by Captain James Cook, the third by Captain James King. Having completed his work for the Admiralty, Webber prepared a series of the more important and interesting views, etched and colored, which he published privately. During the years 1784, 1785, and 1786 he exhibited pictures made on the voyage. He was elected A. R. A., 1785, and R. A., 1791. He died at his home in London, May 29, 1793.

The twelve drawings reproduced at this time are believed to have belonged to the Admiralty. Later they were owned by Sir William Campbell who was Governor of New Brunswick, 1831-1835, from whom they passed to his descendants. Five of the original sketches are reproduced for the first time; others were greatly changed by the engravers when first published. The 12 drawings are now in the private collection of the author.

NOOTKA. MARCH—APRIL, 1778

The expedition reached the Northwest Coast of America late in March, 1778, and found safe anchorage in an inlet which was named King George's Sound. Intercourse with the natives later revealed the name by which it was known to the inhabitants of the villages which stood on its shores and since that day the native name, Nootka, has been applied to the sound. It is about midway on the west coast of Vancouver Island. Captain Cook then wrote: "Were I to affix a name to the people of Nootka, as a distinct nation, I would call them *Wakashians;* from the word *wakash,* which was very frequently in their mouths. It seemed to express applause, approbation, and friendship." The name Wakashan is now applied to the linguistic group to which the Nootka belong.

During the spring of 1778 there were two native villages on the shores of Nootka Sound. One, and evidently the more important, stood near the entrance of the sound, on the northwest shore, "on the side of a rising ground, which has a pretty steep ascent from the beach to the verge of the wood, in which space it is situated." The second village was far distant from the first, in the northeastern part of the sound. Between the two was the site of another, with many houses in ruins but none occupied. The total population of the two occupied villages was estimated at approximately 2,000.

Describing the village near the entrance Captain Cook wrote: "The houses are disposed in three ranges or rows, rising gradually behind each other; the largest being that in front, and the others less; besides a few straggling, or single ones, at each end. These ranges are interrupted or disjoined at irregular distances, by narrow paths, or lanes, that pass upward; but those which run in the direction of the houses, between the rows, are much broader. Though there be some appearance of regularity in this disposition, there is none in the single houses; for each of the divisions, made by the paths, may be considered either as one house, or as many; there being no regular or complete separation, either without or within, to distinguish them by. They are built of very long and broad planks, resting upon the edges of each other, fastened or tied by withes of pine bark, here and there; and have only slender posts, or rather poles, at considerable distances, on the outside, to which they also are tied; but within are some larger poles placed aslant." Such was the construction of the native habitations. Only slight evidence of divisions within indicated the part occupied by different families. Large chests served to hold "their spare garments, skins, masks, and other things which they set a value upon;" their various utensils, "mostly square and oblong pails or buckets to hold water and other things; round wooden cups and bowls; and small shallow wooden troughs, about two feet long, out of which they eat their food; and baskets of twigs, bags of matting, etc. Their fishing implements, and other things also, lie or hang up in different parts of the house, but without the least order; so that the whole is a complete scene of confusion; and the only places that do not partake of this confusion are the sleeping-benches, that have nothing on them but the mats; which are also cleaner, or of a finer sort, than those they commonly have to sit on in their boats."

The interiors of the native houses evidently proved of great interest. Captain Cook referred twice to drawings of interiors having been made by Webber. Fortunately, both of the original pictures are in this collection and are reproduced. The first was made April 22, 1778. On that day Cook visited the village at the entrance of the sound and wrote: "During the time I was at this village Mr. Webber, who had attended me thither, made drawings of everything that was curious, both within and without doors." The sketch reproduced in plate 2 is believed to have been made at that time. Much interesting detail is shown, including "the construction of the houses, household furniture and utensils, and striking peculiarities of the customs and modes of living of the inhabitants."

After mentioning the condition of the interiors Captain Cook wrote, that, notwithstanding the confusion, many of the houses "are decorated with images. These are nothing more than the trunks of very large trees, four or five feet high, set up singly, or by pairs, at the upper end of the apartment, with the front carved into a human face; the arms and hands cut out upon the sides, and variously painted; so that the whole is a truly monstrous figure. The general name of these images is *Klumma;* and the names of two particular ones, which stood abreast each other, three or four feet asunder, in one of the houses, were *Natchkoa* and *Matseeta*. Mr. Webber's view of the inside of a Nootka house, in which these images were represented, will convey a more perfect idea of them than any description." The original view or sketch to which Captain Cook referred is reproduced in plate 3.

The natives were described as being rather short but not slender. "The women are nearly of the same size, color, and form, with the men; from whom it is not easy to distinguish them." Men and women wore similar garments, the principal of which was "a flaxen garment, or mantle, ornamented on the upper edge by a narrow strip of fur, and, at the lower edge, by fringes or tassels." It passed under the left arm and was fastened over the right shoulder. "Over this, which reaches below the knees, is worn a small cloak of the same substance, likewise fringed at the lower part. In shape this resembles a round dish cover, being quite close, except in the middle, where there is a hole just large enough to admit the head; and then, resting upon the shoulders: it cover the arms to the elbows, and the body as far as the waist. Their head is covered with a cap, of the figure of a truncated cone, or like a flower-pot, made of fine matting, having the top frequently ornamented with a round pointed knob, or bunch of leathern tassels, and there is a string that passes under the chin, to prevent its blowing off." Elsewhere Cook wrote: "We have sometimes seen the whole process of their whale-fishery painted on the caps they wear." Garments, similar to those just described, are represented in the two drawings reproduced in plate 4 and plate 5. "The flaxen garments," mentioned above, were made "of the bark of a pine-tree, beaten into a hempen state." The account continues: "It is not spun, but, after being properly prepared, is spread upon a stick, which is fastened across to two others that stand upright. It is disposed in such a manner, that the manufacturer, who sits on her hams at this simple machine, knots it across with small plaited threads, at the distance of half an inch from each other. Though, by this method, it is not so close or firm as cloth that is woven, the bunches between the knots make it sufficiently impervious to the air, by filling the interstices; and it has the additional advantage of being softer and more pliable." A frame of this sort is shown at the extreme right in plate 2. Similar garments were made of wool, which "seems to be taken from different animals, as the fox and brown lynx."

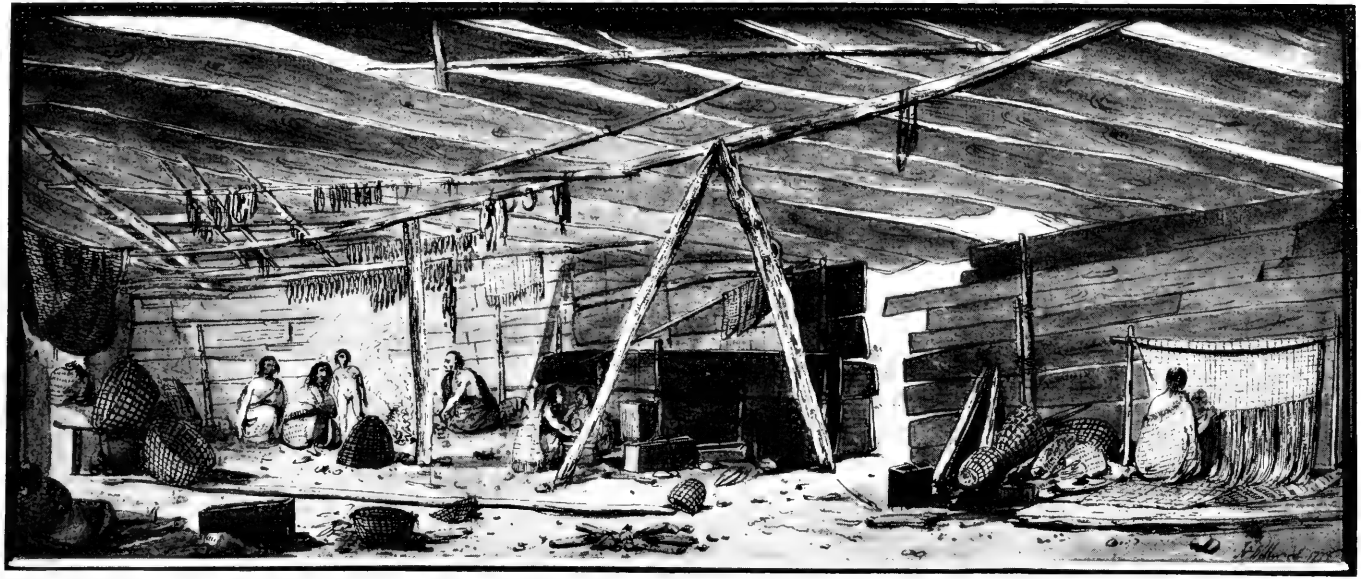
A curious custom prevailed among the men for on certain occasions, so wrote Cook, the face "is variously painted, having its upper and lower parts of different colors, the strokes appearing like fresh gashes; or it is besmeared with a kind of tallow, mixed with paint, which is afterward formed into a great variety of regular figures, and appear like carved work." This is shown in plate 4. "Sometimes, again, the hair is separated into small parcels, which are tied at intervals of about two inches, to the end, with thread."

The drawing reproduced as plate 1 is a beautiful example of the artist's work—a man of Nootka, with the characteristic cap and wearing a heavy skin over his left shoulder, armed with bow and arrows. The quiver, in which are resting several arrows, opened lengthwise, not at one end. This was not described in the narrative and thus tends to prove the value of Webber's drawings, produced "for the express purpose of supplying the unavoidable imperfections of written accounts." The bands over the ankles conform with Cook's statement that "about their ankles they also frequently wear many folds of leather thongs, or the sinews of animals twisted to a considerable thickness."

The food of the people living on the shores of Nootka Sound consisted, as Cook then wrote, "of every thing animal or vegetable that they can procure." But "their greatest reliance seems to be upon the sea, as affording fish, muscles, and smaller shell-fish, and sea animals." The smaller fish were not only eaten fresh, when taken from the water, but were also smoked and dried, thus preserved for future use, and "sewed up in mats, so as to form large bales, three or four feet square." Broth was made by placing pieces of fresh meat "in a square wooden vessel or bucket, with water, and then throwing heated stones into it. This operation they repeat till they think the contents are sufficiently stewed or seethed. They put in the fresh, and take out the other stones, with a cleft stick, which serves as tongs; the vessel being always placed near the fire for that purpose. This operation is represented by Mr. Webber, in his drawing of the inside of a Nootka house." This refers to the group shown surrounding a fire, in plate 3.

Size 17 by 12 inches Signed *J. Webber, del.*

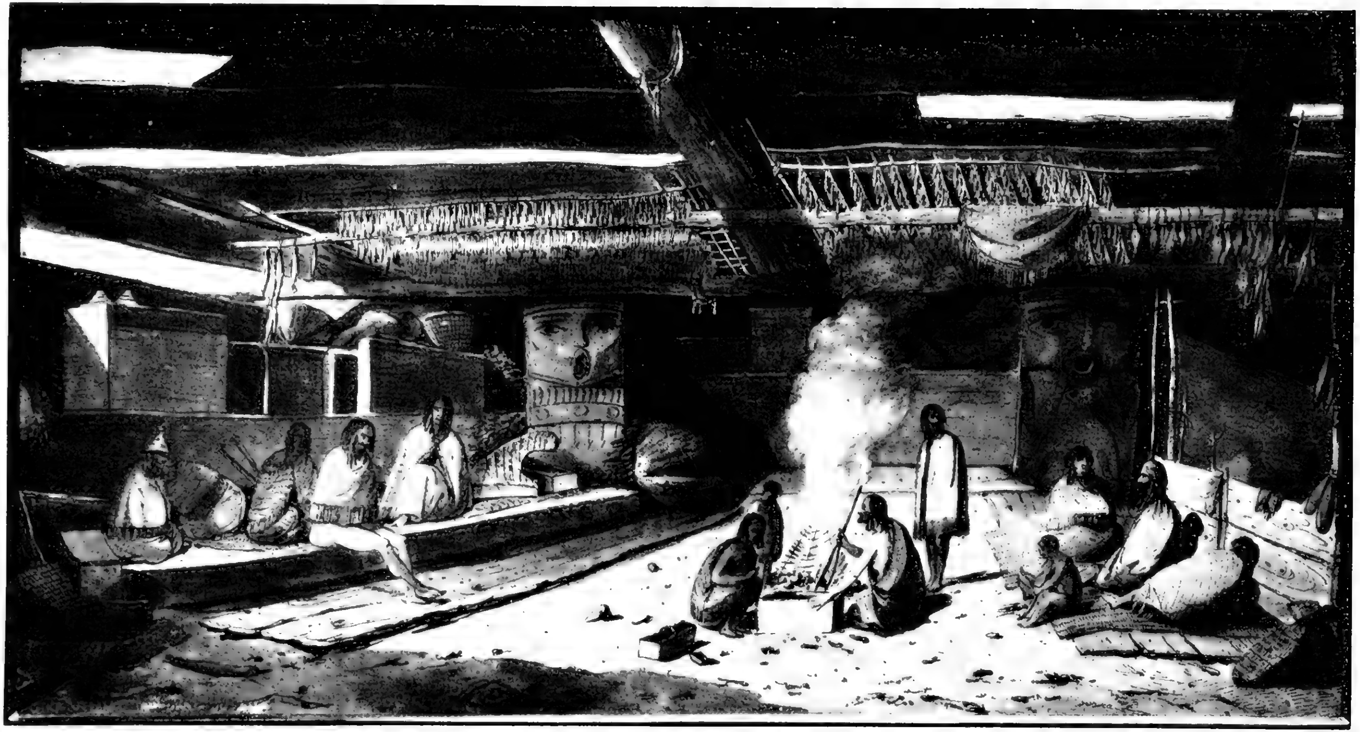
Nootka



Size 7 by 17 inches

Signed *J. Webber, del.* 1778

Nootka



Size 10 by 19 inches

Signed *J. Webber, del. 1778*

Nootka

Size 17 by 12 inches

Nootka

Size 15 by 12 inches

Nootka

PRINCE WILLIAM SOUND. MAY, 1778

Continuing along the coast the expedition arrived at another inlet to which the name Prince William Sound was given. Here were encountered the first Eskimo to be met when coming from the southward, and they were easily recognized as differing in appearance from the people of Nootka Sound.

Evidently the habitations were away from the shores of the sound, or possibly in some protected cove, as none was seen and consequently no description of a native settlement was given in the narrative. But many of the people visited the two ships, coming in boats of their own make, some of which held more than twenty persons each.

Men, women, and children were dressed alike. All wore "a kind of close frock, or rather robe; reaching generally to the ankles, though sometimes only to the knees. At the upper part is a hole just sufficient to admit the head, with sleeves that reach to the wrist. These frocks are made of the skins of different animals. . . . . When it rains they put over this another frock, ingeniously made from the intestines of whales, or some other large animal, prepared so skilfully, as almost to resemble our gold-beaters' leaf. It is made to draw tight round the neck; its sleeves reach as low as the wrist, round which they are tied with a string. . . . . Those who wear any thing on their heads, resembled, in this respect, our friends at Nootka; having high truncated conic caps, made of straw, and sometimes of wood, resembling a seal's head well painted." One of the sketches by Webber, made at that time, shows a man wearing a waterproof garment, such as was mentioned, and also a characteristic hat with figures painted in red and black. The second drawing is that of a man wearing a fur garment, "worn with the hairy side outward," and ornamented with a fringe which appears to have been formed of many small tails.

To quote again from Captain Cook's narrative: "The men frequently paint their faces of a bright red, and of a black colour, and sometimes of a blue, or leaden colour; but not in any regular figures; and the women, in some measure, endeavoured to imitate them, by puncturing or staining the chin with black, that comes to a point in each cheek." Men wore their hair short, "cropt round the neck and forehead," but the women allowed theirs to grow long. Both men and women perforated their ears in several places, "in which they hang little bunches of beads, made of the same tubulose shelly substance used for this purpose by those of Nootka. The *septum* of the nose is also perforated, through which they frequently thrust the quill-feathers of small birds, or little bending ornaments, made of the above shelly substance, strung on a stiff string or cord, three or four inches long, which give them a truly grotesque appearance. But the most uncommon and unsightly ornamental fashion, adopted by some of both sexes, is their having the under-lip slit, or cut, quite through, in the direction of the mouth, a little below the swelling part. . . . . In this artificial mouth they stick a flat, narrow ornament, made chiefly out of a solid shell or bone, cut into little narrow pieces, like small teeth, almost down to the base or thickest part, which has a small projecting bit at each end that supports it when put into the divided lip; the cut part then appearing outward. Others have the lower lip only perforated into separate holes; and then the ornament consists of as many distinct shelly studs, whose points are pushed through these holes, and their heads appear within the lip, as another row of teeth immediately under their own." These curious ornaments are clearly shown in the two sketches by Webber.

Size 15 by 12 inches

Prince William Sound

Size 17 by 12 inches

Prince William Sound

NEAR ICY CAPE. AUGUST, 1778

By the middle of August, 1778, the two ships were in the far northern waters, beyond Bering Strait in the Arctic. At noon on the 18th they were in latitude 70° 44′. To quote from the narrative: "We were, at this time, close to the edge of the ice, which was as compact as a wall; and seemed to be ten or twelve feet high at least. But, farther North, it appeared much higher. Its surface was extremely rugged; and, here and there, we saw pools of water.

"We now stood to the Southward; and, after running six leagues, shoaled the water to seven fathoms; but it soon deepened to nine fathoms. At this time, the weather, which had been hazy, clearing up a little, we saw land extending from the South to South East by East, about three or four miles distant. The Eastern extreme forms a point, which was much incumbered with ice; for which reason it obtained the name *Icy Cape*. Its latitude is 70° 29′, and its longitude 198° 20′. The other extreme of the land was lost in the horizon; so that there can be no doubt of its being a continuation of the American continent. The *Discovery* being about a mile astern, and to leeward, found less water than we did; and tacking on that account, I was obliged to tack also, to prevent separation.

"Our situation was now more and more critical. We were in shoal water, upon a lee shore; and the main body of the ice to the windward, driving down upon us. It was evident, that, if we remained much longer between it and the land, it would force us ashore; unless it should happen to take the ground before us." This was the scene sketched by Webber, the *Resolution* leading with the *Discovery* "about a mile astern."

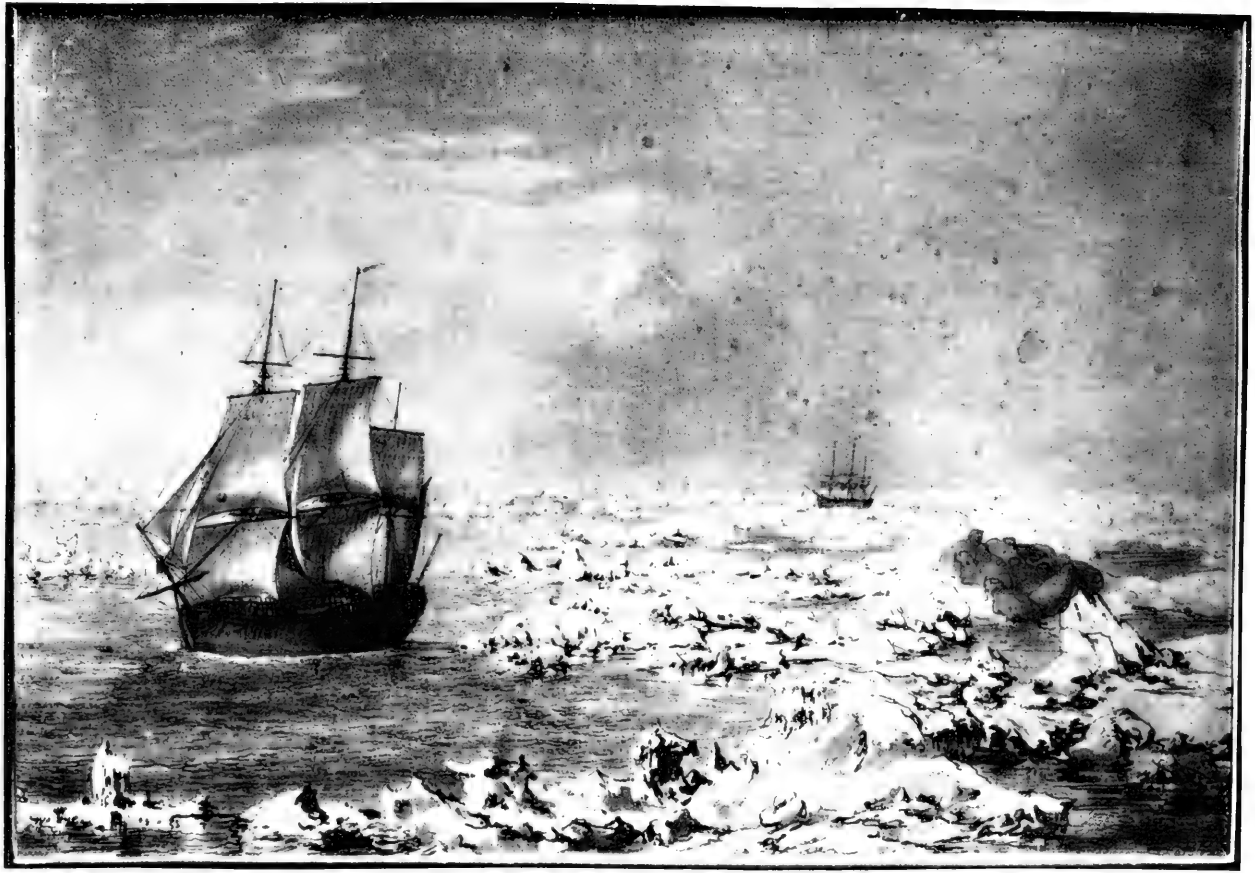
The following day, August 19, the ships were in the midst of much drift ice, with great masses just beyond. "It was not so compact as that which we had seen to the Northward; but it was too close, and in too large pieces, to attempt forcing the ships through it. On the ice lay a prodigious number of sea-horses; and, as we were in want of fresh provisions, the boats from each ship were sent to get some." A small group of "sea-horses" may be seen on the ice to the right in the drawing.

