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10.

ON THE COMPARATIVE OSTEOLOGY OF THE PASSERINE BIRD ARACHNOTHERA MAGNA.

By R. W. SHUFELDT, M.D., C.M.Z.S.

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(Plate LXVIII.*)

A number of years ago Mr. F. E. Beddard kindly sent me for examination, from the Society's Collections, some twelve or thirteen alcoholic specimens of birds representing a variety of genera and species from several parts of the world.

It was only very lately that I could give this valuable material the attention it deserved, and upon comparing it with the list submitted the following forms were found to be at my disposal:—

No.		No.	
289.	*Cyanerpes cyanea.*	306.	*Cœreba chloropyga.*
345.	*Arachnothera longirostris.*	718.	*Acanthorhynchus* sp.?
318.	„ *magna.*	365.	*Prosthemadera novæ-hollandiæ.*
497.	*Leptocoma grayi.*	702.	*Entomyza cyanotis.*
340.	*Cinnyris chalybeus*	725.	*Acanthogenys rufigularis.*
426.	*Diglossa baritula.*	712.	*Climacteris scandens.*
500.	*Anthreptes malaccensis.*		

All these specimens had been in strong spirit for many years; some of them for perhaps twenty years, or even longer. This treatment had very much hardened all the soft tissues and muscles, and, as some of the species are very small and delicate, the labour of cleaning the skeletons was considerable, as I know from the fact that I performed the entire task myself. In some instances, in too many unfortunately, the extremely minute and fragile bones—in such a species, for example, as *Cinnyris chalybeus*—simply refused to hold together. Some of the specimens had been rather roughly eviscerated, thus injuring the skeleton in the neighbourhood of the incision. One or two were headless, and in the case of all some enterprising and enthusiastic ornithotomist had cut down to examine the xiphoidal extremity of the sternum, a perfectly justifiable operation, by the way, and doubtless to ascertain whether it was "notched" or otherwise, that is, passerine or trochilidine. Aside from these various mishaps, which are comparatively few when one comes to think how long all these specimens had been in the hands of science, this material as prepared offers not a little worthy of study and comparison.

The list has been kindly looked over by Dr. Chas. W. Richmond,

* For explanation of the Plate see p. 544.

Assistant Curator of the Division of Birds of the U.S. National Museum, to whom my thanks are extended for having pointed out the changes made in the nomenclature of three of the families, and for having brought up to date the present known habitats of the species represented.

In this list the genera *Cyanerpes*, *Diglossa*, and *Cœreba* belong to the family Cœrebidæ; *Arachnothera*, *Leptocoma*, *Cinnyris*, and *Anthreptes* to the Nectariniidæ; *Acanthorhynchus*, *Prosthemadera*, *Entomyza*, and *Acanthogenys* to the Meliphagidæ; and, finally, *Climacteris* to the family Certhiidæ.

Again, and designating the species in the list by their numbers, we are to observe that No. 289 occurs in S. Mexico to S.E. Brazil and Cuba; No. 345 in the Indian Peninsula to Burmese Provinces and Malay Peninsula; No. 318 in the Himalayas to Burmese Provinces; No. 497 in the Celebes; No. 340 in S. Africa; No. 426 in S. Mexico and Guatemala; No. 500 in Siam to the Malay Peninsula, Java, Sumatra, Bali, Borneo, and Sulu and Tawi Tawi groups, P.I.; No. 306 in Cayenne to S.E. Brazil and Bolivia; No. 718 in Australia and Tasmania; No. 365 in New Zealand; Nos. 702 and 712 in E. and S. Australia; and No. 725 in S.S.E. and West Australia. Thus it will be seen that the species are found to range through Southern Mexico, Bolivia, South-eastern Brazil, West Indies, South Africa, widely over India and the East Indies, Australia, and New Zealand. They are all tropical or subtropical species, and none of them occur in North America north of Southern Mexico; none in any part of Europe or in the larger part of Asia.

My reasons for selecting from the list one of the species of *Arachnothera* as the principal form of which the osteological characters will be given in preference to any of the others are that, practically, the genus is from the centre of the region of the world's avifauna where the other families represented find their habitats, the regions considered being large continental areas of the earth's surface. Secondly, two species of *Arachnothera* occur in the list, and the skeleton afforded by the specimen of *A. magna* is the most perfect of any of those obtained. Finally, in any comparative anatomical work it is always best to select some special form, be what it may, wherewith to compare the structural characters presented on the part of all its supposed-to-be congeners, material for which may be at hand.