The ships were turning southward, to avoid the ice and to seek other lands. On September 2, they passed Eastern Cape and continuing down the coast of Asia arrived in the Bay of St. Lawrence.

Thence they " steered over for the American coast; and, at five in the afternoon, the next day, saw land bearing South three quarters East, which we took to be Anderson's Island, or some other land near it. . . . . On the 6th, at four in the morning, we got sight of the American coast near Sledge Island; and at six, the same evening, this island bore North, 6° East, ten leagues distant; and the Easternmost land in sight North, 49° East. If any part of what I had supposed to be American coast, could possibly be the island of Alaschka, it was that now before us. . . ."

The expedition soon reached Norton Sound. Here they remained several days and had intercourse with the friendly natives from whom they secured a quantity of fish, both fresh and dried. " The dwellings of these people were seated close to the beach. They consist simply of a sloping roof, without any side-walls, composed of logs, and covered with grass and earth. The floor is also laid with logs; the entrance is at one end; the fire-place just within; and a small hole is made near the door to let out the smoke."

Sailing from Norton Sound, " on the 17th in the morning, with a light breeze at East," they sighted many islands, encountered shoal water, and after an uneventful voyage " at length, on the 2d of October, at day-break, we saw the island of Oonalashka, bearing South East."



Size 16½ by 24½ inches Signed *J. Webber, del.*

Near Icy Cape, August 18, 1778, "The *Resolution* beating through the ice with the *Discovery* in danger in the distance"

OONALASHKA, OCTOBER, 1778

The ships touched at Oonalashka on the voyage northward, and just three months later again came in sight of the island. This was October second when they reached a bay some ten miles west of Samganoodha, "known by the name of *Egoochshac*." Many natives lived on the shore of the bay, they visited the ships "bringing with them dried salmon, and other fish, which they exchanged with the seamen for tobacco." The following day, October 3, the ships continued on to Samganoodha Harbor where they remained until the 26th of the same month. There was a small village a short distance from the harbor where, it is quite probable, Webber made his drawings.

Describing the people of Oonalashka, Captain Cook wrote: "These people are rather low of stature, but plump and well shaped; with rather short necks; swarthy chubby faces; black eyes; small beards; and long, straight, black hair; which the men wear loose behind, and cut before, but the women tie up in a bunch." And referring to the dress: "Both sexes wear the same in fashion; the only difference is in the materials. The women's frock is made of seal skin; and that of the men, of the skins of birds; both reaching below the knee. This is the whole dress of the women. But, over the frock, the men wear another made of gut, which resists water; and has a hood to it, which draws over the head. Some of them wear boots; and all of them have a kind of oval snouted cap, made of wood, with a rim to admit the head. These caps are dyed with green and other colours; and round the upper part of the rim, are stuck the long bristles of some sea-animal, on which are strung glass beads, and on the front is a small image or two made of bone. They make use of no paint; but the women puncture their faces slightly; and both men and women bore the under lip, to which they fix pieces of bone. But it is as uncommon, at Oonalashka, to see a man with this ornament, as to see a woman without it. Some fix beads to the upper lip, under the nostrils; and all of them hang ornaments in their ears." Many of the peculiar details of dress, mentioned in this brief description, are shown in Webber's graphic sketches.

The habitations of the natives evidently proved of much interest. "Their method of building," so wrote Cook, "is as follows: They dig, in the ground, an oblong square pit, the length of which seldom exceeds fifty feet, and the breadth twenty, but in general the dimensions are smaller. Over this excavation they form a roof of wood which the sea throws ashore. The roof is covered first with grass, and then with earth; so that the outward appearance is like a dunghill. In the middle of the roof, toward each end, is left a square opening, by which the light is admitted; one of these openings being for this purpose only, and the other being also used to go in and out by, with the help of a ladder, or rather a post, with steps cut in it. In some houses there is another entrance below; but this is not common. Round the sides and ends of the huts, the families (for several are lodged together) have their separate apartments, where they sleep, and sit at work; not upon benches, but in a kind of concave trench, which is dug all round the inside of the house, and covered with mats; so that this part is kept tolerably decent. But the middle of the house, which is common to all the families, is far otherwise."

Although the majority of their bowls, spoons, baskets and other objects of daily use were of their own make, bits of metal and iron kettles and pots were obtained from the Russians with whom they had been in contact some years. The women made "mats and baskets of grass, that are both beautiful and strong."

Fire was produced in two ways, "by collision and by attrition; the former by striking two stones one against another; on one of which a good deal of brimstone is first rubbed. The latter method is with two pieces of wood; one of which is a stick of about eighteen inches in length, and the other a flat piece. The pointed end of the stick they press upon the other, whirling it nimbly round as a drill; thus producing fire in a few minutes." But although fire was so easily obtained, fire places were not seen "in any one of their houses. They are lighted, as well as heated, by lamps; which are simple, and yet answer the purpose very well. They are made of a flat stone, hollowed on one side like a plate, and about the same size, or rather larger. In the hollow part they put the oil, mixed with a little dry grass, which serves the purpose of a wick. Both men and women frequently warm their bodies over one of these lamps, by placing it between their legs, under their garments, and sitting thus over it for a few minutes."

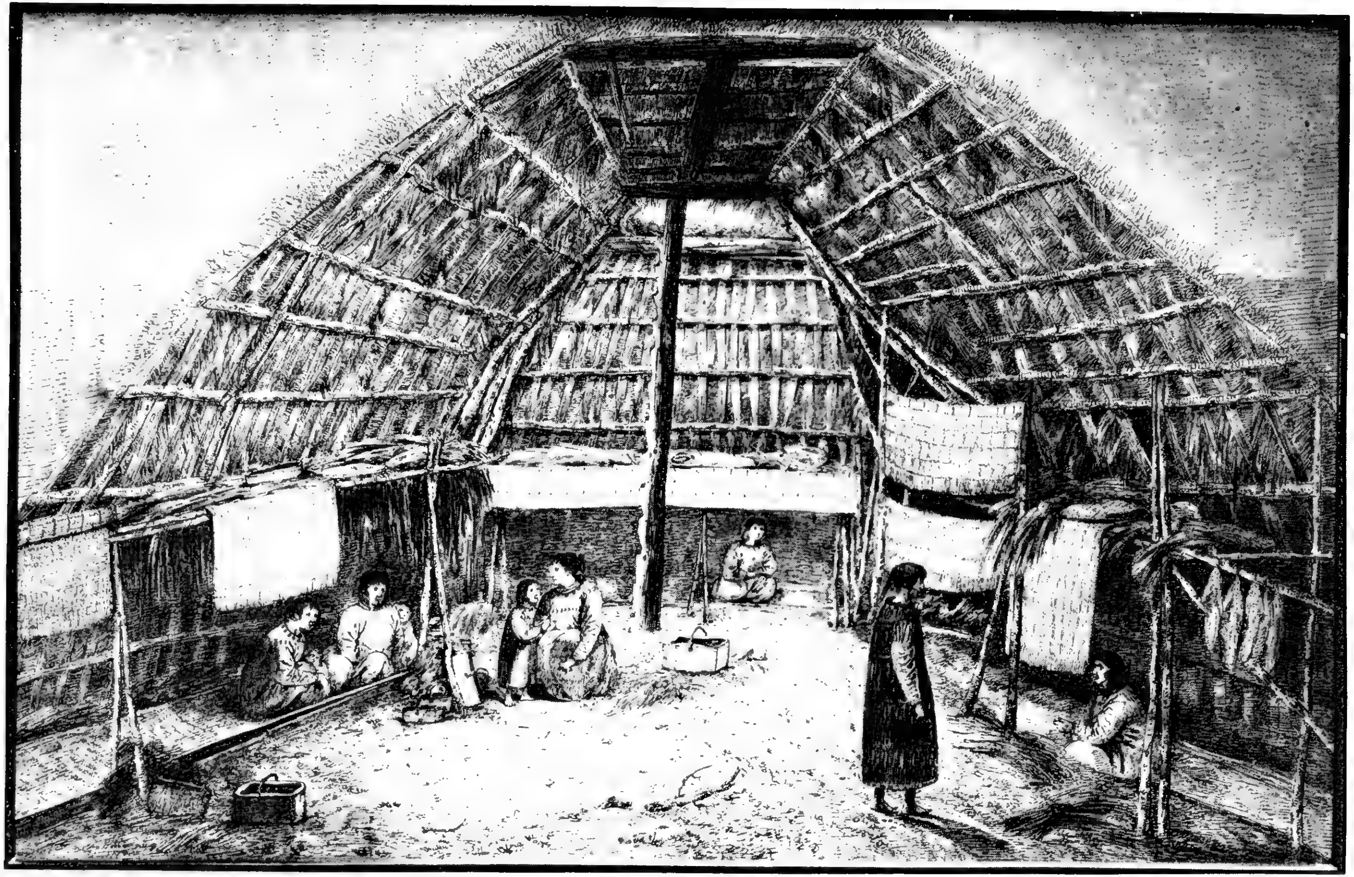
The boats, many of which are shown in plate 10, were described as "the smallest we had anywhere seen upon the American coast; though built after the same manner, with some little difference in the construction."

Size 17 by 12 inches

Oonalashka

Size 16½ by 24½ inches Signed *J. Webber, del. 1778*

Oonalashka



Size 12 by 19 inches Signed *J. Webber, del. 1778*

Oonalashka

Size 17 by 12 inches

Oonalashka

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 11

THE LEGS AND LEG-BEARING SEGMENTS OF SOME PRIMITIVE ARTHROPOD GROUPS, WITH NOTES ON LEG-SEGMENTATION IN THE ARACHNIDA

(WITH 12 PLATES)

BY
H. E. EWING
Federal Bureau of Entomology

(PUBLICATION 2962)

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THE LEGS AND LEG-BEARING SEGMENTS OF SOME PRIMITIVE ARTHROPOD GROUPS, WITH NOTES ON LEG-SEGMENTATION IN THE ARACHNIDA

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(With 12 Plates)

CONTENTS

INTRODUCTION

In attempting to work out the homologies of leg segments in a number of the different groups of arthropods, an effort has been made to find the generalized type for such classes as the Crustacea, the Arachnida, and the Insecta, and by comparing intergrades with these established types to interpret the homologies as far as possible for each group. In such a comparison the position of the segment in the series is determined, but the procedure of prime importance is the definite establishment of a known segment in the series which may be used as a point of reference. Different methods have been employed for the establishment of a "land mark" segment or, what amounts to the same, a "land mark" articulation. Börner (1921) lays great stress on the bend of the leg at the knee, usually regarding such a bend as taking place at the distal articulation of the femur. Snodgrass (1927) uses chiefly the trochantero-femoral articulation in insects as a starting point.

In the Arachnida, where legs appear to show the maximum number of true segments, eight in addition to the claws, it is assumed that all segments are present. Such being the case one may begin at the base of the leg in legs of this sort by calling the first segment the subcoxa. Where there is a reduction of the number of leg segments, it may yet be possible to establish the homology of the remaining segments if the method of reduction can be established. In insect legs it appears, according to the results of recent investigation, that the tarsus never gives rise to muscle fibers, the extensor claw muscle having been lost, and the flexor taking its origin from the tibia or from the tibia and other segments proximal to it. Using this as an established principle the writer has in many instances regarded the last segment giving rise to muscle fibers as the tibia in the case of insects and also in primitive groups related to the insects. Nevertheless the trochantero-femoral articulation should be regarded as a "landmark" of great importance in interpreting the segmentation of insect legs.

The question of the segmentation of the body and the segmentation and musculature of the legs in primitive arthropods has been approached from the standpoint of a taxonomist, using that term in its broadest sense as applying to one who has been interested in classification primarily as bearing on natural relationships and evolution.

It is lamentable that there is so frequently shown a lack of cooperation and helpfulness between the taxonomist and the morphologist. The separation between these two groups of workers has in some instances become so great that not only is there a lack of the proper cooperation in conducting the investigations, but the taxonomist does not even read the literature dealing with the morphology of his own group, and the morphologist seldom consults taxonomic papers, even outstanding monographs. The result is that taxonomy and general entomology have suffered greatly from a multiplicity of terms, from the use of several terms to indicate the same structure, and in consequence many have become befogged in regard to obvious facts in evolution and relationships.

Before passing to the results of this investigation the writer wishes to express his indebtedness to R. E. Snodgrass, whose recent treatise on the "Morphology and Mechanism of the Insect Thorax" (Snodgrass, 1927) has been of great help to him in undertaking this investigation.

THE PRIMITIVE ARTHROPOD APPENDAGE

Two questions of importance arise concerning our concept of the primitive type of arthropod limb: Was it a simple, filiform, unbranched structure or was it biramous; and how many true segments did it contain? There has been a general tendency to look to the Crustacea in searching for the answer to these questions, and doubtless with much reason, yet the writer is of the opinion that a study of the arachnid limbs is equally important if not more so. Probably the Crustacea have been chiefly considered because of their supposed relationship to that very large and very important class, the Insecta, and because of their evident affinity with the much studied, ancient and extinct group, the Trilobita.

Hansen (1893 & 1925), in two highly important papers, has led the way in his investigations in regard to the search for the generalized type of appendage for the Crustacea. He pointed out that an additional segment should be recognized in the unbranched base of the typical crustacean limb, and he recently (1925) holds to the possibility that in a primitive state the crustacean limb was uniramous. He states: " But it seems to me impossible to deny the possibility that the exopod may be anologous with the epipod, and if so the primitive appendage is uniramous." Hansen's contention that the basal or undivided part of a crustacean limb should be considered as three-segmented instead of two-segmented is recently criticized by Borradaile (1926) who states in his paper: " From the foregoing considerations it is evident that the recognition of a three-segmented protopodite in the Crustacea is purely empirical, for the actual third segment is not homologous in all cases, being sometimes the third segment of the primary series, sometimes compounded of the third and fourth, sometimes the fourth alone, and probably in a few instances compounded of the fourth and fifth, the actual second segment in the latter two cases being compounded of the primary second and third."

According to Hansen (1925) the crustacean limb is composed of eight true segments which he names as follows from the body: Praecoxa, coxa, basis, ischium, merus, carpus, propodus and dactylus. If the old terminology were employed these would be: Pleuropodite, coxopodite, basipodite, ischiopodite, meropodite, carpopodite, propodite and dactylopodite.

THE PRIMITIVE ARACHNID LEG

Because the ancient group Arachnida has apparently evolved from extinct types of the same sort as those that gave rise to the Crustacea, it is apparent that a study of the appendages of the more generalized arachnid groups should throw light on the controversy in regard to the leg type for the primitive Crustacea. In working on the homology of arachnid legs the writer follows Hansen's interpretation of the Crustacean leg by calling the first segment in the generalized leg the subcoxa.

LEGS OF SOLPUGIDA

The Solpugida, or sun spiders, have long been considered as being one of the most generalized of the arachnid groups. This is due particularly to the fact that in this group some of the cephalothoracic segments remain free and movable. Much research has been done on the body segmentation in the solpugids and on the morphology of certain specialized organs. The legs, however, have not attracted the attention that they deserve, although it has long been known that the number of segments in a solpugid leg is high, being seven or eight in addition to the claws.

In eight-segmented legs (pl. 1, fig. 1) there is a somewhat flattened, short basal segment, then three short doubly-hinged cylindrical segments, followed by three long segments and lastly by the terminal claw-bearing segment, which has two or more false rings. According to Bernard (1896) the basal segment represents the coxa, but others have regarded this segment as a sternite. Bernard is inclined to follow Gaubert in accounting for the extra segment in the eight-segmented legs through a division of the femur. Yet in regard to this point he remarks, " I am unable to judge, having never seen the animals alive." Sørensen (1914) regards the first long segment (the fifth of an eight-segmented leg) as the femur, which has been the customary practice.

When the musculature and the movements of the third or fourth leg (pl. 1, fig. 1) are studied, a very interesting and unusual condition is revealed. Each of all four of the basal short segments bears the segment distal to it by means of a double hinge, and all of these hinges work along a more or less vertical axis; no two, however, are in the same plane. The type of musculature for each of these segments is the same. There are two powerful muscles in each that arise from the base of one segment and attach to the basal apodeme of the next. One of these muscles moves the segment distal to it backward, the other forward. The first and second long segments each has its interior almost completely taken up by a powerful flexor muscle moving the segment distal to it.

The writer has been unable to detect in the solpugid leg any muscle in the first five segments that passes through more than one segment. Do we not here have another condition, the type of musculature of the legs, which shows a primitive condition? The sixth segment not only gives rise to powerful flexor muscles going to the seventh but sends strands to the flexor of the claws. The seventh gives rise dorsally to the extensor of the claws and ventrally to a flexor of the eighth segment and in addition sends powerful strands to the flexor of the claws. There is some indication of additional strands of muscle fibers going to the flexor of the claws from the basal part of segment eight. If the segment just proximal to the first knee bend be regarded as the femur, or if the basal segment be regarded as the subcoxa, the following names may be applied to the leg segments beginning at the base: Subcoxa, coxa, coxal trochanter, femoral trochanter, femur, patella, tibia, tarsus, foot (pretarsus). It should be added that the tarsus has two or more pseudosegments and that the claws themselves are segmented near the end. Barrows (1925) states that the tendon of the flexor of the claws divides, and each element traverses the long proximal part of the claw to attach to the terminal part. The writer has been unable to find a division of this tendon and is of the opinion that it attaches in the usual manner at the claw bases. It was noted, however, that a tracheal branch traverses most of the length of the basal element of each claw. When a solpugid leg is compared with that of a primitive mite, a tick or a primitive phalangid or with certain other arachnids, the homology of the leg segments is indicated.

While discussing the legs of solpugids it is pertinent to recall that Bernard (1896) concluded, "that the 'sterna' along the abdominal segments represent rudimentary limbs which have simply flattened down." He claimed that the two pairs of stigmatic opercula repeat the genital opercula so closely that they must also be vestigial appendages; that the abdominal vestiges are often covered with hair differing from the hair on the rest of the abdomen; that the same difference applies to color; that the vestiges meet in the middle line like the coxae of the functional legs; and finally that the stigmatic apertures, which are always associated with rudimentary legs, have moved into the ventral middle line.

THE LEG SEGMENTS OF PRIMITIVE PHALANGIDS

The phalangids with which most American entomologists are acquainted are called daddy-long-legs. They are quite different in appearance from the most primitive members of the group which are placed in the suborder Cyphophthalmi. Members of this suborder do not have the long many-ringed legs of the familiar daddy-long-legs. They are much smaller and in appearance are mitelike. The resemblance to mites is more than superficial. According to the writer (Ewing, 1923) it is from very similar arthropods that the mites have evolved.

The leg of one of the Cyphophthalmi, as represented by *Holosiro acaroides,* has been regarded as seven-segmented with the addition of the foot. However, the first two legs have a divided basal segment, the most proximal section being known as the maxillary lobe. In *Holosiro acaroides* (pl. 1, fig. 2) there are rudiments of this lobe of the basal segments to all the legs though they are very small for the last two pairs.

Unfortunately the writer has had only two specimens of this primitive group for study and these are balsam-mounted types. It may be added incidentally that they are the only two individuals ever taken in the New World. Under these conditions it has been impossible to study the muscles, hence the following homology, that is given only as a suggestion, is based on a comparison of the *Holosiro* leg with that of a solpugid and of a primitive mite genus, both of which have the same number of segments.

The basal segment, the so-called maxillary lobe, is probably the subcoxa, the next is a large coxa, flattened so as to be platelike at the base, then follows the first trochanter, a short segment, pedicellate in the first two pairs of legs. The next segment is the longest of all and in size and position suggests the femur. A comparison, however, with the leg of the related primitive mite genus *Labidostomma*, the musculature of which was worked out, shows that this long segment probably represents the second trochanter. The fifth segment is short in the first legs but is one of the longer segments in leg IV. It should be regarded as the femur. It is a more important segment than the femur of *Labidostomma* (pl. 2, fig. 3). There follow three somewhat similar segments, the last bearing a single claw. These should be regarded as the patella, tibia and tarsus respectively. The homologizing of the leg segments of *Holosiro* with those of the more highly developed phalangids is not attempted.

THE LEG SEGMENTS IN SOME OF THE ACARINA

Probably the most nearly related to the generalized phalangids of all the mites, and hence the most primitive, are those placed in the rare and little studied genus *Labidostomma*. The writer is fortunate in possessing a number of mites of this group representing several species.

In recently transformed adults with a thin coat of chitin the muscle attachments may be made out without difficulty. In the front leg of *Labidostomma* (pl. 2, fig. 3) there is a broad basal platelike segment with hinged articulations for the second short, stout segment. The latter bears a pair of hinged articulations for the third reduced segment. The third small segment is immovably joined to the fourth, which is femurlike and the largest of all. Then follows a short movable segment, two long movable ones and a long terminal claw-bearing segment. If the basal, platelike segment be regarded as the subcoxa, then there follow a rather small but fairly typical arachnid coxa, a very large divided trochanter, a reduced femur and another segment which is here regarded as the patella, and lastly the tibia and claw-bearing tarsus.

When a comparison is made between the leg of *Labidostomma* and that of a free-living member of the family Gamasidae (pl. 2, fig. 4) the homology of the segments is easily determined. In a gamasid mite there are also the eight full rings to a leg but here the last two are immovably joined. It has been customary to consider these two together as a divided tarsus, but this practice appears to be without justification. A comparison, segment for segment, between the leg of *Labidostomma* and that of a gamasid indicates that the short penultimate segment of the latter should be the tibia. The other segments of the gamasid leg are almost identical with those of *Labidostomma* except that the precoxa is more coneshaped than platelike.

An excellent intergrading of connecting species exists between the Gamasidae and the Ixodoidea, hence a comparison of the leg of the latter with that of the former should be illuminating. This is given in plates 2 and 3. Here again the homology is clearly indicated. The subcoxa has become platelike, the femur is somewhat larger, and the penultimate segment is better developed, giving rise to most of the muscles moving the claws. In the tick leg both an extensor and a flexor muscle of the claws is present (pl. 3, fig. 5), the latter arising chiefly if not entirely from the patella.

It appears that in the Arachnida a segment additional to any found in insects must be recognized. It is here regarded as the patella. The patella, whatever its fate among the immediate ancestors of insects may have been, appears to be totally lost in that class. Not even a rudiment of it has been successfully accounted for. In the Arachnida, a group much more nearly related to the Crustacea, it remains, representing probably the meropodite of a primitive crustacean leg according to Hansen's interpretation.

Among the orders of Arachnida, the mite leg, be it of the eight-segmented or the five-segmented type, is characterized particularly by the passing of the large flexor muscles entirely through one segment to the base of the next. This condition is especially apparent in the leg of a cheese mite, family Tyroglyphidae, as shown by Michael (1901). In part it may have been brought about by the shortening of the segments of the legs but probably also by a shifting of the position of the origin of the flexor muscles entirely to the dorsal wall of the segments.

LEG-SEGMENTATION IN VARIOUS ARACHNID GROUPS WITH SPECIAL REFERENCE TO THE PSEUDOSCORPIONIDA

Three well-known Arachnid groups have a leg that is typically seven-segmented, not counting the foot. They are the scorpions, the spiders and the pseudoscorpions. In the spiders there are two short basal segments, followed by the largest segment of the leg, then a short and a long segment usually fused together, and finally two long segments, the distal one bearing the claws. Comstock (1912) regards these as follows: Coxa, trochanter, femur, patella, tibia, metatarsus and tarsus respectively.

In the pseudoscorpions, a leg typically consists of six segments in addition to the pretarsus. However, in the genus *Obisium* all the legs show seven segments. Börner (1921) has described the segmentation and musculature of the leg in this group. In a typically six-segmented leg there is a fixed platelike basal segment that meets its fellow from the opposite side of the cephalothorax on the median line. This basal segment is attached to the second, short, ringlike segment with a double hinge set almost vertically. The third segment is short and moves on a double horizontal hinge upon the second. This third segment may be free or it may be immovably fused with the fourth. When fused with the fourth (pl. 3, fig. 6, A), as it has been in the hind legs of *Chelifer,* the fourth is much enlarged. Distal to the fourth are two long slender segments and then the terminal claws and pulvillus. Where the legs are seven-segmented there is a suture in the last true segment beyond the muscle attachment (pl. 3, fig. 6, B).

In the six-segmented leg, the last true segment (pl. 3, fig. 6, A) giving rise to some of the claw-moving muscles is the last segment of the leg. It should be regarded as the tibio-tarsus, as its derivation through a union of the tibia and tarsus is made clear through a series of intergrades.

The next segment proximal, which is the first beyond the knee and is always present and well developed, should be regarded as the patella. Proximal to the patella is the femur. It is sometimes cylindrical and sometimes enlarged, usually the latter in the case of the hind legs.

The segment just proximal to the femur varies greatly. In the hind legs of *Chelifer* (pl. 3, fig. 6, A) it is completely fused with the femur, and has no special muscle inserted on it. In the first and second legs, however, of the same genus, this segment is free, and the femur is attached to it by a double hinge which works in almost the same plane as the hinge at the base of this short segment. The fact that this segment comes next to the femur and is frequently fused with the same indicates that it is one of the trochanters.

There remains the platelike basal segment and the one next to it which is hinged to the short femoral trochanter. Does this platelike basal segment represent the coxa, the name by which it has gone in the past, or is it in reality the subcoxa? If it is a true subcoxa, the second segment becomes the coxa, instead of the first trochanter, as it is commonly regarded. Evidence as to the homology of these two basal segments is wanting, hence no serious objections should be raised to the prevailing practice of calling them the coxa and first trochanter.

The legs of scorpions appear to be seven-segmented, not counting the claws, but in reality are only six-segmented. The bend of the leg takes place between the third and fourth segments, while in pseudoscorpions it is between the fourth and fifth. The scorpion leg segments have not heretofore been homologized.

The leg of a thelyphonid shows a large number of rings, but three of these represent subdivisions of the tarsus. Börner has worked out the muscles. Judging from the muscle attachments figured by Börner the present writer would regard the leg of a thelyphonid of the genus *Thelyphonus* as composed of the following segments: Subcoxa, coxa, trochanter, femur, patella, tibia and tarsus, in addition to the foot. The tarsus itself has false segments, and the first trochanter is vestigial. The thelyphonid leg is, therefore, more like the leg of a solpugid or a phalangid than like one of a scorpion or pseudoscorpion.

THE PYCNOGONIDA AND RICINULEI

Mention should be made of two arachnid orders in which the legs show a large number of segments. In the Pycnogonida the legs are very long and are composed of eight segments in addition to the claws. Börner (1921) has worked out the musculature. The writer has also done the same for *Colossendies macerrima* and finds practically a complete agreement in regard to the facts presented by Börner, but a different interpretation is made of them. The wall of the body extends outward in the form of a cylindrical process for the articulation of the first leg segment. This first segment is very short and similar to the next two short ones, which possess dicondylic hinges. The fourth and fifth segments are very long and have dicondylic hinges. The very long sixth segment has but a single hinge and only a flexor muscle. The short seventh segment is immovably hinged to the short eighth and has no muscles originating in it. The eighth bears alone the extensors and flexors of the claws. Each of the first five segments is provided with a levator and a depressor muscle. In no instance does any muscle in the pycnogonid leg pass entirely through a single segment. Although segment seven has no muscles originating in it, it should be regarded as a true segment because the flexor muscle of the sixth segment inserts on its base and its articulation with segment eight indicates that the hinge was once functional. The conditions of this segment are entirely analogous to those of the trochanter in a lepismid leg where the muscle is usually lacking. The writer finds the leg segments of Pycnogonida entirely homologous with those of other generalized arachnids and consisting of the following: Subcoxa, coxa, trochanter I, trochanter II, femur, patella, tibia, tarsus and pretarsus.

In the Ricinulei, according to Hansen and Sørensen (1904), the second and third pairs of legs have eight segments. These authors regard the basal segment as the coxa and allow for two trochanters, a patella and a metatarsus. Their figures would indicate that the leg of a member of the Ricinulei is entirely of the type found in the solpugids, the primitive phalangids and primitive mites. This being the case, the first segment should be regarded as the subcoxa, the femur would become the trochanter and the other segments would be renamed according to their positions, the term metatarsus being discarded.

CONCLUSIONS IN REGARD TO ARACHNID LIMBS

It appears, therefore, that the generalized arachnid limb is composed of eight segments in addition to the foot or claws. This is a condition found today in the Solpugida, the Phalangida, the generalized Acarina, the Ricinulei and the Pycnogonida. Such a condition gives much weight to Hansen's contention that eight segments should be recognized in the crustacean limb. Since the foot, or claws in Arachnida, as in all arthropod groups, should be considered as a segment, one segment more in this class is to be reckoned with than in Crustacea, Insecta, or apparently in any other arthropod class. This segment should be called the patella. It is situated between the femur and the tibia.

The subcoxa is evident and well developed in most arachnid groups. The Arachnida thus shows in this respect a condition not found in the Crustacea and a more primitive one.

The tarsus, although frequently possessing a number of false segments, as in insects, is of a more primitive type than the insect tarsus. This is particularly true in regard to its musculature, there being an extensor of the claws present, while the flexor of the claws sends fibers to attach to the segment proximal to the tibia.

LEG-SEGMENTATION AND MUSCULATURE IN THE PROTURA

Leg segmentation in the Protura was first described by Silvestri (1907), while the musculature was first studied by Berlese (1910). More recently Prell (1912) made the leg segmentation and musculature in this order the subject of a special paper. In regard to the segmentation of the movable limb there has been agreement among these three workers. All recognize the large somewhat triangular basal segment (pl. 4, fig. 7) as the coxa, the small ringlike second segment as the trochanter, the next and largest of all the segments as the femur, the two following smaller segments as the tibia and tarsus respectively. Prell also calls the foot the pretarsus. In regard to the musculature there are some differences in the results of these workers, the chief of which has to do with the tarsus. Berlese (1910) figures a conspicuous muscle arising from the dorsal wall of this segment and attaching to the dorsal aspect of the foot in *Acerentomon doderoi*. The action of such a muscle would be to extend the claw. Also in the same species both a levator and a depressor muscle of the femur are represented. Prell, who worked with the same species and also with *Eosentomon germanicum*, finds no such extensor of the claws in any of the tarsi. In all legs he found a levator of the femur but no depressor.

Prell's paper is so complete that the writer has done but little beyond verifying his results except with regard to structures and muscles that occur about the base of the leg. Here in front of the coxa the present writer has always found two crescentic sclerites as represented by Berlese (1910) for *Acerentomon doderoi*, but a somewhat different interpretation is placed on their homology and function. Berlese regarded the more ventral sclerite as the subcoxa or trochantin and the more dorsal as the epimeron. The present writer would consider the two together (pl. 4, fig. 7) as a real subcoxa which, however, has largely lost its function. The shape and position of these sclerites indicate that they are more of the nature of leg structures than body structures. Berlese (1910) shows no articulations between the more ventral one and the coxa, but Prell (1913) finds the coxa articulating dorsally with the ventral sclerite near its middle and anteriorly with the anterior end of the same. Although the writer has always found the dorsal articulation he has failed to verify Prell's results in regard to a ventral articulation.

The musculature of the legs of *Acerentulus barberi* will now be described (see pl. 4, fig. 7). From the dorsal walls of the third and fourth complete segments arise the fibers of the most distal muscle, the flexor of the claws. This muscle is attached to the claw base. It can be traced backward as a minute, poorly chitinized tendon which passes very soon into the strongly chitinized end of the tendon of the muscle proper (pl. 4, fig. 7). As the muscle is followed proximally through the tarsus it enlarges until about half of the area of a cross section is occupied. The most of the fibers attach dorsally to the wall of the tibia, but in the second and third pairs of legs some strong strands extend into the femur attaching dorsally near the tip of this segment. In neither *Acerentulus barberi* or *Eosentomon vermiforme* or any of the other American species examined were muscle attachments found on the tarsus. The next (proximally) muscle is the powerful flexor of the tarsus. It arises, as far as could be ascertained, entirely from the femur. The flexor of the tibia follows. It has also a powerful muscle arising from the chitinous ring of the base of the trochanter and attaching to the ventral side of the base of the tibia. Prell (1912) finds extensor muscles attached to the femur. In *Acerentulus barberi* such a muscle could not be detected. However, a small flexor muscle was found as represented by Berlese (1910) for *Acerentomon doderoi* except that it arises from the base of the trochanter instead of the base of the coxa. Two powerful muscles are situated in the coxa, one a levator of the trochanter and the other a depressor. The coxa, which is hinged above to the lower sclerite of the subcoxa and below to the sternum, is rotated by two powerful muscles arising from the dorsal wall of the thorax, the anterior being the protractor of the coxa and the posterior the retractor of the same.

Snodgrass (1927) has emphasized the similarity between the musculature of the proturan leg and that of a caterpillar. These resemblances have to do with the simplicity of the musculature, the almost complete absence of extensor muscles and the passing of strands of several muscles through more than one segment. In the leg of a caterpillar the flexor muscle of the claw sends some fibers to attach to the base of the coxa. Here, therefore, is an instance of a muscle passing through the entire length of a leg.

The presumption is frequently made, and doubtless with reason, that in the leg of a proturan and that of an insect larva we have not only a simple type of musculature but also a primitive one. If this is a primitive insectan type, and the present writer believes it is, it is quite different from the primitive type for the Arachnida. In the Solpugida and other primitive arachnids the legs are composed of a large number of segments and but few of the muscles pass through more than one segment, and there are several extensors. The Arachnida are believed to have had their descent from ancestors similar to those from which the Crustacea descended. If the insects have descended from Crustacea-like ancestors, a primitive condition in Insecta should simulate some condition evolved in the Crustacea; but in the Arachnida it should simulate a condition established among *the ancestors* of the Crustacea.

LEG SEGMENTATION AND MUSCULATURE IN PAUROPODA

Because of their relation to the Crustacea on the one hand and to the Protura on the other (see Berlese, 1910) the Pauropoda should be considered as a likely group in which to increase our knowledge as to the typical form of an insectan leg. According to Kenyon (1895) all the legs in pauropods are composed of six segments except the first and last pairs which have only five segments. Kenyon called the basal segment the coxa and believed that the fifth and sixth segments in six-segmented legs equalled together the last segment in the five-segmented legs. After studying specimens prepared in various ways the writer has concluded that two additional rings should be recognized in all legs of *Pauropus*. Near the base of the segment regarded as the third by Kenyon there is a small rudiment of a segment which in some of the legs has considerable size (pl. 4, fig. 8, *tr*II), and his sixth segment shows an incomplete division near its middle (pl. 4, fig. 8). Thus the writer would recognize eight rings to the generalized *Pauropus* leg; however, as we shall see when the muscle attachments are studied, not all of these are to be considered as true segments.

In well-mounted specimens of *Pauropus* all the legs except the first and last show the following segmentation (pl. 4, fig. 8):

The basal segment is barely a completed ring. It is more or less triangular in shape and ends in a long apodeme which extends upward in the lateral body wall. The next segment is short and stout and sets on the first by means of a rocking hinge. The third segment, never a completed ring, is fused with the fourth, which is short. The fifth is the longest leg segment. It is singly hinged dorsally to the fourth and bears the sixth by means of a similar hinge. The seventh and eighth segments are not completely separated by a suture, which is always evident along the ventral margin of the leg. The claws set directly on the end of the last segment without any interpolated chitinous piece.

When the muscles are studied it is found that there are no fibers originating in any of the last three segments. Segment six is a complete ring and is movably fastened to seven by membranous tissue yet gives rise to no muscle fibers. All three, of these segments should, therefore, be regarded as the tarsus. In the first and last legs the last two segments only are without muscle origins. Apparently segment six of the generalized legs has fused with seven to make the single but very long sixth segment, in the first and last legs as claimed by Kenyon (1895).

Next to the three-segmented tarsus is the last segment giving rise to muscle fibers. It is the longest segment and should be regarded as the tibia. Proximal to the tibia is the stouter and shorter femur with its adhering incomplete ring at the inner basal aspect. This rudiment of a segment gives rise to no muscles. Such a condition, as well as its fusion with the femur, indicates that it is the trochanter, yet concerning this point there is not conclusive evidence. Dorsally the femur gives rise to powerful flexor muscle fibers, some going to the claws and some to the tarsus. Between the third segment and the incomplete basal segment is a short but very broad segment which bears ventrally a clavate appendage, regarded by some as being analogous with the stylus of Thysanura. When this large segment is compared with the coxa of a proturan leg it is observed that it not only has a similar position in the leg series of segments but has the double rocking type of hinge at both ends just as the proturan coxa has; however, the first segment is also decidedly like the coxa of many generalized insects. Although the writer is inclined to recognize this second segment as the first trochanter we are not sure that it is such. Regarding the subfemoral segment as the true coxa leaves only the decision that the incomplete basal segment is the subcoxa, yet if so it is more completely developed than in any insect. In pauropods this first segment is an integral part of the leg, although barely a complete ring and with only a few levator muscle strands. The depressors, however, are large and powerful (see pl. 4, fig. 8). Although the first segment is a movable segment in Pauropoda, at the same time it partakes of the nature of a body sclerite by sending upward a long apodeme which rests vertically in the body wall, rotating slightly when the subcoxa is moved.

THE SO-CALLED COXAL APPENDAGES IN PAUROPUS

In *Pauropus* the two proximal segments of the legs bear on their ventral surfaces conspicuous spatulate structures. In the posterior legs these structures appear to be forked. A closer inspection, however, shows that those on the posterior legs bear laterally a clublike appendage and are hardly biramous. These appendages have been regarded by some as true vestiges of real segments and as homologous with the coxal appendages of Symphyla and Thysanura.

The writer has made a special attempt to locate muscle fibers passing to these clavate structures (pl. 4, fig. 9) but has failed in every attempt although the muscular tissues in the segment from which they spring were clearly revealed. In some instances a few minute strands (sensory nerve?) were found passing into the coxa from the clavate structure, but in no instance did these reveal the striations characteristic of muscles. Probably the more plausible explanation of these clavate structures is that they are modified setae. Somewhat similar pectinate setae are found on the body in *Pauropus*. But these specialized body setae all possess a seta pit, or alveolus; such a structure is wanting at the base of the clavate structures.

THE PAUROPUS TYPE OF LEG

The question may be asked: How does the leg-segmentation and musculature of *Pauropus* compare with that of primitive insects? Compared with that of Protura the following differences are noted: The tarsus is three-segmented instead of one-segmented, two trochanters may be regarded as present instead of one, and the subcoxa exists either as a ringlike, functional, movable segment, instead of being represented by two motionless plates, or according to the other interpretation shows no vestige. In *Pauropus,* also, more of the muscles pass through two or more segments. Compared with the legs of Thysanura and Collembola, and of insect larvae a general correspondence is indicated. In one respect the pauropods appear to be more primitive in their leg characters than most insects, *i. e.,* in the great length of the flexor muscles, which pass through two or more segments.

LEG-SEGMENTATION AND MUSCLE ATTACHMENTS IN SYMPHYLA

In Symphyla the generalized legs, *i. e.,* the ambulatory appendages except for the first pair, show five complete and movable segments and in addition an immovable basal sclerite with a hinge for the first complete segment. The muscle attachments for these segments are shown in pl. 4, fig. 10. According to the musculature the long penultimate segment should be regarded as the tibia since it gives rise to the flexor muscles of the claws. The last, claw-bearing segment is the tarsus. The antepenultimate segment, the one proximal to the tibia, is very short and is at or beyond the bend of the leg. It has the size and function of a patella in the Arachnida. Furthermore, this is the segment that is eliminated in the four-segmented front legs of certain genera. Its position as well as its rocking hinge and attached levator muscle fibers indicate that it is the femur. The next proximal segment is the largest of all and suggests a true femur. However, its position in the leg series and its musculature indicate that it is only a much enlarged trochanter. There remains the basal segment, always short and stout and nearly always bearing an unsegmented appendage, the stylus, at the base on its ventral side. This segment should be regarded as the coxa, on account of its position in the leg series, its musculature and its bearing of the so-called stylus. In addition to these complete, or ring segments, there is a chitinous plate of varying shape to which the coxa is attached and on which the coxa moves by means of a rocking hinge. This is the subcoxa. I have failed to find muscles attached to it although powerful depressor muscles arising from the postero-ventral angle of the coxa pass inward to attach somewhere in the body.

The segmentation here described at first seems to be out of harmony with that of any of the other groups of primitive arthropods, but when articulations and muscle attachments were studied, the very unusual size and position of the femur became evident, thus making the homology of the segments clear. Of all the leg segments the femur is the least liable to be greatly reduced in size or to drop out entirely, yet in the legs of symphylids apparently both of these things have happened to it.