The Skull.—Viewing this part of the skeleton upon its superior aspect, it is to be observed that the cranial portion is globular in form, smooth, and is marked, mesially, by a broad shallow furrow that runs forward and to the right, to be lost at the cranio-facial line. This furrow is far better marked in *Arachnothera longirostris*, and in both species affords lodgment in life for the *thyrohyals* or "greater cornua" of the hyoid arches. A similar groove is found in the same locality on the skulls in the Trochilidæ, only

in those birds it is better marked as a rule, and carried further backward, having the supraoccipital prominence standing between the furrows after the common one separates posteriorly. This character is also a feature of the skull in *Acanthorhynchus* among the Meliphagidæ and probably other honey-sucking species which possess tongues, the thyro-hyals of which curl over on top of the skull and are extensible. *Cinnyris chalybeus* is another example.

In *A. magna* the frontal region is rather broad between the peripheries of the orbits, and still broader in front of the lacrymals, where the cranio-facial line is quite distinct. The superior mandible seen from above is smooth and the culmen rounded. This part of the skull can best be studied on side view. Here it will be noted that it is gently decurved for its entire length, which is just double of that of the rest of the skull. It tapers very gradually to the sharp apex, while its tomia possess clean cutting-edges. The rather large elliptical external narial apertures open far back just beyond the cranio-facial hinge, or rather line (see Plate), and they have no true bony partition separating them mesially. This is entirely different from what we find in the Humming-birds, where these mandibular narial openings are long and slit-like. They are very large, and occupy a mid-position on the bill in such species as *Prosthemadera novæ-hollandiæ*, *Acanthogenys rufigularis*, and other Meliphagidæ, forms with shorter and stouter mandibles.

We find that *A. magna* has a capacious orbital cavity with its osseous walls fairly entire. The *pars plana* is large and thick and faintly shows above its union with the lacrymal. Its outer margin, forming a part of the periphery of the orbit, is, like the rest of this margin round to the postfrontal, sharp and defined. On its orbital side the *pars plana* is markedly concave, but convex in front, while below it meets the anterior end of the quadrato-jugal bar. The latter is almost of hair-like proportions, very delicate, and straight. This is also the case in other species of the Nectariniidæ, some few Meliphagidæ, and in the Trochilidæ. Nearly all of these birds have a vacuity of a greater or less size in the *interorbital septum*, and the openings for nerves on the anterior wall of the brain-case, within the orbit, as those for the first pair, are large, and in *A. longirostris* merge with the foramen in the interorbital septum. The optic foramen, however, is generally distinct, and in such a species as *Climacteris scandens*, and probably its near allies, there exists no deficiency in the orbital septum, while the brain-case above exhibits a very large opening into the orbit.

Owing to the extreme slenderness of the osseous structures at the roof of the mouth posteriorly, the floor of the orbital cavity is distinctly deficient in bone, and this is the case with all the species in this genus, as well as in some of the related forms. On the lateral aspect of the cranium we find the *postfrontal process*

so feebly developed as to be barely noticeable, while the *squamosal process* below it is rather long, though extremely slender. The valley between them is only fairly well-marked. Hummingbirds exhibit similar characters with respect to these two apophyses, but, taken as a whole, there is nothing, beyond the big *pars plana* in one of this family, to remind us of the orbital cavity as a whole in *Arachnothera*. To be sure, the anterior wall of the brain-case is deficient in bone in both, markedly so in the Trochilidæ, but, in so far as that goes as indicating any affinity between the two groups, it stands for very little.

The external aural aperture in the skull of *Arachnothera* is large, and admits of a full view of the interior of the bony ear. Posteriorly, and to some extent below, this entrance is protected by a thin scroll of bone, seen in so many other passerine forms, and very prominent in the Trochilidæ *. Among some of the Cœrebidæ, as, for example, in *Diglossa baritula*, these bony parts of the external ear are remarkably developed; the aperture upon either side looks directly to the front, while the bulbous, thin, and scroll-like wall protecting it above, behind, and below is a striking feature upon this aspect of the cranium.

Posteriorly, the skull of *Arachnothera* offers but little for examination beyond what we would find in the skull of any ordinary passerine bird. The *occipital ridge* is but faintly defined, while the *supra-occipital prominence* is above the average in size, and especially so in *A. longirostris*. This is also seen in *Trochilus*, whereas among the Meliphagidæ it is not the case.