In all the symphylids the first pair of legs has undergone a reduction in size. In *Scolopendrella* the front legs are about three-fourths as long as the others and have the typical number of segments, *i. e.*, five. The shortening has been brought about by a big reduction in the length of the second segment which is but slightly longer than the third. In *Scutigerella* and *Hanseniella* the front legs are further reduced, but in these genera are only four-segmented (pl. 5, fig. 11). Here the short third segment has either dropped out or has been incorporated with the fourth which has been much reduced in length. In *Symphylella* only papillalike remnants are left of the front legs which do not show segmentation.

The symphylid leg, characterized by the presence of an appendage on the coxa, a platelike subcoxa and a greatly reduced femur situated at the bend of the leg, is probably nearer to the leg of *Machilis* than to that of any other group. It differs from the leg of *Machilis* particularly in the small size of the femur and the large size of the trochanter.

THE COXAL APPENDAGE IN SYMPHYLA

The coxal appendage in Symphyla arises in nearly all the species from the coxa on its inner side very near the articulation of the latter with the body and the subcoxa. In a few species it arises from the body proper near the origin of the coxa, but in such instances moves with the coxa. It is a small, slender, cylindrical appendage, and is clothed with minute setalike projections (pl. 5, fig. 12). On the tip of the appendage these setalike structures are longer than the width of the appendage, but on the body of the latter are only visible with very high magnification. The writer has not studied stained sections of symphylids, but since these setalike structures lack seta pits he is inclined to consider them as scobinations. It is possible that the longer terminal ones are different from the minute lateral ones, in which case they should be regarded as true setae.

All efforts to locate muscle fibers passing to the coxal appendages have failed, although such fibers do pass from the body wall to the chitinous base ring of the eversible sac.

In the Lepismatidae Escherich (1905) has found muscle fibers passing both to the eversible sacs and the styli of the abdomen. It is probable that the coxal appendages in Symphyla are not true segmental appendages. They may or may not be homologous with the coxal appendages in Pauropoda and Machilidae. Their position on the inside of the coxa indicates a homology with the appendages of Pauropoda rather than with those of Machilidae, which are external.

THE LEGS IN THYSANURA

The Thysanura have long been an interesting group for the student of the phylogeny of insects. Their primitive wingless condition, their possession of vestigial abdominal appendages and several other morphological characters have stamped them as an outstanding generalized group among their class.

An examination of the legs of each of the four families of Thysanura, the Machilidae, Lepismatidae, Japygidae and Campodeidae shows that they all have the same type of segmentation and musculature and the same number of true segments. For this reason the leg of *Machilis,* the first to be here considered, may be taken as a type. Börner (1921) has described the musculature of *Machilis.*

In *Machilis* the first movable segment of the leg (pl. 5, fig. 13) is the largest. It has the general shape of a femur but is placed in a reverse position, *i. e.,* it hangs downward and outward from the body. At about one-third the distance from its proximal to its distal end there is a very strong, transverse apodeme on the outside margin. The apodeme does not extend entirely across as an unbroken ridge, but in it there is a gap. At this gap there is situated a prominent fusiform appendage, the much discussed "coxal appendage." The second segment is small and much curved. It is hinged to the first by a rocking double hinge. It extends upward and outward. The third segment is large and long and is immovably attached to the second. Distally it supports the fourth by means of a double hinge. The fourth is about as long as the third but is smaller. Beyond the fourth segment are three small ones that move together as one. The distal one of these bears the two equal claws. An examination of the attachments of the muscles shows that the fourth segment gives origin to the last muscle of the leg, the flexor of the claws. It should, therefore, be regarded as the tibia. Then the three small ones distal to it should be considered as the tarsus and the large one proximal the femur. Because the small second segment is immovably fused with the femur, gives origin to muscle fibers that flex the tibia, and is moved by a double hinge on the first segment, it must be considered as the trochanter. The basal segment is regarded as the true coxa. Although it is very large its musculature and the attachment of the appendage to it indicate clearly its homology. The coxa itself is hinged to an incomplete segment which has a stout apodeme. This incomplete segment gives rise to levator muscles of the coxa. It should be regarded as a functional subcoxa.

In the Lepismatidae, *Thermobia* is taken as the type. In this genus the leg (pl. 5, fig. 14) is similar to that of *Machilis,* but lacks first of all the appendage to the coxa. The subcoxa here is a complete segment, and frequently shows two pseudosegmental sutures on its antero-dorsal aspect. The coxa lacks not only the appendage of *Machilis* but also the conspicuous transverse apodeme. The trochanter differs from that of *Machilis* in two ways; it frequently gives rise to a very short muscle going to the base of the femur as shown by Escherich (1905) or again it may be entirely without muscles, even without fibers from the flexor of the tibia. Such a trochanter has been drawn by Carpenter (1916). The femur, tibia, and tarsus are essentially the same as in *Machilis*.

The legs in Campodeidae and Japygidae are essentially the same in segmentation and musculature. Those of *Campodea* are taken as the type (pl. 6, fig. 15). The *Campodea* legs are very slender as compared with those of *Machilis* and have the following outstanding differences: The coxa is greatly reduced, very short and is without the transverse apodeme and appendage; the trochanter is a free-moving segment and in it arise the levator and depressor muscles of the femur; the tarsus is only two-segmented (false segments). The other segments have the same relationships as in *Machilis.*

REMARKS ON THE THYSANURAN TYPE OF LEG

A comparison of the thysanuran type of leg with those of other primitive groups indicates its closest affinity with the pauropod type. In fact there appear to be a similarity and homology throughout the segmentation series of both groups. If the first segment of the pauropod leg be regarded as the coxa, however, instead of the subcoxa, the small third segment of the pauropod leg should be regarded as a part of the femur.

THE NATURE OF THE COXAL APPENDAGE IN THE MACHILIDAE

For years after Verhoeff (1903) claimed to have demonstrated a muscle attached to the coxal appendage the belief grew that this appendage should be regarded as a true branch of the limb. By some it was considered as a homologue of the exopodite of crustaceans, and exponents of the crustacean theory of the origin of insects seized upon this bit of evidence in support of their contentions. The writer has examined this structure with care and has noted the following:

1. It arises at a break in the transverse apodeme of the coxa on the outside of this segment (pl. 5, fig. 13).

2. It has no muscles in it and no muscles passing to it and none having any relation with it.

3. Muscle fibers do pass from near the base of the appendage and extend distally. These are probably the ones figured by Verhoeff (1903), but they are clearly a part of the conspicuous levator muscle of the trochanter.

4. The appendage can in no way be considered as a modified seta, since it possesses a lining of hypodermis with many cells from which several complete and typical setae themselves have been developed.

5. The appendage is a development from the outer wall of the coxa of which it is a direct continuation.

THE LEG SEGMENTS OF COLLEMBOLA

In general form and position the collembolan legs have been modified somewhat by the fact that the body is compressed and locomotion is greatly aided by a powerful springing organ, the furcula, near the end of the abdomen. The compression of the body has frequently brought the legs of a pair into a contiguous position at their bases.

The great thrusting power of the furcula has been matched to a certain degree by the superior development of the posterior legs and their backwardly appressed position. This peculiarity of the legs is probably an adaptation to receive the shock of alighting after each spring into the air.

According to the external sutures collembolan legs are six-, or seven-segmented. The seven-segmented legs are particularly evident in the family Entomobryidae and such legs have been figured by Carpenter (1916) and by Folsom (1924). The more common type, here regarded as six-segmented, has been considered as five-segmented. Such a leg according to Guthrie (1903) is composed of a coxa, trochanter, femur, tibia and tarsus. Börner (1921) has figured this type of a leg in *Orchesella.*

The seven-segmented leg will be taken here as a generalized type for the order, and the third leg of *Tomocerus arcticus* will be described. According to external sutures there are five short basal segments all of about the same length. The most proximal is the stoutest, and the most distal the longest. The sixth segment is long and straight, the seventh is of similar length but tapers distally to the base of the two unequal claws which it bears directly on the end of the segment. An examination of the muscles (pl. 6, fig. 16) shows that this seventh segment bears powerful strands going to the base of the claws. It, therefore, should be regarded as the tibia. The sixth segment becomes the femur, and has the femur type of musculature. Segments four and five, each very short and each with a dicondylic hinge at the base and apex, should be regarded as the two trochanters. They both have the articulations and musculature of a primitive type. There remain the proximal three segments. Muscle attachments show that the first external suture produces only a false segmentation, hence one and two together form the basal segment which should be regarded, mostly on account of its position, as the subcoxa. There remains the third ring, or segment. It is very short, has a dicondylic articulation with the first trochanter and an oblique, incomplete apodeme for the attachment of powerful muscle fibers of the depressor of the second coxa. Although this segment is far from being typical of an insect coxa, it should be regarded as such because of its dicondylic articulation and its position in the segmental series.

The peculiarities of such a leg are evident; a falsely divided subcoxa, a reduced and modified coxa and a missing tarsus.

In most collembolan legs, particularly in the six-segmented legs (pl. 6, fig. 17), there is a small but complete ring inserted between the claws and the tibia. This ring varies from a length equal to about a fourth that of the tibia to zero. Distally the two claws are inserted into the membrane and about completely fill up the unchitinized space. There is attached to the unguitractor plate, which possibly is attached to the ventral wall, the tendon of the flexor of the large claw, which muscle may also in some instances lift the smaller claw. By comparing the legs of various species it is observed that as this unguitractor plate disappears the tendon of the flexor of the claws shifts over until it comes to attach to the enlarged base of the large claw. Such a shift indicates, it is believed, an obliteration of a tarso-pretarsal articulation rather than the tibio-tarsal articulation. The tarsus, therefore, has either fused with the big claw or has dropped out entirely. The writer believes that in some instances it has done the one and in others the other.

The subcoxa not only frequently shows an external division into two false segments, but many possess a transverse apodeme (pl. 6, fig. 18, *scx*).

THE COLLEMBOLAN TYPE OF LEG

Although much variation is encountered in the legs of Collembola, some of them being much modified and showing special adaptation and some of them the loss of the tarsus, in general it may be stated that they are of a very primitive type. The possession of a complete and functional subcoxa and two typically articulated and muscled trochanters is certainly a rare, primitive condition for the group Insecta. While being of a primitive type the collembolan leg is of somewhat unusual position and conformity.

THE PRIMITIVE TYPE OF TARSAL CLAWS IN INSECTA

The general belief among many entomologists has been that the foot of a generalized insect possessed typically but a single claw. As evidence for such a belief it has been pointed out that in certain primitive insects, the Protura and certain springtails, there is but a single tarsal claw. Also in most insect larvae and in centipeds such a condition exists. It would appear, however, that much other evidence is somewhat at variance to the one-claw theory. As pointed out by Escherich (1910), the Lepismatidae have a three-clawed tarsus. Many other Thysanurans also have the same type. As for the one-clawed Collembola (pl. 7, fig. 19 B), such a condition is clearly secondary and not primitive. In all the two-clawed Collembola the second claw is much reduced and modified (pl. 7, fig. 19, A), in many species it is vestigial and in some few clearly wanting. A complete series exists among the various species showing the reduction from the normal condition for the group to the smallest vestige and to a one-clawed condition.

The best evidence as to the nature of the primitive type of insect claws is to be found, it is believed, by a comparative study of the claws of primitive insects with those of the primitive arthropods most closely related to them. When this is done we find in all instances, the present writer believes, that either the three-clawed type exists, as found in most Thysanurans, or a two-clawed or one-clawed type the origin of which may be clearly traced from the three-clawed type.

In pauropods the generalized legs all show a tarsus (pl. 7, fig. 20) terminated by a large central claw and two small, lateral and frequently unequal, claws which spring from a basal foot-pad at almost right angles to the central claw. There is a tendency among the generalized legs in *Pauropus* for one of the lateral claws to become vestigial, and this tendency reaches a climax in the last pair of legs of *Pauropus* (pl. 7, fig. 20, C) where one claw is entirely lost.

In Symphyla the different genera show a marked similarity in regard to the tarsal claws. The prevailing type is a tarsus with two unequal claws (pl. 7, fig. 20, D), a type comparable with that of the posterior legs of *Pauropus*. However, the tarsi of the first pair of legs in some symphylids as well as those of some of the other legs show three claws, one of the lateral ones being reduced and modified so as to be somewhat setiform.

In the Protura only a single claw has been described, but Berlese (1910) pointed out that there exist rudiments of a second claw on the first tarsus of *Acerentomon doderoi*. It is observed, further, that in one of our American proturans, *Acerentulus barberi*, two functional claws are present on tarsus I (pl. 7, fig. 23). In this species the large claw is posterior in position, the small one is middle, and a claw rudiment is anterior. This small claw is somewhat setiform, but its position and articulation indicate its homology. In those tarsi that have only the single claw, this claw usually occupies a posterior position indicating its homology with the large claw of the first tarsus. The dominance of the posterior of the three primitive claws in the Protura appears to be quite a different condition from that which is found in the Collembola.

The two-clawed tarsi of *Campodea* and certain other thysanurans are explained by Snodgrass (1927) as being a derivation from the three-clawed Lepismid type. Here it appears evident that the middle claw has disappeared. In some members of *Campodea* the middle claw has become transformed into a featherlike empodium. In *Japyx* it is reduced almost to a vestige (pl. 7, fig. 22), while in some *Campodea* no vestige remains (pl. 7, fig. 22).

A peculiarity in the two-clawed Collembola is that the smaller element, which may or may not be a true claw, occupies a ventral and a reversed position to the large claw. This smaller element is referred to as the unguiculus by Folsom (1916), as the inferior claw by Guthrie (1903) and as the empodial appendage by Carpenter (1916). De Meijere (1901) has discussed its homology and calls attention to the fact that it is not entirely ventral median in position. Hansen (1893) considers the smaller claw a true claw and a primitive condition from which type the two-clawed pretarsus of higher insects was developed by a shifting in position and enlargement of this element. By comparison with the claws of Symphyla and Pauropoda one would be inclined to consider the inferior pretarsal element in Collembola as one of the persisting lateral claws of the three-clawed type of tarsus. In Symphyla the smaller lateral claw stands at about right angles to the large claw. But in Collembola the inferior appendage is usually reversed and in some instances is detached from the chitinous base of the large claw which alone usually bears the tendon of the flexor muscles. Furthermore there exists a type of pretarsus in *Tomocerus* (pl. 7, fig. 23) in which the large dorsal claw is accompanied by two lateral claws springing from its base, in addition to the ventral appendage. These facts would indicate that the so-called unguiculus, or empodial appendage, is not the true claw but a secondary development, possibly only a modified seta.

In the Crustacea, as stated by De Meijere, several genera of isopods show the presence of a large and a small tarsal claw, as is commonly found in Symphyla and Collembola. A drawing is here given of a sow-bug tarsus showing the second claw (pl. 7, fig. 24). That the two-clawed condition in the Crustacea should develop among land forms is significant in considering the evolution of terrestial arthropods. Probably it is correlated with the habit of crawling about objects in a nearly vertical or even in an inverted position. The almost universal presence of two tarsal claws among insects speaks much in favor of this arrangement for an efficient clinging organ.

POSTCEPHALIC BODY-SEGMENTATION IN ARTHROPODA

Theoretically arthropods, as we know them today, have been considered as descendants from a type in which the whole body consisted of a series of similar segments arranged end to end along the body axis and each bearing a pair of similar segmental appendages. Evolutionary forces have not only tended to bring about diversity among these different segments and their appendages but have caused certain segments either to fuse or to act together more or less as a unit in performing certain classes of functions. Thus in certain arthropods a group of the most anterior segments became fused to form the head, in which most of the special senses were lodged, others posterior to the head in certain arthropods became grouped or fused together to form the thorax which became chiefly devoted to locomotion, and lastly the remaining segments became an abdomen, a unit having to do largely with digestion and reproduction.

In the insects alone do we find these three body regions completely developed and students of the evolution of this class are particularly interested in finding out how many and what segments of the primitive arthropod enter into the formation of the insect head, thorax and abdomen.

That the head was the first of these three body regions to become differentiated appears evident, for in a number of classes of land arthropods it is completely formed while the remainder of the body is composed of many segments, the most of which are very similar and have each a pair of similar appendages.

In discussing the origin of the thorax we are particularly interested in the origin of certain structures found in the insect neck region. If the so-called cervical sclerites are true sclerites, could they have been derived from the basal segments of an arthropod appendage, and if so does the neck itself represent the rudiments of a postcephalic segment?

THE FIRST BODY SEGMENT OF SYMPHYLA

In the Symphyla it is observed that the first pair of legs are always reduced. In some instances this is due only to the shortening of certain segments, particularly the femur. In *Hanseniella,* however, one segment, the femur, has dropped out entirely. In other symphylids the leg becomes quite rudimentary.

THE FIRST BODY SEGMENT IN PAUROPODA

The evidence of a much reduced first body segment with vestigial legs is very convincing in the case of pauropods. Not only is there a complete suture setting off a neck region but on the sternum there is a pair of very short disclike structures that should be regarded as leg rudiments. Kenyon (1895) pointed out that these structures each bear a pair of clavate organs (pl. 8, fig. 25) similar in shape and position to those on the basal segment of the legs. Kenyon refers to these structures as "papilliform processes," but the present writer regards them as exceedingly short, cylindrical segments, so short in fact that they are like discs.

EVIDENCE OF A CERVICAL SEGMENT AMONG INSECTS

But we do not have to turn to Symphyla or to Pauropoda to find structures that indicate the existence of a cervical segment. In *Japyx*, as is indicated by Snodgrass' drawing (Snodgrass, 1927, p. 16), there is a repetition of the **Y**-shaped thoracic sternal apodeme on the ventral aspect of the neck. Enderlein (1907) has figured this structure for *Japyx japonicus,* but he regarded it as being comparable to the segmental folds of the meso-, and metathorax and called the same a prothoracic apotom. The writer has made a special examination of it and here gives a detailed drawing of the same (pl. 9, fig. 26). The *Japyx* species studied is the large eastern *Japyx bidentatus.* This **Y**-shaped sternal apodeme is indeed very similar to the one found on each of the three thoracic sterna. From the fork of the **Y**, a median process passes backward, as in the case with the others, to the base of the following sclerite. The branches of the **Y**, however, do not end in a headlike condyle as in the case of the thoracic apodemes but become fused with the lateral angles of the included sternite, and the sternite and the apodemes together form a more or less hingelike fulcrum for the head.

In *Japyx isabellae* (pl. 12, fig. 38) no cervical **Y**-shaped apodemes are noted, but the cervical region is well developed. In this species the same sternite that is included between the forks of the **Y** in *bidentatus* is enlarged and strengthened. This sternite bears an articulating surface with a condyle from the head at the median line. Thus a similar function is performed in the absence of any apodemes.

THE SEGMENTS INCLUDED IN THE INSECT THORAX

It might appear, therefore, that the insect thorax is composed of the second, third, and fourth body segments behind the head, and, if so, further evidence would be found in some of the primitive insects. The most primitive group of arthropods to show the thorax developed is the Protura. In the Protura we have true hexapods, although in this group a number of myriapod characters are retained.

Unfortunately in proturans the first pair of legs have been developed as feelers, and the prothorax accordingly modified and reduced. The first legs of proturans have more of a lateral than ventral position and are held over the body, not under it. Consequently the muscles and the sclerites have become so shifted that their homologies cannot with definiteness be worked out.

It may be also that the first postcephalic segment of Symphyla and Pauropoda becomes incorporated with the head in Insecta; possibly becoming or in fact being the labial segment. If so the head of Pauropoda and Symphyla should have one less segment than an insect head, which appears contrary to known facts.

ABDOMINAL SEGMENTATION

In this paper, abdominal segmentation will only be touched upon. Of special significance among primitive land arthropods is the occurrence of double segments which characterize particularly the Diplopoda. The opinion has been frequently expressed that such a condition is brought about by the pairing or coupling of two contiguous segments.

THE DOUBLING OF BODY SEGMENTS

In pauropods there is some variation in regard to the individual dorsal and ventral segmentation. The genus *Eurypauropus* shows what Kenyon (1895) regarded as an indubitable diplopod condition, but the same authority held that in *Pauropus* (pl. 8, fig. 25) about half of the legs came in between the dorsal plates. Kenyon even described and figured intersegmental pleural areas bounded by conspicuous folds over the so-regarded intersegmental legs. Although the diplopod condition is not so evident in *Pauropus* and does not hold for the first two body segments, the present writer has failed to substantiate Kenyon's contention that pronounced intersegmental pleural regions exist. It does appear, however, that some of the legs arise almost directly below the dorsal segmental sutures.

In Symphyla the diplopod condition does not exist, although there is evidence, as in *Symphylella,* that small legless segments have united with legbearing segments. According to Muir and Kershaw (1909) the young of *Scutigerella* have seven pairs of legs, twelve tergites and nine sternites when newly hatched. When adult they have twelve pairs of legs, sixteen tergites and fourteen sternites. It is important to note that *Scutigerella* has the same number of body segments when hatched that proturans have, but, according to Muir and Kershaw, must add one more than proturans do during postembryonic development.

EMBRYONIC REDUCTION OF ABDOMINAL SEGMENTS

Of much interest and of somewhat uncertain significance is the embryonic reduction of abdominal segments. It has appeared to be a general law that in insects the maximum number of abdominal segments is to be found at the time of hatching from the egg; and that postembryonic changes, if there are any, are toward the reduction in the number possessed at hatching.

The Protura, of all the hexapods, show both a reduced number of abdominal segments (nine) at hatching and add segments during postembryonic development. It was largely for this reason that Berlese (1910) regarded them as occupying a position between the true insects and the myriapods and gave to them the name Myrientomata.

The Collembola show a reduced number of abdominal segments at hatching (six) but do not add segments during their postembryonic development.

It may be that in both of these groups, the Protura and the Collembola, the reduction during the embryonic development of the number of abdominal segments is an inherited condition from myriapodlike ancestors and, if so, should indicate a closer affinity between these groups than has been suspected. In this connection, however, it should be noted that some or all of the abdominal segments of Collembola may in certain genera remain fused throughout life. This suggests the possibility of an adaptive reduction during the embryonic life, possibly during a deutovum stage. Such stages, or instars, inside of the eggshell are very generally met with in arthropods and are typical of arachnids. A reduction of abdominal segments during a deutovum or a tritovum stage or during both of these stages should not be regarded as in any way indicating a primitive condition for insects. The deutovum and tritovum instars are comparable to the protonymphs and deutonymphs of arthropods undergoing a normal development.

THE TERGAL PLATES OF THE LEG-BEARING SEGMENTS

Examinations of insect larvae and apterygotan insects have revealed the presence of a very simple dorsal plate, or tergum, for most of the body segments. The simplest type consists of an undivided plate, without ridges, sutures or apodemes, which does not fully occupy the dorsal surface of the segment. Snodgrass has very fully described the types of terga found in winged insects (Snodgrass, 1925). More recently he has described a type among wingless insects (Snodgrass, 1927) which is considered as showing certain features found in the thoracic terga of most winged insects.

In *Pauropus* the tergites (pl. 9, fig. 27) are simple, oval-shaped plates, seven in number, which fit the lateral curvature of the body and extend down less than half way on the sides of the same. There is no tergum over the first body segment. The first tergal plate covers dorsally the second body segment. The next four tergal plates are allotted to body segments 3-10, all of which bear legs. The last two tergal plates cover roughly the remainder of the body. In *Pauropus* the tergites do not cover entirely the dorsal surface. There is present between adjacent tergites a considerable area that is membranous (pl. 9, fig. 27).

In Symphyla the terga are very similar to those of *Pauropus,* being simple plates that do not completely cover the dorsal surface. These plates may be variously shaped. In the genus *Symphylella* the tergum of the first body segment is reduced and divided both transversely and longitudinally, making four smaller plates (pl. 9, fig. 28). Terga vary in size in Symphyla according to the size of the segment each covers.

In the Protura the terga no longer have the simple structure found in Pauropoda and Symphyla. Typically each of the thoracic, as well as the abdominal, terga possesses a strong transverse apodeme near the anterior margin. This apodeme (pl. 10, fig. 29) may be simple or may be singly or doubly branched laterally. The writer (Ewing, 1921) has utilized this variation as a generic character. Just posterior to this apodeme is a transverse groove. Prell (1913) has represented both this transverse suture and the apodeme, but he also shows two poorly chitinized regions posterior to the terga proper. The writer has not located such regions in our American proturans. Snodgrass (1927) considers the apodeme as representing the antecostal suture and the small area in front of it as being the precosta, and both structures as being typical of an insect tergite.

The tergal region of the prothorax is much modified, suggesting a condition found in the tergal region of the first body segment of Symphyla. The tergum proper (pl. 10, fig. 29) is reduced and poorly chitinized in front, while laterally there is a prominent fold over the coxa. This fold corresponds to the intersegmental lobe of the neck as regarded by Berlese (1910).

In *Eosentomon* a median apodeme is present on the thoracic tergites. This median ridge is found in many pterygote insects.

The thoracic terga of *Japyx* are taken as a sample representing the Thysanura for two reasons. They have been much discussed previously, and they show considerable variation. In *Japyx isabellae* (pl. 10, fig. 30) the thoracic terga are oval plates that almost join each other at the intersegmental sutures. The tergum of the prothorax is without apodemes or sutures, but each of the other two possesses three longitudinal internal ridges (pl. 10, fig. 30). One of these is straight and median; the other two are lateral and outwardly curved. In *Japyx bidentatus* the median ridge is wanting, but a transverse groove divides the tergum proper from an anterior region termed the precosta by Snodgrass (1927). This area is very large in *Japyx bidentatus,* being about one-fourth as long as that of the remaining part of the tergum.

In the Collembola the thoracic terga extend far down on the sides of the body, reaching in some instances the bases of the legs (pl. 10, fig. 31). The tergum of the prothorax is always reduced and may be almost obliterated in certain genera. In *Isotoma* only two minute, transverse strips of chitin remain as vestiges of the first thoracic tergum. In general the collembolan thoracic terga may be said to be of the simplest type, being without apodemes or sutures.

CONCLUSIONS REGARDING THE TERGA OF LEG-BEARING SEGMENTS OF PRIMITIVE ARTHROPODS

The prevailing type of terga found on the leg-bearing segments of Pauropoda, Symphyla, Protura and Apterygota is the simplest type known—a tergum without apodemes, sutures or specialized areas of any kind. This is the type found in the larvae of many insects. The presence of an anterior, transverse apodeme dividing the tergum into a very small anterior area and a very large posterior one is noted in the Protura and the Thysanura. This area, which has been termed the precosta, and the apodeme which has been termed the antecostal suture, appear to be structures fundamental to the terga of winged insects.

THE STERNAL PLATES OF THE LEG-BEARING SEGMENTS

STERNA IN ARACHNIDA

In the more generalized arachnids like the Solpugida, Cyphophthalmi, and Pedipalpida, sternites are frequently wanting from some or all the cephalothoracic segments. In such cases the basal segment of the leg, the subcoxa, usually is flattened and more-or-less platelike. These subcoxae are liable to be fixed and fused each with its fellow of the opposite side along the median plane. Such a condition is found in the Cyphophthalmi (pl. 11, fig. 32). In the Pedipalpida, as illustrated by *Mastigoproctus giganteus,* the giant whipscorpion of the South, the first and last cephalothoracic segments are each provided with a triangular sternite, situated between the subcoxae of these segments. The second and third cephalothoracic segments are without a sternite, the subcoxae of each practically touching on the median line. This condition of the second and third segments is rather remarkable in this group, as the subcoxae of these segments, like those of the first and last, are movable and undergo a rolling motion while the arachnid is walking.

In tarantulas (Araneida) the movable basal segments of the legs (coxae?) come close together on the median line. The first three pairs are separated by a sternal ridge, but the coxae of the last pair are contiguous. Muscle attachments in the cephalothorax of spiders are largely from an elaborate endosternite, the origin of which in the Solpugida has been worked out by Bernard (1896), who finds that it results from the fusion of infolding apodemes, particularly between the third and fourth segments.

In the Solpugida the subcoxae meet on the median line, but are not movable. They retain the shape and the function of a basal leg segment. Bernard (1896), as already quoted, believed that the so-called abdominal sternites of solpugids represent the rudiments of a flattened leg. Holding such a view it is interesting to note that in the same paper he describes and figures a hypothetical primitive arachnid as having typically a sternal plate between each pair of coxae. If abdominal sternites in the Solpugida are derived from the appendages why not the thoracic sternites, not possibly in this group but in many other arthropods?

STERNA IN PAUROPODA

In *Pauropus* there are no sternites to the leg-bearing segments except for the segment bearing the last pair. This segment has an anterior and posterior plate (pl. 11, fig. 33). From each subcoxa there extends upward along the pleuron a long rod-like apodeme (pl. 11, fig. 33). During leg movements the subcoxa rocks, or rolls, along the axis of this apodeme. On the first body segment there is a pair of ventral discs, believed to represent vestigial legs (see page 25), and the last visible body segment is covered below with a very large sternal plate.

STERNA IN SYMPHYLA

There is a marked contrast between the Symphyla and the Pauropoda in regard to the sternal region. In the genera *Scutigerella, Symphylella,* and *Hanseniella,* not only is there always a pair of sternal plates just in front of the coxal bases, but a curved, rodlike apodeme extends outward and forward from the median line to articulate with the front margin of the coxa. In addition to these structures in *Scutigerella* (pl. 11, fig. 34) there is an unpaired anterior sclerite and a pair of smaller lateral ones. In *Scutigerella* and *Hanseniella* (pl. 11, fig. 35) the eversible sac is surrounded at its base with a chitinous ring. This ring is broken in *Symphylella* producing two crescentic pieces (pl. 12, fig. 36).

THORACIC STERNA IN PROTURA

Berlese (1910) was the first to describe the sternites in the Protura. He found that each thoracic sternal region was covered by two large sternal plates. The anterior one he called the sternum and the posterior one the sternellum. On the lateral margin of the sternellum near its anterior corner is an articulating condyle for the coxa. The present writer has worked out the sternal region for *Acerentulus barberi* (pl. 12, fig. 37). He has little to add to that found by Berlese, but suggests the term basisternum for the more anterior of the two sternites.

In *Eosentomon* the second and third sternella have developed a median apodeme which shows an anterior forking. This is doubtless a structure found better developed in many insects, being particularly conspicuous in *Japyx*. In *Eosentomon ribagai,* Berlese (1910) represents the third sternellum with the forks of the **Y** passing laterally to the articulating condyles for the coxae. In *Eosentomon vermiforme,* an American species, the forks of the **Y** are found only on the third sternellum. These pass outward to the articulation condyles for the coxae but do not quite meet inwardly on the median line.

THORACIC STERNA IN THYSANURA AND COLLEMBOLA

In the Collembola the legs are brought so close together that the sternal characters cannot be made out satisfactorily.

The sternal plates of Thysanura differ radically from those of Protura in their musculature. In this order the ventral longitudinal muscles extend between the posterior parts of the thoracic sterna as they do in pterygote insects. This condition is radically different from that found in the abdominal sterna and the terga of probably all insects where the longitudinal muscles attach to the anterior ridges. Carpenter (1916) has figured the sternites of *Lepidocampa.* In the case of the meso-, and the metasternum, each is provided with a single plate, which has a posterior chitinized ridge and an incomplete median apodeme.

In *Japyx* (pl. 12, fig. 38) the meso- and metathoracic sternal regions each is covered by a large plate which is heavily reinforced by a **Y**-shaped apodeme. The base of this **Y** rests against the anterior margin of the following sternal plate, and the forks pass outward to articulate with the condyle of the coxa. In *Japyx isabellae,* however, they do not stop here but extend forward to the lateral margins of the plates. The prothoracic sternal region of *Japyx* is provided with two sternal plates, and in front of these there is a neck region that has already been discussed (page 26).

In *Japyx solifugus* according to Börner (1903) and in *Japyx japonicus* according to Enderlein (1907) and in certain other *Japyx* species there are found posterior to the large sternal plates of the pro-, and mesothorax two or three broad folds which in *Japyx solifugus* are provided with ventral plates. These conspicuous folds indicate what has been termed the intersegmental region. Verhoeff believed that they represented true body segments and called the mesothoracic folds the stenothorax and the metathoracic ones the cryptothorax. Enderlein (1907) holds that they represent only a semidetached part of the true meso-, and metathoracic segments and calls them the "mesothoracical-apotom" and "metathoracical-apotom" respectively. Crampton (1926) refers to them as "intersternites," and Snodgrass (1927) states that they belong to the sternum following as "is shown by the fact that the anterior margin of the first one of each thoracic set, as seen in side view, coincides with the line of antecostal suture of the tergum of the same segment."

The thoracic stigmata are situated ventrally in *Japyx,* although this point appears to have been overlooked by most workers. Börner (1903) represents the anterior pair as being situated in the membrane near the posterior corners of the prothoracic sternite, while the second pair is represented as being in the membrane, laterally between the "intersegmental folds" behind the mesosternite. In *Japyx isabellae* (pl. 12, fig. 38) the anterior thoracic stigmata are situated in the chitinous shoulderlike areas in front of the mesosternum, while the second pair of thoracic stigmata are situated in a pair of diamond-shaped platelets at the corners between the meso-, and metasterna.

The trochantin (subcoxa) appears to be wanting in *Japyx,* but constitutes a condyle-bearing plate in *Machilis* (pl. 5, fig. 13) and an unarticulated crescentic plate in *Campodea* (pl. 6, fig. 15). In *Thermobia* there is a true subcoxa, a segmentlike structure (pl. 5, fig. 14), present instead of the trochantin. It has been previously discussed (page 19).

PLEURITES IN LEG-BEARING SEGMENTS

The method of origin of the pleurites of insects has been an interesting subject for speculation to students of the phylogeny of arthropods. The theory put forth that they represent the residual chitinous elements of a subcoxal segment of the leg present in ancestors of insects has been recently supported and reviewed by Snodgrass (1927).

Although most attention has been focused in the past on the pleural region in the study of more primitive types of crustaceans and in the study of millipeds, it would appear that the evidence found either for or against this theory in pauropods and symphylids would be even of more importance since these arthropods are more nearly related to insects.

In *Pauropus* (pl. 8, fig. 25) it is observed that the pleural region is entirely membranous, there being no pleural plates of any kind. The tergal plates in this genus are curved down laterally but a short distance, leaving a large unchitinized area. The need of plates in this region is met in a way by long dorsal apodemes, one of which passes upward in the body wall from each basal leg segment.

In Symphyla similar conditions are found but in this class the coxae are supported and hinged to a subcoxal plate. In *Symphylella* (pl. 12, fig. 36) the pleural regions are bare and membranous as in *Pauropus*. In *Hanseniella* (pl. 11, fig. 35) the subcoxal plate is not differentiated laterally, so that the pleural region becomes well chitinized ventrally and anteriorly but passes gradually to a membranous state at the posterior margin of the body segment. In *Scutigerella* (pl. 11, fig. 34) a definite pleural plate is developed. Dorsal to this plate the body wall is membranous, ventrally it is chitinized. There is little evidence to show how this plate originated or what it represents.

The pleural region of proturans has been investigated by a number of entomologists. The so-called subcoxal plates have already been discussed (page 34). In addition to these plates others have been described (Prell, 1913; Crampton, 1926). The writer must confess that he has never found such additional plates. Slides cleared in potassium hydroxide and mounted either in balsam or glycerine show only the two crescentic sclerites represented in plate 12, figures 37 and 39. The same is true of specimens mounted in glycerine jelly, of specimens mounted in the glycerine + chloral hydrate + gum arabic + water mixture. This latter mixture is one of the very best of media for observing such structures. It has been extensively used by Berlese for various minute arthropods, and by Walch for mite larvae to excellent advantage, also by several other workers. Specimens stained with acid fuchsin after proper caustic and other treatment show the same conditions.

The pleural regions of the thorax in Protura are not bare and membranous as in *Pauropus* and certain symphylids, but are almost completely covered by the downward continuation of the tergal plates (pl. 12, fig. 37). These may actually reach to the sternites.

In the Collembola (pl. 10, fig. 31) the pleural regions of the thorax are very similar to those of Protura. Pleural plates appear to be absent. Crampton (1926) has figured several thoracic pleural plates for collembolans. The writer has not verified his results, but in *Isotoma* finds only the subcoxal plates. The pleural region of the prothorax in *Isotoma* is membranous, but that of the mesothorax and metathorax is covered by the downward continuations of the large tergal plates, which actually reach to the subcoxae of the legs.

THE ORIGIN OF INSECT PLEURITES

Snodgrass (1927) has presented an excellent exposition of the possible method of the origin of the thoracic pleurites from the subcoxae of the legs. Those desiring a summary of this theory are referred to his paper. The evidence presented in the writer's investigations in general strongly supports the theory of subcoxal origin. However, the writer is inclined to hold the view that the first process toward the production of the eupleural sclerite and the trochantin—fundamental elements found in many generalized insects—was the formation of a pseudojoint in the primitive subcoxa. A divided, functional and almost complete subcoxal segment is found today in certain collembolans (pl. 10, fig. 31) and in certain thysanurans (pl. 5, fig. 14). As such subcoxal segments became reduced, they probably lost their cylindrical shape by their inner parts being obliterated, which would leave them crescentic; and at the same time the chitinous part of their outer walls became reduced forming crescentic plates. Such plates exist today in *Japyx* and certain other thysanurans; are found fused in certain springtails (pl. 10, fig. 31) and are particularly characteristic of the Protura (pl. 12, fig. 39).

Some would evolve the trochantin from a primitive sclerite which had both a dorsal and a ventral condylic articulation with the coxa. In fact Prell (1913) holds that the Protura have such a primitive trochantin. In this contention, however, there may be an error. According to the writer's observations the ventral articulation of the coxa in the Protura is entirely with the sternum. It is probable that the ventral trochantinal articulation found in many insects is a secondary development.

GENERAL CONCLUSIONS

Some of the more important conclusions resulting from this investigation may be enumerated as follows:

1. The generalized type of an arachnid leg appears to possess one more segment than the maximum number of eight allowed by Hansen for the Crustacea, but this point needs further investigation. An arachnid leg so constituted should have the following segments, named from the base to tip: Subcoxa, coxa, coxal trochanter, femoral trochanter, femur, patella, tibia, tarsus, and pretarsus.

2. The generalized pauropod leg is composed of eight rings, which represent, however, only six or possibly seven true segments, the first three of which probably represent the coxa, first trochanter, and second trochanter. The last four true segments of the pauropod leg are the femur, tibia, tarsus, and pretarsus.

3. The generalized symphylid leg is composed of seven true segments, the first being represented by a condyle-bearing plate. They are: Subcoxa, coxa, a greatly enlarged trochanter, a much reduced femur, a tibia, tarsus, and pretarsus.

4. The generalized thysanuran leg is completely homologous with the pauropod type, with the exception that it possesses a subcoxa, usually in the form of a platelike structure.

5. The typical collembolan leg possesses a subcoxal segment and either lacks the tarsus entirely or has it represented by a short rudiment at the base of the claws.

6. The so-called coxal appendages in the Pauropoda, Symphyla, and the Thysanura are not true appendages and have no muscle fibers attaching to them. They are probably not homologous among themselves. Some may represent structures analogous, or possibly even homologous, with either the epipods or the exopods of Crustacea.

7. The primitive insectan type of tarsus was three-clawed. Two-clawed or one-clawed types found in the Thysanura or the Collembola are clearly not primitive but evidently were derived from the three-clawed type as found today in the Pauropoda, Symphyla, and certain Thysanura.

8. Much evidence exists indicating the presence of an additional segment to the insect thorax, which should probably be called the cervical. It should be considered as being homologous with the legless postcephalic segment of pauropods and certain symphylids.

9. The so-called intersegmental region of certain thysanurans should not be regarded either as a distinct segment or as an intersegmental structure but each region as an integral part of the segment bearing the adjoining posterior sternite.

10. The primitive thoracic tergal plates are simple structures without condyles or apodemes and did not completely cover the dorsal surface of the segments on which they were situated.

11. The primitive thoracic sterna of an insect were probably transversely divided into two sternal plates, the posterior of which articulated laterally with the inner condyles of the coxae.

12. In general, all vestiges of pleural plates are wanting in those arthropods which have a cylindrical and functional subcoxa. As the subcoxa becomes reduced and its inner (ventral) walls obliterated, two outer crescentic plates persist as body sclerites. They appear to have resulted from the development of a pseudosegmentation of the subcoxa. The distal one of these two sclerites becomes the trochantin of generalized insects and the proximal one the eupleuron, or " mother " pleural plate from which certain others were later derived by " fragmentation."

13. The subcoxal theory of the origin of the pleural plates of insects is sound, and receives further support because of this investigation.

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ABBREVIATIONS USED ON PLATES

ac, anterior tarsal claw
ant, antenna
ap, coxal, or trochantal appendage
bs, basisternum
cl, claw
cx, coxa
dc, depressor of coxa
dt, depressor of trochanter
evs, eversible sac
extc, extensor of claws
extf, extensor of femur
extt, extensor of tibia
extp, extensor of patella
fe, femur
flc, flexor of claw
flf, flexor of femur
flp, flexor of patella
flt, flexor of tarsus
fltb, flexor of tibia
h, head
intl, intersegmental lobe of neck
l, leg
lI, leg I
lap, lateral apodeme
lc, levator of coxa
ls, laterosternum
lt, levator of trochanter
map, median apodeme
pat, patella
pc, posterior tarsal claw
plp, pleural plate
prec, precosta
pt, pretarsus
rc, rotator of coxa
rt, rotator of trochanter
s, sternum
sI, first body segment
scx, subcoxa
sl, sternellum
sp, spiracle
sps, specialized seta
stn, sternite
ta, tarsus
terg, tergite
thI, prothorax
ti, tibia
tr, trochanter
trI, first trochanter
trII, second trochanter
un, unguiculus
utr, unguitractor plate
x, Y-shaped sternal ridge
y, sternal rod

EXPLANATION OF PLATES

(All drawings are by the writer)

PLATE 1

FIG. 1. The third left leg of a solpugid, showing muscle attachments.

FIG. 2. Leg I of the primitive phalangid, *Holosiro acaroides,* with segments labeled.