Passing to the *basis cranii* we have to note the large subcircular *foramen magnum*, and the extremely minute *occipital condyle*, which is distinctly hemiglobular in form. The basitemporal area is smooth and convex throughout, presenting at the usual localities the foramina for the entrance and exit of vessels and nerves to and from the cranial cavity. The double entrance to the Eustachian tubes, one to either side, is shielded below by a very narrow rim of bone. The basi-presphenoidal rostrum presents nothing peculiar, and is thoroughly coössified anteriorly with the mesethmoid and the pars planæ.

The *quadrate* possesses a sharp, compressed orbital process, that in articulation comes in close contact with the cranium. Its mandibular facet for the lower jaw is double, there being a small mesial elliptical facet and an outer and larger irregular-shaped one. A longitudinal groove stands between them. As usual, the mastoidal articular head is double, and the bone, as a whole, is highly pneumatic. Apart from the quadrates, all the other osseous structures at the base of the cranium in *Arachnothera* are characterised by extreme slenderness and delicacy of structure. And, in passing, it may be said that all the articulations,

* Shufeldt, R. W. "Contribution to the Comparative Osteology of the Trochilidæ, Caprimulgidæ, and Cypselidæ." P. Z. S. Lond., Dec. 1, 1885, pl. lviii. fig. 2.

especially at the base of the skull, in this genus of birds are notably small, to the very limits of minuteness. This includes the articulation of the skull with the spinal column, the quadrato-jugal articulation, those with the *pterygoids*, and to some extent others.

These last-mentioned bones are very slender, straight, and rather short, presenting nothing peculiar in their articulations with the quadrates and palatines. They do not appear to be in contact with each other in the middle line, though they do articulate with the sphenoidal rostrum.

The postpalatine portion of either *palatine* is a delicate scroll of bone that articulates mesially with its fellow of the opposite side beneath the presphenoid, while the prepalatine portions are well apart, straight, and here reduced to a degree of slenderness rarely met with in birds of this size. A *vomer* is well-developed, spatulate in outline, and compressed throughout in the vertical direction. It is firmly coössified with a palatine upon either side. Each *maxillo-palatine* is reduced to the extreme in the matter of delicacy of structure, being but feebly developed.

Coming to the *mandible* it is to be observed that it has the long V-shaped pattern, with a curvature for its anterior two-thirds corresponding to the curvature of the upper jaw, while its posterior third is somewhat flexed upon the anterior part of the bone (see Plate). The rami are very slender and very narrow from above downward, the structure upon the whole impressing one with its feebleness. *A. magna* has the length of the symphysial portion about equal to the posterior moiety of the bone; in *A. longirostris* it is considerably longer, and in this species, too, the curvature is greater and, if anything, the bone still weaker. Inferiorly, the symphysis is smooth, and roundly convex transversely; the tomia for this part being sharp. A small "ramal vacuity" is present in the mandibles of both these species, and the free ramal extremities are more or less pneumatic. There is at each end a small blunt postangular process, otherwise these ends are practically truncated and concaved behind. The usual inturned angular processes are present, each having at its tip or apex the pneumatic foramen found there in so many of the Class. The *coronoid processes* are aborted In *A. longirostris* the mandible is 4·8 cm. long and only 2 mm. deep at its deepest part, about opposite the ramal vacuity.

When normally articulated, the superior and inferior mandibles in the skull of *Arachnothera* are in contact for their entire lengths. I find nothing to note especially in regard to the intrinsic ossicles of the internal ear, the *siphonium*, or the *sclerotals* of the eye. All are exceedingly passerine in character.

For a representative of this group, however, the *hyoid arches* in this species are remarkable. Not only is the *glossohyal* greatly elongated to meet the requirements of the feeding-habits of the bird, but the *thyrohyals* are similarly produced. The

distal ends of the latter run out to hair-like proportions, which in life curve over the top of the skull, being harboured in the groove there formed for their reception. This admits of very considerable extension on the part of the tongue. The *ceratobranchial* elements of the thyro-hyals are very long, each being about half the length, or rather less, than the corresponding *epibranchial*. They are more or less straight, and take no part in the curvature of the posterior ending of this lingual apparatus. The *basihyal* is very short, and possesses, distally, a circular tip for articulation with the glossohyal. A slender, very short, straight *urohyal* is present; the heads of the ceratobranchials articulating, one on either side, at the junction of the basi- and urohyal.