PLATE 2

FIG. 3. Front leg of *Labidostomma* sp. showing muscle attachments.

FIG. 4. Third leg of the gamasid mite, *Macrocheles tridentifer,* showing muscle attachments.

PLATE 3

FIG. 5. Front leg of tick, *Rhipicephalus sanguineus,* showing muscle attachments.

FIG. 6. A, hind leg of pseudoscorpion, *Chelifer cancroides,* showing muscle attachments; B, end of hind leg of pseudoscorpion, *Obisium maritimum,* showing same.

PLATE 4

FIG. 7. The second leg of *Acerentulus barberi* showing segmentation and musculature.

FIG. 8. Leg IV of *Pauropus* sp. showing segmentation and musculature.

FIG. 9. Coxal appendage of last pair of legs of *Pauropus* sp.

FIG. 10. Antepenultimate leg of symphylid, *Scutigerella immaculata,* showing segmentation and muscles.

PLATE 5

FIG. 11. Front leg of a symphylid of the genus *Hanseniella* showing segmentation and musculature.

FIG. 12. The region about the coxa in a symphylid of the genus *Hanseniella,* showing muscle attachments.

FIG. 13. Third leg of *Machilis* sp. showing segmentation and muscles.

FIG. 14. Middle leg of lepismid, *Thermobia* sp., showing segmentation.

PLATE 6

FIG. 15. Second leg of *Campodea* sp., showing segmentation and muscles.

FIG. 16. Third leg of the collembolan, *Tomocerus arcticus,* showing musculature.

FIG. 17. The musculature of third leg of the collembolan, *Aphorura ambulans* (Linn.).

FIG. 18. Prothorax, with attached leg, and neck region of collembolan (*Isotoma* sp.). Specimen cleared with KOH and stained with acid fuchsin.

Plate 7

Fig. 19. The two types of tarsi found in the generalized Collembola of the family Poduridae: A, *Achorutes;* B, *Podura.*

Fig. 20. The evolution of the two-clawed tarsus in *Pauropus* and its comparison with the two-clawed tarsus in *Symphylella.* A, B & C; tarsi I, III and last tarsus of *Pauropus;* D, tarsus of *Symphylella.* (All views from above.)

Fig. 21. Vertical "optical section" of tip of tarsus I of proturan, *Acerentulus barberi.*

Fig. 22. The evolution of the two-clawed type of tarsus in Thysanura and the one-clawed type in Protura.

Fig. 23. Dorsal view of feet of collembolan, *Tomocerus arcticus,* showing variation in claws; I, II, III = tarsi I, II and III respectively.

Fig. 24. Two-clawed tarsus of isopod crustacean of family Oniscidae.

Plate 8

Fig. 25. Lateral view of *Pauropus huxleyi* showing body segmentation, chitinized parts and specialized setae.

Plate 9

Fig. 26. Prothorax and neck region of *Japyx bidentatus.*

Fig. 27. Dorsal view of first six segments of body of *Pauropus* sp. showing chitinous plates.

Fig. 28. Dorsal view of first five segments of body of *Symphylella* sp., showing chitinous parts.

Plate 10

Fig. 29. Dorsal view of thorax of *Acerentulus barberi* showing chitinous parts.

Fig. 30. Dorsal view of thorax of *Japyx isabellae* showing sclerites.

Fig. 31. Lateral view of thorax of a springtail, *Isotoma* sp., together with proximal parts of legs.

Plate 11

Fig. 32. Ventral view of cephalothorax of *Holosiro acaroides.*

Fig. 33. Ventral view of last leg of left side of *Pauropus* sp. and the sclerites of body segment it is attached to.

Fig. 34. Ventral view of left half of body segment of *Scutigerella* sp. showing chitinizations.

Fig. 35. Ventral view of left half of body segment of *Hanseniella* sp. showing chitinizations.

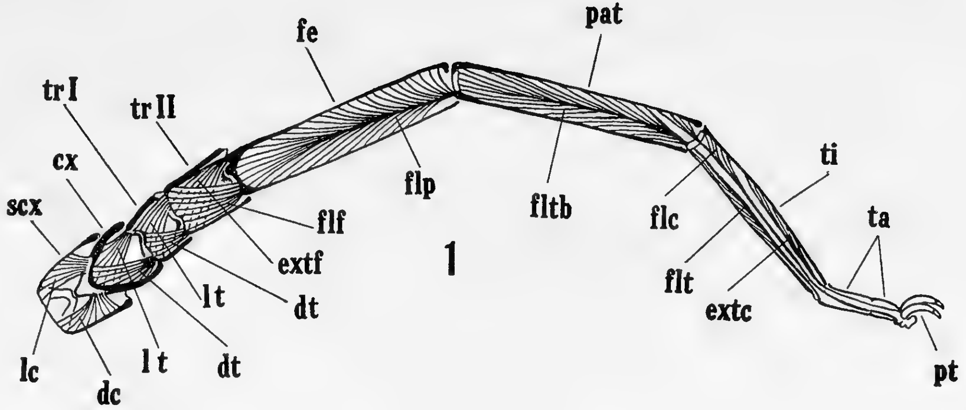
Plate 12

Fig. 36. Ventral view of left half of body segments of *Symphylella* sp. showing chitinizations.

Fig. 37. Ventral view of thorax of proturan, *Acerentulus barberi.*

Fig. 38. Ventral view of thorax of *Japyx isabellae,* showing sclerites.

Fig. 39. Lateral view of left side of mesothorax of *Acerentulus barberi.*



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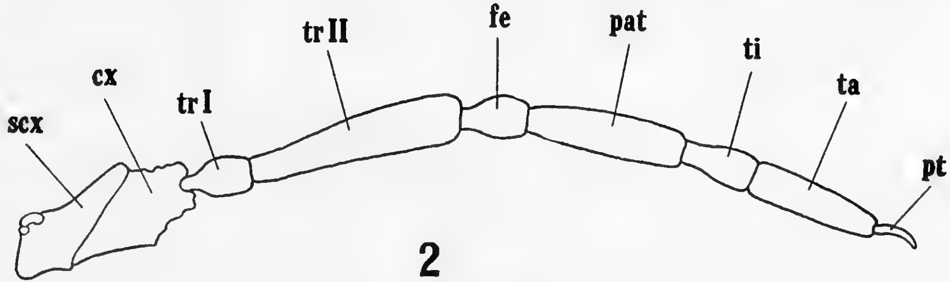

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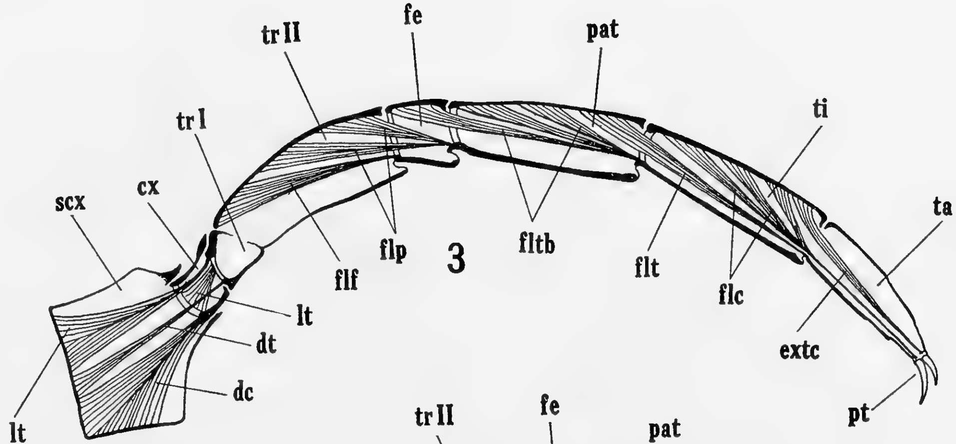

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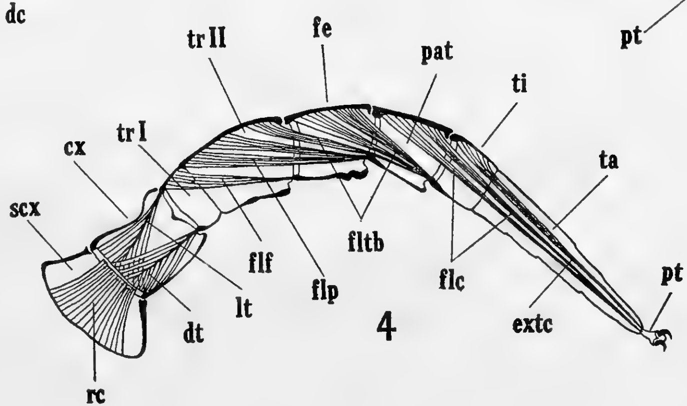

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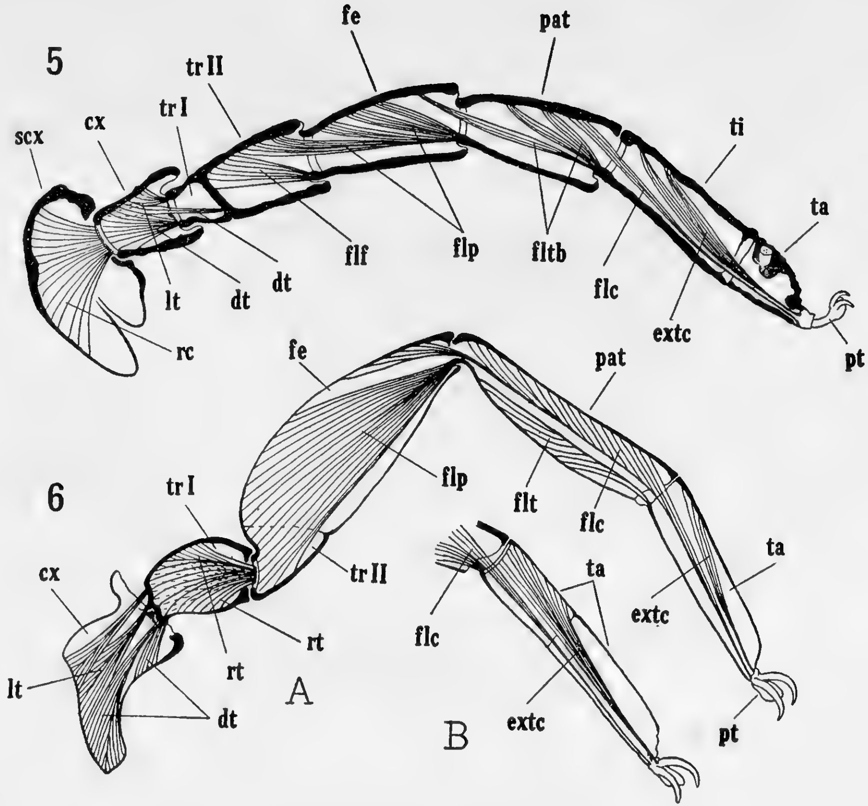

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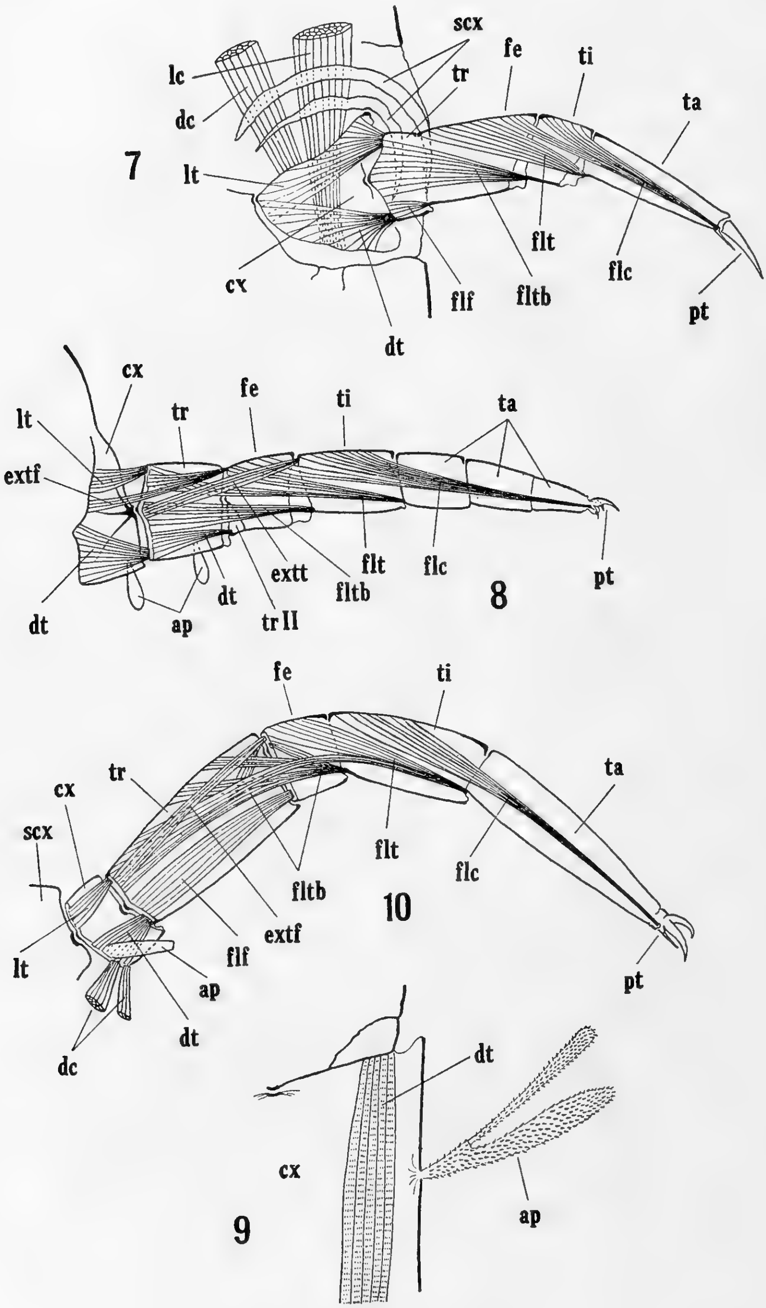

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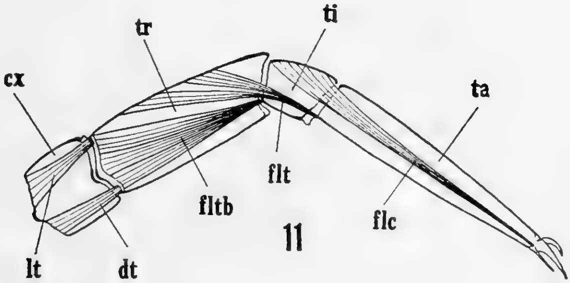

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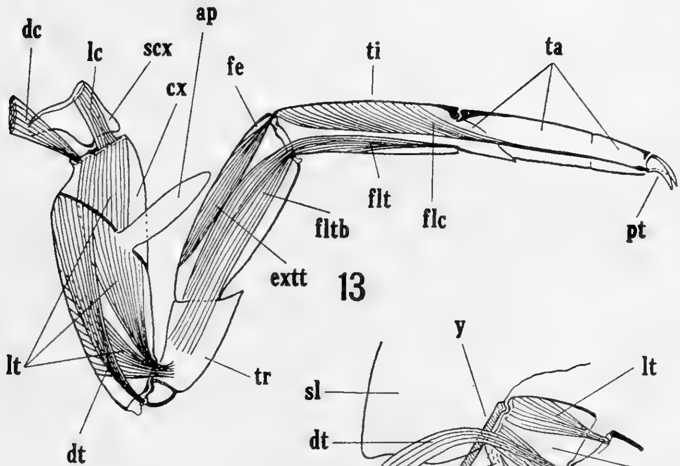

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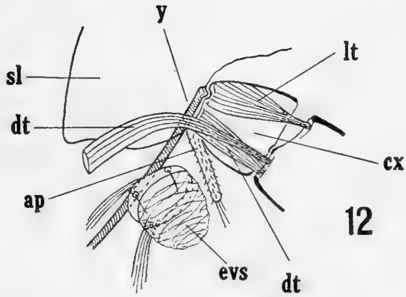

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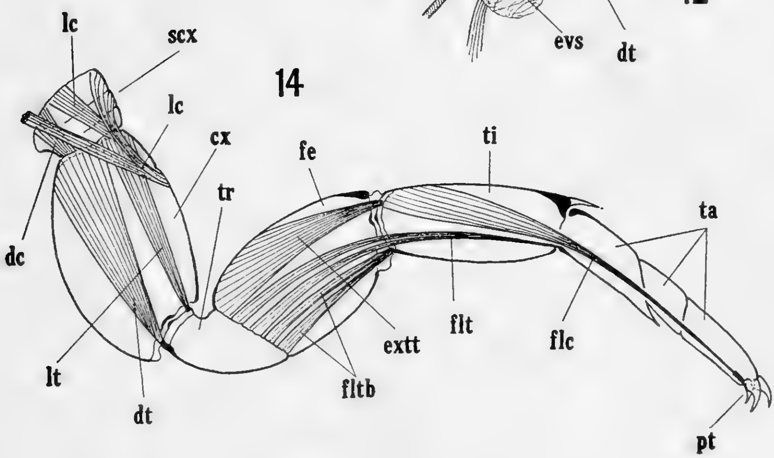

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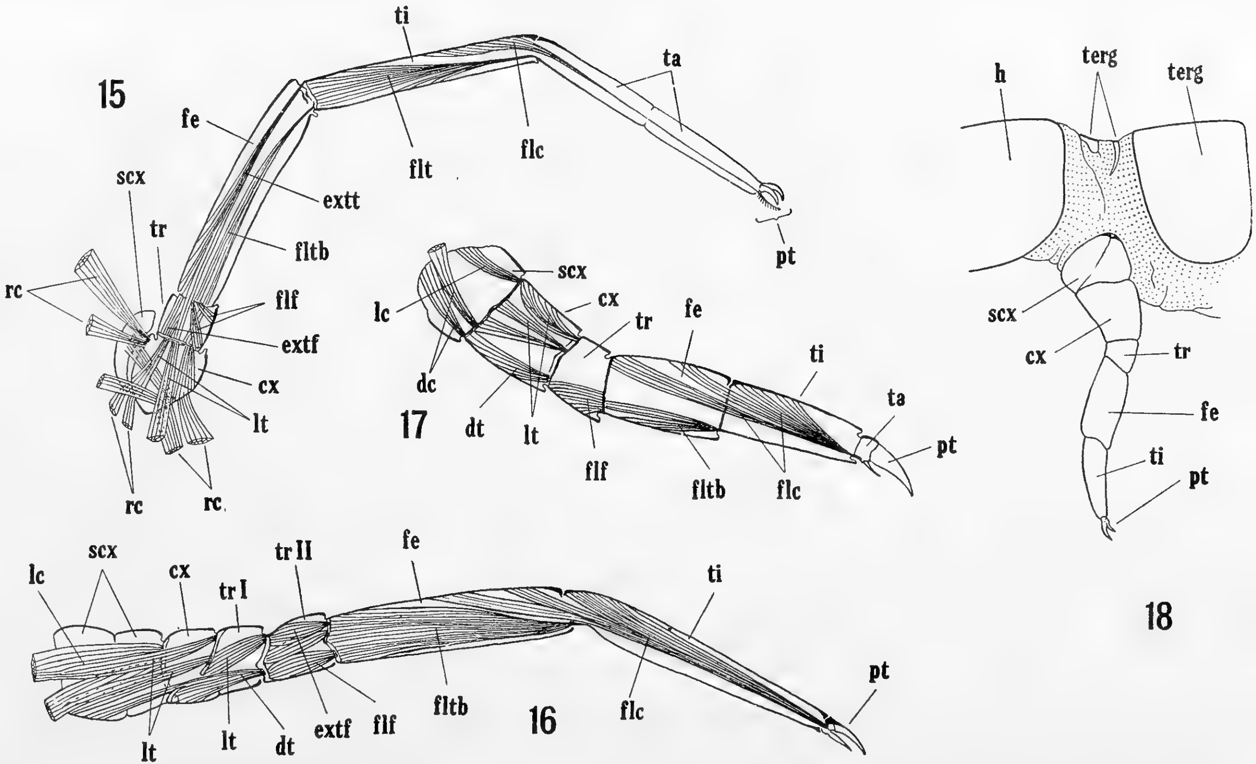

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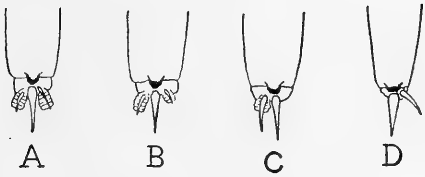

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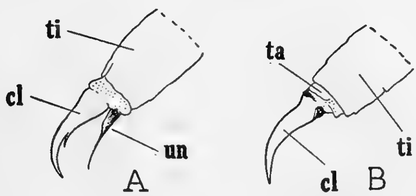

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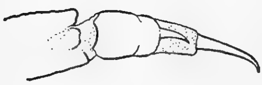