A. longirostris has the skeletal parts of its tongue as they exist in *A. magna*. The general structure is the same among most of the Meliphagidæ; but in that family there exists no marked elongation of either the glossohyal anteriorly or of the thyrohyals behind. In them the lingual apparatus is typically passerine. Exceptions to this rule, however, exist, and in such long-billed forms as *Acanthorhynchus* and some few others the skeleton of the tongue agrees more or less with what has just been described for *Arachnothera*.

Glancing for the moment at the skulls of other species representing other families at hand, it is to be noted in the skull of such a bird as *Diglossa baritula* that in the case of the interorbital septum it is almost entirely absorbed, a very thin and extremely narrow piece of bone simply spanning its centre, and the minutest possible spanlet below is just sufficient to individualize the two foramina rotunda. The anterior wall of the brain-case immediately above where these two striplets of bone join is entirely absent except a very narrow strip just within the orbital borders. Its occipital condyle is barely any larger than is to be found in *Trochilus*, and its sphenoidal rostrum is much compressed from side to side. Anteriorly, the rhinal chamber is very poorly off for bony protection, inasmuch as the elliptical external narial apertures are very large for the size of the beak: there is not a vestige of an internasal septum, while the *palatal processes* of the premaxillary almost require a lens to see them at all. In this species the ramal vacuities of the mandible are larger than we find them in *Arachnothera*, although the latter is a bird double its size.

Cinnyris chalybeus presents some interesting cranial characters of its own, for here we find the *nasal bones* reduced to their very minimum proportions; the external narial openings are large, being barely separated above by the culmen. *Pars planæ* are much reduced in size, and the fronto-interorbital area on the superior aspect of the skull of this species is notably narrow transversely. Its *mandible* is feebly constructed, and the whole beak considerably decurved.

In *Cœreba chloropyga* the skull is typically passerine, and in some respects resembles the skull as found in certain American Warblers, being quite distinct from what we find in *Arachnothera*, to which genus it bears no special affinity.

So entirely different is the skull in such a species as *Prosthemadera novæ-hollandiæ* of New Zealand, a bird placed among the Meliphagidæ, that a separate description would be required to give an account of it. Here the *nasals* are very broad antero-posteriorly, and each is pierced by a central foramen, an unusual character. Then the *pars planæ* are very thick from before backwards, and a longitudinal groove marks the external aspect of each.

In not a few particulars *Acanthogenys rufigularis* of Australia is a Meliphagidine species with a skull not at all unlike what we find in the species of *Acanthorhynchus*, and these forms are more or less nearly related. *Acanthogenys* has the broad nasals, each pierced by the small central foramen, and there are several other points in the two skulls of more or less close agreement. But such representatives of the Meliphagidæ have no special relationship with the Cœrebidæ, and even less with the typical Nectariniidæ. Judging from the skulls alone, it is not difficult to recognize the more or less close relationship existing among the species I have before me of the genera *Entomyza*, *Acanthogenys*, and *Prosthemadera*, all of which present characters in this part of the skeleton quite different from anything we find in *Arachnothera*, and surely offer no skull-characters at all approaching any of the Trochilidæ.

I have made no attempt to either study or compare the ossifications presented on the part of the tracheæ in any of these birds. From superficial examination only, I would say that although generic and family differences are easily to be seen in these parts, yet at the same time no very striking departures are to be noticed from the general passerine character in any of them.

Having then compared the morphological characters of the skull and the associated osseous structures in such species as there are at hand representing the families Cœrebidæ, Nectariniidæ, Certhiidæ, and Meliphagidæ, and these characters with the corresponding ones in the skull of *Trochilus*, it is clear that, in so far as this part of the skeleton is concerned, these four passerine families are a very long way removed from the Super-suborder *Trochiliformes*, and this is no more than one would naturally expect to find.

My views upon the position in the system of the four above-named families have already been published, and I see no special reason for changing them *. From this point on any further comparison of the skeletons of these birds with the osteology of

* Shufeldt, R. W. "An Arrangement of the Families and the Higher Groups of Birds." Amer. Nat. vol. xxxviii. nos. 455–456, Boston, Nov.–Dec. 1904, pp. 835–856.

the Humming-birds would be quite unavailing. In all respects it is very different. I shall proceed, then, to complete this account with a description of the remainder of the axial skeleton and the skeleton of the limbs in *Arachnothera*, comparing the principal characters with those presented by the skeletons of the other families above-named.