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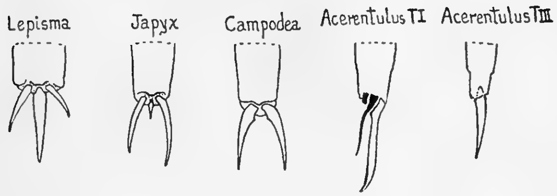

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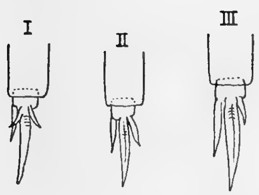

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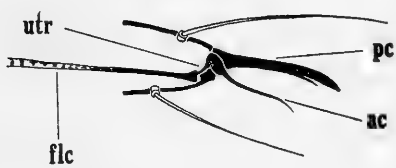

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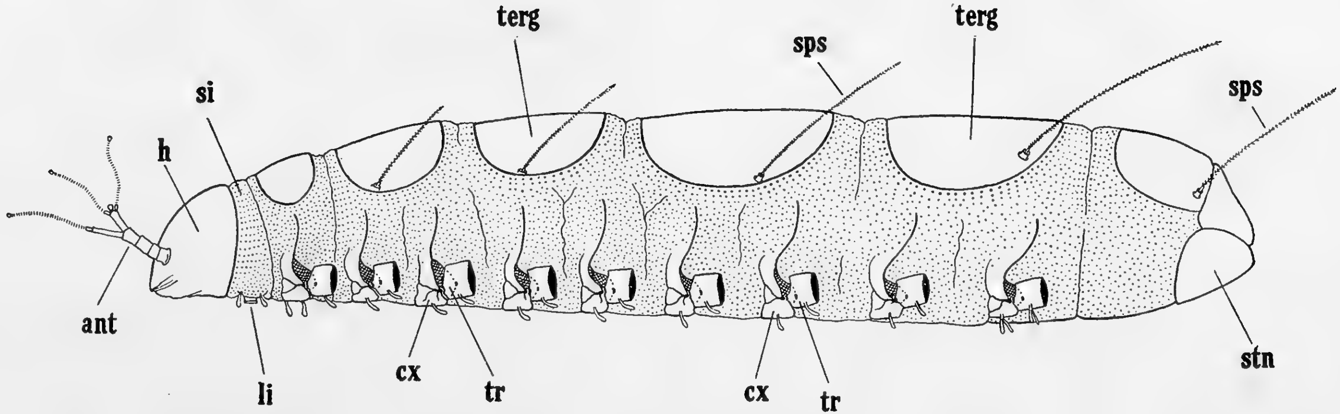

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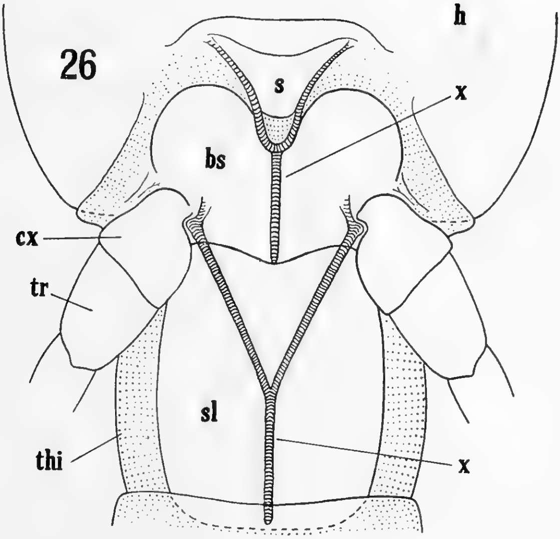

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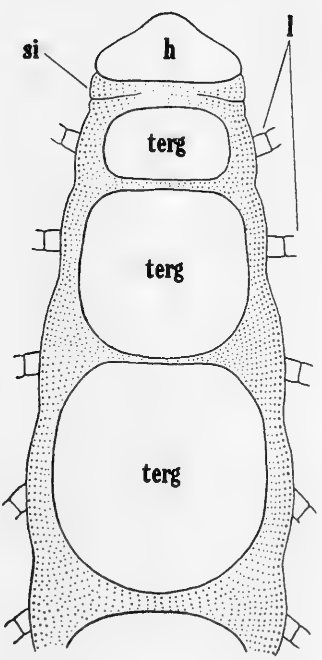

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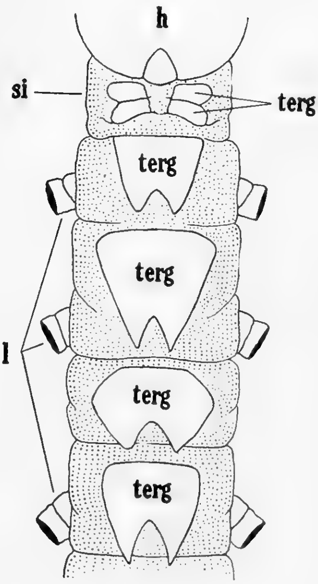

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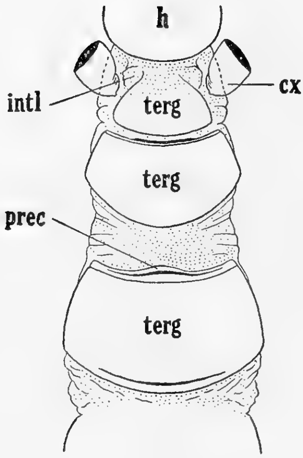

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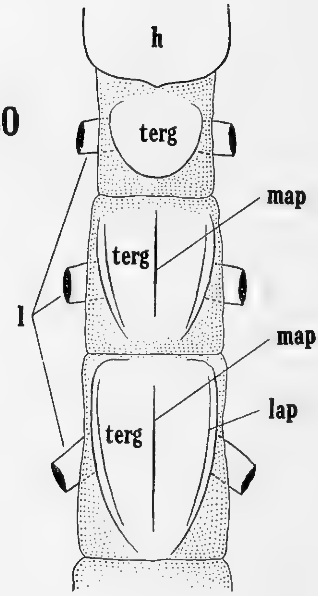

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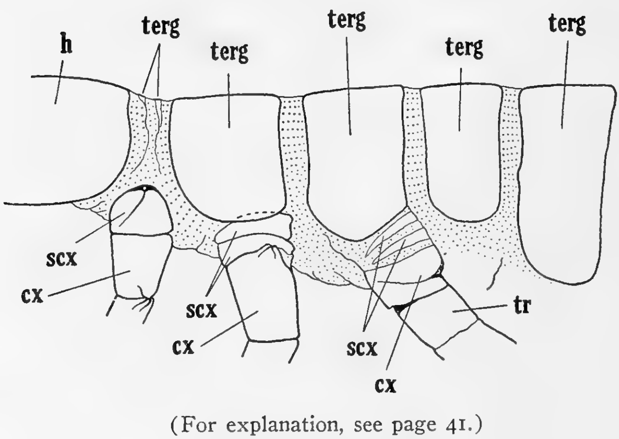

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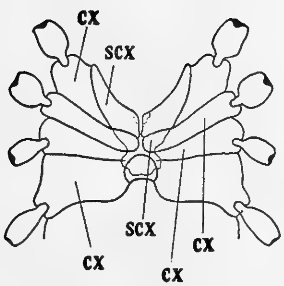

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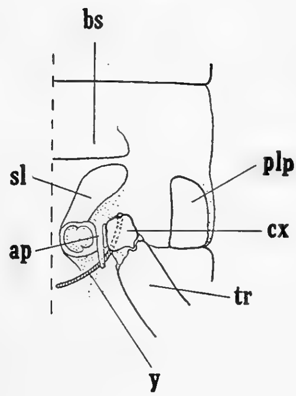

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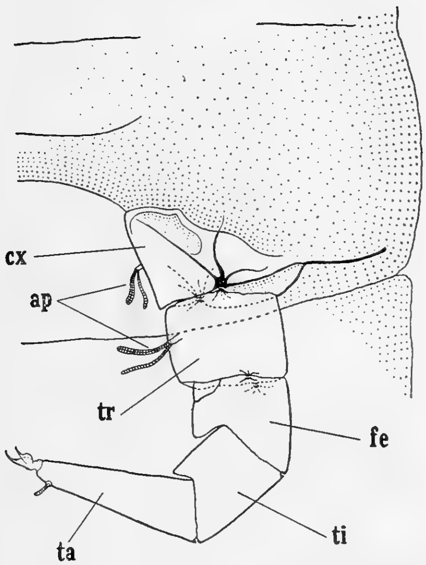

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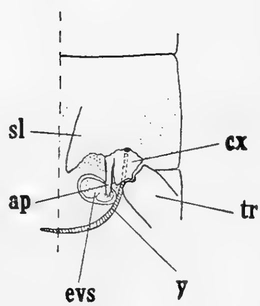

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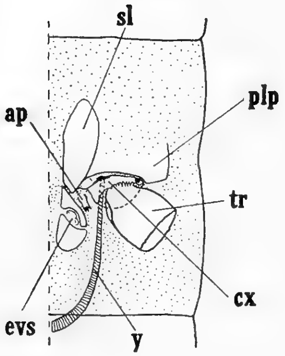

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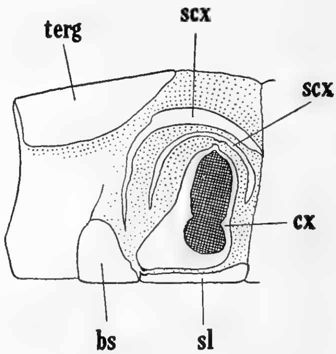

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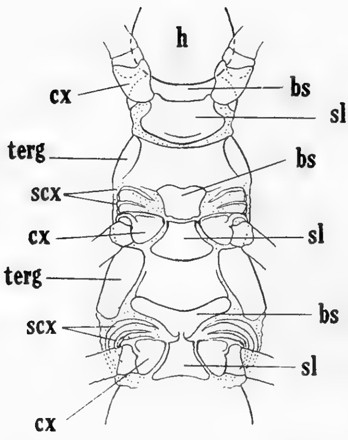

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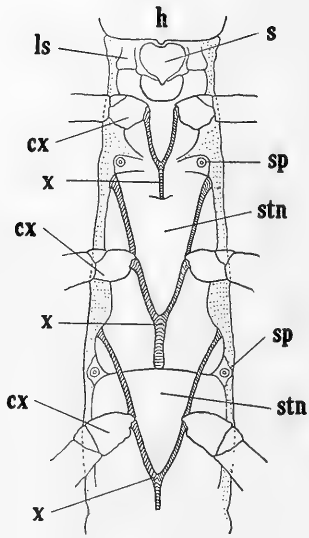

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 80, NUMBER 12
(End of Volume)

CHARLES DOOLITTLE WALCOTT

SECRETARY OF THE SMITHSONIAN INSTITUTION
1907–1927

(With One Plate)

MEMORIAL MEETING

JANUARY 24, 1928

(Publication 2964)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
MAY 12, 1928

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

In Memory

OF

CHARLES DOOLITTLE WALCOTT

Born in New York Mills, N. Y., March 31, 1850

Died in Washington, D. C., February 9, 1927

SMITHSONIAN INSTITUTION

CITY OF WASHINGTON

THE REGENTS AND ACTING SECRETARY OF THE
SMITHSONIAN INSTITUTION
INVITE YOU TO ATTEND A MEETING
TO COMMEMORATE THE LIFE AND SERVICES OF

CHARLES DOOLITTLE WALCOTT

SECRETARY OF THE SMITHSONIAN INSTITUTION FROM 1907 TO 1927

TO BE HELD IN THE AUDITORIUM OF THE
NATURAL HISTORY BUILDING
TENTH AND B STREETS NORTHWEST
TUESDAY MORNING, JANUARY TWENTY-FOURTH
NINETEEN HUNDRED AND TWENTY-EIGHT, AT 11.00 O'CLOCK

THE CHANCELLOR OF THE SMITHSONIAN INSTITUTION
THE HONORABLE WILLIAM H. TAFT
CHIEF JUSTICE OF THE UNITED STATES
WILL PRESIDE

ADDRESSES WILL BE DELIVERED BY
THE FOLLOWING REPRESENTATIVES OF ORGANIZATIONS
WITH WHICH SECRETARY WALCOTT
WAS ACTIVELY AFFILIATED:

DOCTOR JOHN C. MERRIAM
THE CARNEGIE INSTITUTION OF WASHINGTON

DOCTOR JOSEPH S. AMES
THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

DOCTOR GEORGE OTIS SMITH
THE UNITED STATES GEOLOGICAL SURVEY

DOCTOR CHARLES G. ABBOT
THE NATIONAL ACADEMY OF SCIENCES
AND
THE SMITHSONIAN INSTITUTION

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CHARLES DOOLITTLE WALCOTT
Fourth Secretary of the Smithsonian Institution, 1907-1927

CHARLES DOOLITTLE WALCOTT

Memorial Meeting, January 24, 1928

(With One Plate)

At the meeting of the Board of Regents of the Smithsonian Institution on February 10, 1927, the Chancellor announced the death, on February 9, 1927, of Charles Doolittle Walcott, Secretary of the Institution from 1907 to 1927. The following resolutions were adopted by the board:

The Board of Regents of the Smithsonian Institution have received the intelligence of the death, on February 9, 1927, of Charles Doolittle Walcott, Secretary of the Institution since 1907. It is thereupon

Resolved. That the board record both their sense of personal bereavement and their keen realization of the loss sustained in the death of their distinguished secretary, whose geological researches and varied scientific attainments have brought him eminence in the world of scholarship, and whose administration as the executive officer of the Institution has made it more than ever a predominant force in scientific thought and achievement, and enlarged its influence for the attainment of the founder's purpose—"the increase and diffusion of knowledge among men."

Resolved, That the executive committee be requested to arrange for a memorial meeting to be held in Washington and for the submission at such meeting of a suitable record of the life and work of Doctor Walcott.

Resolved, That a copy of these resolutions be transmitted by the chancellor to Doctor Walcott's family, with an expression of the sense of the heavy loss sustained by the Institution, and of the sympathy of the Regents with the family in this the hour of their bereavement.

In accordance with these resolutions, a memorial meeting was held in the auditorium of the U. S. National Museum on January 24, 1928, which was attended by a large number of Dr. Walcott's friends and official associates. The Chancellor of the Institution, the Honorable William H. Taft, Chief Justice of the United States, presided.

INTRODUCTORY REMARKS

BY THE HON. WM. H. TAFT

Charles Doolittle Walcott was Secretary of the Smithsonian Institution, and served for twenty years. Like his predecessors, Henry, Baird, and Langley, his activities in behalf of the Institution were so comprehensive and constant that he typified, and with many, he was, the Institution itself. Doctor Walcott was one of the few leaders in the field of science who had no collegiate or scientific education. As early as his thirteenth year he had manifested his interest in fossil collecting and local geology. His circumstances required him to act as a clerk in a hardware store in early life, but at twenty-three he sought to study at Harvard under Louis Agassiz, whose death defeated his purpose. His interest in geology led him to become an assistant to the New York State Geologist, James Hall, at twenty-six years of age, and three years thereafter he joined the staff of the United States Geological Survey.

His original researches in paleontology in Eastern and Western United States and in Wales gave him a reputation, and thereafter he pursued his investigation into the fossil life of the earliest geological eras, and led in that field, so that much of the general knowledge in that field came from him. To win such a position in science without preparation in a scientific institution was remarkable, and the branch of science that he embraced he carried on to the end of his life, in spite of the heavy duties he discharged not only in the Smithsonian but in the government and in the care of the National Museum. He was a marked administrator.

In 1894, at its head, he reorganized the United States Geological Survey, and greatly expanded its usefulness in the thirteen years of his control, during which the Reclamation Service, the Forestry Service and the Bureau of Mines were all founded and bore the effect of his shaping hand.

During his administration of the Smithsonian, the Freer Gallery and the National Gallery of Art became part of the greater Institution.

He was a leader, full of suggestion. He was sought for by scientific institutions as trustee or director. He was a leading spirit among the trustees of the Carnegie Institution, and he established the National Advisory Committee for Aeronautics, and was its leader until his death. He became first a member, then a Vice-President, and then President for five years of the National Academy of Sciences.

Doctor Walcott was of substantial assistance in promoting cooperation among the many agencies which were called upon to prepare the enormous material which the country produced and the War demanded. He made the supreme sacrifice of a son in that great conflict.

Toward the close of his association with the Smithsonian, he saw the necessity for increasing its usefulness by a large private endowment, and he himself contributed substantially, both in life and by will, to that endowment.

Doctor Walcott made himself. His career is a long list of arduous deeds done in helping the cause of geological science and in helping the government by a disinterested devotion to its usefulness in many scientific avenues. He was a civil servant of the highest value.

Our government of course is made up of a great many different personal factors. We cannot escape in our minds giving to it a quasi personal character which it derives mainly from those whose relation to it in its administration is non-political but constant in carrying on its activities, with no ambition moving them except the country's progress toward better things. Through all the departments of the government will be found men who have given their lives to the cause, without publicity, without advertisement, without profit. Their happiness and their reward are in the achievements of the government itself and its departments in which they play a part. Walcott was a leader of this kind among such men.

The authorities of the Smithsonian have felt that this meeting should be held in memory of a man whose work promoted real scientific investigation and discovery in his particular field, who was a shining example of a government civil servant of the highest ideals and success, and who for twenty years gave greatly of his energies and the hardest kind of labor to expanding the usefulness of the Smithsonian Institution.

DOCTOR WALCOTT AS A PALEONTOLOGIST, AND HIS RELATIONS WITH THE CARNEGIE INSTITUTION OF WASHINGTON

BY JOHN C. MERRIAM

Of many relationships to Doctor Walcott those which I shall cherish most in memory are the two concerning which I am privileged to speak on this occasion. One relates to the closely binding tie of common interest in a fundamental subject of research to which his life and mine have been in part devoted, namely, the real significance of the paleontological or life story. The other concerns one expression of Doctor Walcott's interest in creative work, as illustrated in his twenty-five years of service as an organizer and leader in the program of a research agency with which I am connected, that is, the Carnegie Institution of Washington.

It was a mutual interest in the importance of paleontological problems that brought about my first conference with Doctor Walcott. The discussion related to the future of research on the history of life in America. It was by reason of our common interest in application of research results for the benefit of the people that I worked with Doctor Walcott on many enterprises of national scope. It was through a realization in my mind, as in Doctor Walcott's, that the lesson of evolution of the living world suggests the importance of continuing investigational or creative effort, that I came into continuing touch with administration of research problems.

Doctor Walcott's personal contact with research questions, his effective practical grasp of methods of investigation, and his recognition of the meaning of creative effort in terms of human service, made him a critical figure in the initial planning, as through all stages of organization and development, of the Carnegie Institution. The statement in the charter of the Institution defining its purposes, which reads—" to encourage in the broadest and most liberal manner investigation, research, and discovery, and the application of knowledge to the improvement of mankind "—expressed the specific interest of Doctor Walcott in this agency.

As one of the original incorporators and a member of the first Board of Trustees of the Carnegie Institution, Doctor Walcott served continuously from the time of organization until his death. He was its first Secretary, was a member and Chairman of the Executive

Committee, and Vice-Chairman of the Board. As a member resident in Washington his advice and counsel played a large part throughout the twenty-five years of his membership. His wide contacts with government departments, universities, and research agencies of all types, his exceptional range of interest in the various fields of science gave him a point of view and a quality of judgment of inestimable value. The Institution owes much of its accomplishment to his conscientious adherence to a program of high ideals based upon practical, intensive study of facts.

I know that I express the wish of the trustees, directors, and members of the staff of the Carnegie Institution in voicing on this occasion our heartfelt gratitude for Doctor Walcott's contribution in the building of many departments, as Mount Wilson Observatory, Geophysical Laboratory, and others, and his assistance and advice on nearly all of our greater projects.

The major research efforts of Doctor Walcott's life were directed toward the earlier portion of the historical record of the earth. Though he contributed much toward our understanding of general geological phenomena, his interest centered upon the earlier chapters of the history of life.

One source of Doctor Walcott's power in research lay in his never losing sight of the fact that there is really only *one* history, which includes the record of physical phenomena and the relation of the story of life to the sequence of events in their environment. Whether he happened to be concerned with determining the sequence of strata necessary as the guide to succession of events in time, or with interpretation of great gaps or erosional intervals between such series, or with details of structure in any of the many groups of trilobites or other invertebrate animals which he loved to study, there was always before him the idea that the facts fitted into *one* scheme of interlocking events in earth history.

As another aspect of the attitude toward his subject which gave Doctor Walcott exceptional power in furtherance of the study of his subject, one may note that he had at the same time a reputation as a collector with rare penetration of vision, and as a generalizer with almost superhuman judgment as to where in the geological or geographical scheme of things new data would have exceptional interpretive value. The relation between these two characteristics expresses in a manner the breadth of his view and the keenness of his perception. He found types of life new to science in unexpected places, not because of luck or *mere* persistence. His success was partly due to exceptional keenness and alertness, but largely to his having a picture of the kind of thing that it would be important to find and of the place where if found, it would be especially significant.

This is not the time or place to discuss in detail the contributions Doctor Walcott made to the study of the early life of the earth, as to the structure of ancient animals, their biological classification, their faunal grouping, or their succession in time. It is, however, important to note that in all of these aspects of the problem his accomplishments belong in the first rank of the world's researches. In studies ranging from a fundamental investigation of structure and habits of many groups of trilobites and other crustaceans, of the mollusca and the mollusk-like brachiopods, the early coral-like forms, the simple protozoa, and the bacteria, his work was of the pathfinding type.

In the whole range of researches of the world Doctor Walcott's studies of the earliest known assemblages of life, and his working out of the facts relating to the earliest traces of life upon the earth, constitutes the most important single contribution. It marks his greatest achievement in contribution to knowledge and to constructive or interpretative thought.

In his work on the " Origin of Species," Charles Darwin gave large value to certain evidence against his theory of evolution which is presented by the earlier part of the geological record of life. With that perfectly balanced judgment which characterized his work, Darwin discussed the fact that a full representation of highly developed and widely differentiated life beginning in the formations known as the Cambrian at the bottom of the geological column, did not give the picture of beginnings of life that his theory of evolution seemed to require. Darwin considered (to quote his words) that " The difficulty of assigning any good reason for the absence of vast piles of strata rich in fossils beneath the Cambrian is very great. . . . . The case at present must remain inexplicable, and may be truly urged as a valid argument against the views here entertained." He believed, however, that many existing factors opened the way for satisfactory interpretation of the situation and that it would (to quote him) " be about as rash to dogmatize on the succession of organic forms as it would be for a naturalist to land for five minutes on a barren point in Australia, and then to discuss the number and range of its productions."

It was this field which Darwin considered so difficult and so important, extending from the better understood ancient or " Paleozoic " rocks through to the lowest known strata, in which Doctor Walcott planned his attack and made his outstanding contribution. His full description and interpretation of the earliest faunas, and his suggestions as to the significance of the preceding record, or absence of record, have not only given a clear understanding of what we see, but have led us to appreciate as well the true significance of those portions of the record for which we have as yet no complete interpretation.

Doctor Walcott recognized that, of all the ideas in the field of knowledge, there is none more important than the suggestion that the life world as we know it in paleontological history has tended definitely to build itself forward from age to age. He realized that this principle furnishes one of the essential elements for belief in the possibility of continuing progress in the living world as a whole including man—a belief or faith which is clearly an indispensable ingredient of human happiness whether it be expressed in our philosophy, in our religion, or in the affairs of everyday life.

But Doctor Walcott did not assume that science can present a complete explanation of everything that is, or was, or that will be. He saw the long story spread before us, as we trace the intricate and fragmentary records through the rocks. He understood its meaning to us, as have few students whose privilege it has been to walk back along the path of history. On the basis of his experience he visualized more clearly than Darwin the two terminal fields of our historical series—the future, of which we can judge mainly by the past, and at the other end the seemingly abrupt initiation of the living world. His effort was consciously directed toward attainment of an interpretation of the beginning of our record as we find it, and on the basis of facts and reason, rather than upon purely mystical construction of a sequence without data.

His work, together with that of the many others who have helped in the initial unravelling of the tangled threads, has shown in large measure the correctness of Darwin's assumption that while the long record from present back to Cambrian and earlier time serves to define certain general principles of primary importance, we are not yet permitted to see the whole of the panorama. But this situation need not today serve as an argument against the idea of organic development which Darwin discussed with such marvelous honesty in presentation of argument. It means only that time is vastly longer than Darwin saw it, and from the wreckage of the most ancient stages of the world, the changing story may be hard to read or may perhaps have been erased completely from the book.

It is not an uncommon belief that the fortunes and achievement of outstanding characters in history depend in large measure upon chance. The incident which seems to turn the trend of life, as we see it in the history of a great character, seems to the purposeless individual an accident which provides a way not possible to others. But frequently the thing which seems so easily, and yet so oddly to open the door, merely represents one of many avenues which might have led to the same goal. The fact that a particular individual has used it to advantage is likely to be dependent in larger measure upon interests or attitude of mind, than it is upon the particular opportunity. Had he perhaps waited, with the stimulus of his pressing interest he might have found another way much easier.

Perhaps it is merely in support of a desire to feel that the universe *is* dependable, and that directed human effort *may be* fruitful, that we take the view that life can be *guided* and *determined,* rather than be the result of fortuitous influences.

The achievement of Doctor Walcott's researches in the unbelievably difficult field which he chose indicates that luck comes to the man with penetrating vision and unceasing industry. The major contributions which Doctor Walcott made to the story of earth history, bring a deepening of our faith that in the sea of time, behind the froth and broken waves that may deceive us, there is a moving tide—controlled by law—that we begin to understand.

DOCTOR WALCOTT AND THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

BY JOSEPH S. AMES

The relations of Doctor Walcott with the National Advisory Committee for Aeronautics differed in several important respects from those which he had with the other institutions referred to today. The National Advisory Committee for Aeronautics owes its origin to Doctor Walcott, and whatever success it has achieved is due in a large degree to his personality and influence. When one speaks of the Committee or its work, one thinks instantly of Doctor Walcott.

In tracing the origin of the Committee one is struck with the fact that a man of vision, of judgment and of scientific talent may plan with success an organization to consider problems in a field quite remote from his own. Few branches of science are as far apart as geology and aeronautics. I doubt if Doctor Walcott knew the meaning of such words as lift and drag, thrust and torque, pressure distribution, scale-effect, etc., words occurring in the every day language of those engaged in aeronautic research. Yet Doctor Walcott organized successfully a committee whose fundamental purpose is the study of aeronautic problems. By his vision he saw the need of systematic investigation of these, by his judgment he was able to draft a measure to establish the Committee which met the approval and support of the Congress and the President; his own standards of scientific work were so high that all those working for the Committee were impressed from the beginning with the need of making their researches reach the same standards.

But Doctor Walcott's wisdom extended much further. While he recognized the importance of the scientific investigations to be undertaken by the Committee, he knew that it would be at least two years after it was organized before a staff of workers could be collected and even simple laboratories equipped. He felt the need of having at once an organization under the President, and reporting to him directly, made up of men high in the service of the government and of others drawn from civil life, who commanded the respect of the country, an organization able and willing to give advice on aeronautic matters to all branches of the government, one which even on its face had such a standing that it could invite to conference any group in the United States and be sure that the invitations would be accepted.

These matters may be made clearer and Doctor Walcott's farsighted wisdom may be better understood if a chronology is introduced, for times and seasons have an important part in the history of any idea. From the time when Doctor Walcott became Secretary of the Smithsonian Institution in succession to Samuel P. Langley, he was interested in aeronautics, desiring specially to reopen the aeronautic laboratory of the Institution. He realized the need, however, of obtaining government grants for its support and did not see his way to securing them. He had formed a committee to advise him, but soon disbanded it. Then the Great War came, and with it the realization of the existence of a new weapon, and, in fact, a new military arm. It was also realized by a few that those countries which had studied aeronautics scientifically were at a great advantage with reference to those countries which had not. Doctor Walcott was one of these few; and so strongly did he feel the need of this country beginning such work that he secured the passage in 1915 of an enabling act establishing the National Advisory Committee for Aeronautics, the bill being immediately signed by the President. The essential features of this legislation were the constitution of the Committee, its members serving without compensation; the statement of its duties as an advisory body; and its freedom of action, subject only to the President.

At the organization meeting of the Committee Doctor Walcott was elected Chairman of the Executive Committee, a position which he filled till 1919, when he was elected Chairman of the Main Committee. He honored the Committee by remaining its Chairman till his death.

In 1915 the question of preparedness for war was uppermost in the minds of everyone, specially those responsible for the state of the army and the navy. Doctor Walcott made himself familiar, by conversation, by study and by correspondence, with the existing situation so far as aircraft were concerned, and with the needs and plans of the two military arms of the nation; and, then, as the day of our own entry into the war was seen to be approaching rapidly, he called, in the name of the Committee, a series of conferences with those interested in the construction of airplanes, conferences which are of historic importance, because it is as a result of them that the airplane industry is in the condition it is today, and that the army and navy are as well equipped as they are.

To the first of these conferences representatives of the aircraft and aircraft engine industry were invited to meet with the Executive Committee of the National Advisory Committee for Aeronautics. The needs of the army and navy were stated fully, and the representatives of the industry explained their difficulties. Three notable results followed; first, the representatives, who had seen each other as a group for the first time, became acquainted; second, the industry began to work on definite problems; and last, the National Advisory Committee for Aeronautics saw the need of a sub-committee on power plants, and one was formed immediately so as to supervise systematic investigations on the subject. When the demand arose for the Liberty Engine, the way had been cleared.

The second conference, or rather, series of conferences, was called to discuss the difficulties which had arisen out of the patent situation. The army and the navy were in despair over the failure to have their orders for airplanes filled. This was in January, 1917. The immediate result of the conferences was the creation of a "cross-license agreement," under which the industry began to operate and has continued to do so.

The third conference referred to was in March, 1917, when the days before the declaration of war could be numbered. The outstanding problem then was production; the capacity of the existing plants, their capability to expand, the supply of raw material, etc. The immediate result of the meeting was the formation by the National Advisory Committee for Aeronautics of a sub-committee on production, to cooperate with the industry. It soon became evident that the task of organizing production was a gigantic one; and, on the initiative of Doctor Walcott, the National Advisory Committee for Aeronautics adopted a resolution, recommending to the Council of National Defense that it form an Aircraft Production Board. This was done; and later, when the magnitude of the undertaking was appreciated more fully, this board was made an independent organization and called the Aircraft Board.

These conferences are mentioned particularly to show Dr. Walcott's grasp of the situation, the use he made of the National Advisory Committee for Aeronautics, and his power to secure results. He was indeed a wonderful chairman of a conference. He could state a question clearly, and could by his courtesy, fairness and eagerness to help, secure the cooperation of all present. Discordant elements came together under this influence; all agreed to help. Most important of all, results were always accomplished.

Before speaking of the scientific work of the committee, which was in the end Doctor Walcott's chief interest, reference should be made to the fact that it was he who first clearly formulated a policy for the control and encouragement of commercial aviation. This was in 1919; and his work bore full fruit in the Air Commerce Act of 1926.

Since the organization of the National Advisory Committee for Aeronautics in 1915, it has published 282 Technical Reports dealing with original investigations conducted under its direct supervision and, for the most part, in its own laboratories at Langley Field, Virginia. In addition, it has issued 266 Technical Notes on what may be called matters of secondary importance. No one can estimate the value of these scientific papers to engineers, designers and manufacturers. But there is a more important side to the matter. Each of these papers was a distinct contribution to knowledge; not a few were of fundamental importance in the theory of aeronautics. In this side of the Committee's work Doctor Walcott took keen interest; not that he ever read the papers themselves, but he was eager to know their content and to be told how they were received by those competent to pass judgment on them. In a very real sense, too, he inspired the men responsible for the research work, because they knew that not alone was their reputation at stake, but his too, because he was the Chairman under whom the laboratories operated.

Not the least of Doctor Walcott's services to Aeronautics and to the Committee was his insistence upon the location of the laboratories of the Committee in the closest possible proximity to a fully equipped aviation field. He secured the agreement of the army and navy to a plan for a joint experimental field and proving ground for aircraft upon which would be placed the research laboratory of the Committee, and he was Chairman of the committee for the selection of the site. This ended in the establishment of what is now known as Langley Field, a few miles from Hampton, Virginia. As plans finally shaped themselves, the navy did not join in the project; but the army has developed on this site one of their largest aviation posts, and the Committee occupies an allotment on the field. The cooperation between the Army Air Corps and the Committee has been close and unbroken, and the importance of this in the latter's development cannot be overemphasized. All this Doctor Walcott in some way foresaw. This condition is unique in the world so far as governmental aeronautical research laboratories are concerned.

Doctor Walcott watched with the deepest pleasure the expansion of the Committee's laboratories at Langley Field; the construction of new pieces of equipment, new wind tunnels, new testing mechanisms. He was gratified at the constantly widening scope of the research problems, and at the ever increasing interest in these taken by the army, the navy and the industry.

The success of any institution, especially one under the government, depends upon two factors. The more important is its personnel, including both the board of directors and the employees. The other is the financial support it receives. The underlying reason why the National Advisory Committee for Aeronautics has continued to grow from year to year is that Dr. Walcott has been trusted absolutely by three Presidents, by the Congress and by the Bureau of the Budget. When he said that the Committee needed a certain appropriation to carry on its work, he was believed; everyone felt that he could be trusted. He himself always presented the formal requests for grants, each year with greater confidence and enthusiasm.

Such were Doctor Walcott's relations with the National Advisory Committee for Aeronautics. He created it; he planned its duties wisely; he guided and inspired it; he secured the appropriations for its support. Each year he took more interest and pride in its operation. There can be no doubt but that from all this he himself received his reward of pleasure and satisfaction.

CHARLES D. WALCOTT AND THE UNITED STATES GEOLOGICAL SURVEY

BY GEORGE OTIS SMITH

In 1879 Charles D. Walcott and the United States Geological Survey began their service to the nation together. Young Walcott had already been an assistant to James Hall, the State Geologist of New York. Even before that he had been an enthusiastic student and successful collector, so that he brought to the position of assistant geologist maturity of mind and seriousness of purpose. Unlike most of his associates in the new Survey he had not been connected with any one of the four pioneer organizations that for 10 years or more had so vigorously competed in the field of Western geologic exploration. He was therefore relatively immune to the keen and at times bitter feelings of rivalry and partisanship that persisted even after the four illustrious leaders, Wheeler, Hayden, King, and Powell, had passed from the stage.

During 28 years of active connection with the United States Geological Survey Doctor Walcott demonstrated his exceptional capacity for the dual duties of research and administration. The earlier years were crowded with field excursions and laboratory study—researches alike extensive and intensive. He was not only the specialist among specialists, concerned, for instance, with the concealed appendages of the earliest crustaceans, but also the broad-minded geologist whose vision comprehended the most ancient seas, teeming with primitive forms of life, and the beginnings of continents being prepared for the advent of man. It is the linking of the name of Walcott with Cambrian stratigraphy and paleontology that gave him international fame as a contributor to geologic and biologic science. Even after administrative responsibilities demanded more and more of his time the eagle-eyed collector and painstaking student continued his productive investigations on a scale unrivaled by most other workers far less burdened with conflicting duties. In those days the Director of the Geological Survey might commonly be found closeted with his beloved trilobites in the back room, though always ready to turn aside from these messengers from the dim past and equally interested to discuss and decide questions relating to present procedure for the Survey or to the future coal supply for the nation. This devotion to research while under stress of administrative duties was a source of both inspiration and dismay to some of his associates; he did both jobs so well.

The period of 13 years, from 1894 to 1907, in which Doctor Walcott was Director, was the period of the Geological Survey's greatest growth. The large increase in Congressional support and the continued advance in popular appreciation of its varied activities in fact-finding together gave this scientific bureau an ever-expanding sphere of usefulness. As defined by Director Walcott, the public to be served included Western rancher and miner, Eastern landowner and investor, as well as student, teacher, and research specialist. He united the scientific and the practical, without compromise, in effective service of a type that won acceptance and approval by the many even if not by the few.

With his rare combination of executive ability, business sense, and personal tact, Director Walcott let his talents contribute to larger endeavors connected with the work of his bureau. In the fashioning of government policy bearing on the settlement of the public domain and the wise utilization of its great resources, he was the trusted adviser of Presidents and Congresses—a wise counselor, for he knew his West at first hand. Reclamation projects, national forests, national parks, fuel-testing plants, and mine-safety stations—all these were the visible evidence of new activities in federal engineering that benefited by Director Walcott's early sponsorship and became great national undertakings as they were later expanded under four important federal bureaus—in a way, children of the Geological Survey. It was fortunate for the nation that the obvious genius for business early displayed by Charles Walcott had been turned into channels of public service.

This notably successful career in which scientific endeavor and public service were happily and fruitfully combined also had its personal side; after all, it is the man behind the career that counts. Charles Walcott was great as the scientist famed the world over; he was great as the public official honored the length and breadth of his own country; he was also great as the man in his home, among his friends, in this community. His record in the United States Geological Survey as scientific worker and executive head will stand, but it is most of all to the man his associates would pay tribute. His inspiring fellowship and his helpful friendship have left us his debtors.

DOCTOR WALCOTT, THE SMITHSONIAN SECRETARY AND NATIONAL ACADEMY PRESIDENT

BY C. G. ABBOT

In Secretary Walcott we found a chief who was cheerful, patient, serene, unostentatious, easy in manner, yet every inch an administrator. Walcott left every responsible subordinate to carry on his problem in his own way, watching unobtrusively till the worker wished to report, needed help, or had gone wrong. Thus the Secretary tested his men and developed their responsibility. He acted decisively when there was occasion, praised and loyally supported all who did well. He never wasted his own or anybody's time with prolonged or needless conferences, and was amenable to good suggestions. In short, he was the ideal administrator from the point of view of his subordinates.

From long and varied experience he drew wisdom for every emergency, and said many words to mean little, or few words to mean much, as the occasion demanded. He knew men and how to deal with them. I attended him once at a Congressional sub-committee, when, as we were leaving, a prominent representative said to me that he thought government should not support science except for fully developed utility. As I was arguing the contrary, my chief casually interrupted with what seemed a complete change of subject. The Congressman was interested and Walcott led him on, until, in a moment, my antagonist was facing the proposition that a research which had been begun with no thought of utility five years before, now saved the government millions. As we drove away, I ventured to express my admiration of his adroitness. Doctor Walcott replied, "These lawyers can beat you in argument, but they can't beat plain facts."

He schooled us that the way to get action is fully to prepare the case. The estimates must be complete, the reasons succinctly plain, the authorizing letter ready for signature. Confidence that schemes so thoroughly prepared will be strongly executed, nine times out of ten causes your man to sign on the dotted line.

Doctor Walcott was highly influential, but not by oratory. His way was to invite a man to dinner, and have a cozy talk before the fire, or to look in, bright and cheery, upon some busy Senator at breakfast, after taking a brisk walk in the park. A little word or two in a magnetic moment was all he needed to clear the situation.

In recognition of his great attainments in the sciences of paleontology and geology, Doctor Walcott was elected to the National Academy of Sciences in the year 1896. He served continuously on committees of the Academy, and much of the time in high office from 1899 to 1927. He was Treasurer 1899 to 1902, Vice-President 1907 to 1917, and elected President in 1917, serving in that highest office until 1923. The full list of his services with the Academy is as follows:

Treasurer	1899-1902
Member of Council	1902-1905
Vice-President	1907-1917
President	1917-1923
Committee on Publications	1903-1913
Committee on Historical Documents (Chairman)	1915-1925
Committee on Finance	1916-1925
Committee on Daniel Giraud Elliot Fund	1917-1927
Committee on Mary Clark Thompson Fund (Chairman)	1924-1925

Member of Building Committee and Committee on Exhibits.

Awarded the Mary Clark Thompson Medal in 1921 for distinguished contributions to the sciences of Geology and Paleontology.

Thus, although he never received collegiate or technical scientific education, Doctor Walcott attained through merit the highest of scientific positions.

As Secretary of the Smithsonian, his principal monument is the Freer Gallery, and the outstanding enterprise while he was President of the Academy was the achievement of the palatial Academy building. In both, his share was highly important. The good judgment of the man, expressing itself in the control of situations in business meetings will be long remembered by his associates on the Council of the Academy. The shaping up with Mr. Freer and Colonel Hecker of the conditions of the great Freer gift and bequest was a far reaching accomplishment, of which the beneficent unfolding is only just begun.

The great War hurt him sorely, in that it took a much loved son. Yet he did not repine, but carried on cheerfully, with the very many and intricate enterprises which he was then engaged in for the national safety and success. Religious faith comforted him, and family affection supported him. He told me on two occasions that he had no dread of death. That just as he stepped upon the train here and soon arrived in the Canadian mountain field to take up his summer work, just so simply he expected to pass by death to a life of new satisfactions.

Doctor Walcott was very helpful in securing the endowment of the National Academy and its National Research Council. He greatly desired to obtain also a largely increased endowment for the Smithsonian. He sought many times to interest wealthy friends to assist in this. Being unsuccessful, he proposed the establishment of a Society to befriend the Institution, but this has not as yet been accomplished. Two projects which are now in progress he actually initiated, and himself by personal gift and bequest added all he could to the endowment.

Honored with the presidency of several of America's foremost scientific societies, holding numerous honorary degrees and memberships in societies at home and abroad, and awarded many medals of highest rank for his pre-eminence in paleontology and in administration, the Smithsonian Institution may well be proud of its fourth Secretary, and the National Academy of its ninth President.

COMMUNICATIONS FROM SCIENTIFIC SOCIETIES

Among many communications from scientific societies and individuals received on the occasion of the Memorial Meeting for the late Secretary Charles Doolittle Walcott, were the following:

"Musée Royal de Histoire Naturelle de Belgique salutes the glorious memory of Charles Doolittle Walcott."

(Signed) VAN STRAETEN.
Director.

"Vienna Academy of Sciences joins you in honoring the memory of the great geologist Walcott, pioneer promoter of international scientific cooperation."

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