Remainder of the Axial Skeleton.—So far as the vertebræ are concerned between the skull and the pelvic sacrum, the several families of birds here being considered are all strictly passerine in character. I have counted and compared them in a representative of each family, and am satisfied that these bones offer nothing worthy of an extended and detailed description. To be sure, we find some differences in form among the various species, genera, and families, but such characters are of but slight importance, and in all instances the variations are no more marked than those which obtain among more or less nearly related passerine birds in the avifauna of any country of great extent, as, for example, in *Sialia*, *Mimus*, and American Warblers, as compared with the Passeres of the Pacific Coast region *. Both *Arachnothera magna* and *A. longirostris* possess 19 vertebræ between the skull and the pelvic sacrum; the first twelve are true cervical vertebræ without free ribs. The 13th and 14th are also cervicals, the first supporting a pair of very small free ribs, and the last a far better developed pair, which are likewise free and without *unciform processes*. The next five are true dorsals and possess these appendages, and also connect with the sternum through the intervention of *costal ribs*. We also find a very delicate pair of ribs attached to the leading vertebra of the sacrum, the sternal ribs of which are "floating ribs." Dorsal vertebræ have well-developed neural spines which are in contact with each other anteriorly and posteriorly, the ultimate dorsals being lacking in hæmal spines.

There are *seven* free caudal vertebræ in the skeleton of the tail in *A. magna*, in addition to a rather large *pygostyle*. The form assumed by the latter is well-shown in the Plate illustrating this paper. In the family Meliphagidæ there appear to be but *six* caudal vertebræ and the pygostyle, and this is likewise the case among the Cœrebidæ, as, for example, in *Cyanerpes cyanea*. However, we know that even in the same species these caudal vertebræ may vary to the extent of one, or may be two; they are not constant even in our own species.

As well as can be made out from an adult skeleton, or rather a skeleton from an adult individual, it would appear that there are *eleven* vertebræ fused together to form the pelvic sacrum in

* Shufeldt, R. W. "Contributions to the Comparative Osteology of the Families of North American Passeres." Jour. Morph. vol. iii. no. 1, Boston, June 1889, pp. 81–114, pls. v. & vi. A large number of the passerine birds of the United States are osteologically compared in this paper.

A. magna, and they present the usual passerine characters. Only *ten*, it would seem, are thus fused together among the Cœrebidæ, but in these birds the pelvis is relatively shorter and wider than it is, as a rule, among the Nectariniidæ. The Meliphagidæ have eleven—that is, in the species at hand, though *Acanthogenys rufigularis* may be an exception and possess only *ten*; in any case, an extra vertebra in the sacrum may account for one less in the caudal series.

Among all small, ordinary, and more or less typical Passeres all over the world where they may occur, we meet with but little variety in the form of the *pelvis*. Its passerine characters are very uniform. Some birds of the group have it rather narrow and deep; in others it is wider and more compressed from above downward, with the pubic elements far apart—but the *general* characters remain the same. In *A. magna* it is of the narrow and deep variety, with the *ilio-neural canals* open for their entire lengths, and the "sacral crista" standing between them very prominent. On the postacetabular area parial foramina occur among the diapophyses of the ultimate sacral vertebræ. Anteriorly the ilia are truncated from their mesial angles, backward. Posterior to an acetabulum, on a side view, we note the large *ischiadic foramen*; a small, circular *obturator foramen*, which is barely separated from the large *tendinal vacuity*. Behind this last the ischium dips down, as usual in Passeres, to meet the pubis, or pubic style, near its distal termination. The post-acetabular, external free margin of the ilium to some extent overhangs the ischiadic foramen, while the preacetabular part of one of these bones is hollowed externally throughout its extent. The pelvis exhibits specific differences in *A. longirostris*, where the postsacral foramina are large, and the internal iliac margins in the postacetabular region do not coössify with the sacrum.

Among the Meliphagidæ, we find that in *Entomyza cyanotis* the ilio-neural canals or "grooves" remain open only anteriorly, and this is the case with other species of this family. On lateral view of this pelvis all the openings are very large, the osseous side of the bone here being reduced to the minimum thereby. This statement refers also to the large circular *cotyloid ring* (acetabulum) and the mergence of the obturator foramen with the tendinal vacuity. In *Cyanerpes cyanea* the essential characters are the same, but the pelvis, as a whole, is broader and flatter than it is in *Arachnothera*, coming in this respect nearer some of the Nectariniidæ, as, for example, *Anthreptes malaccensis*.

Passing to the *shoulder-girdle* and *sternum*, we find all this part of the skeleton very distinctly passerine in character, the matter of size of the bones often being all there is to differentiate them with respect to the species they belong to: as, for example, the *os furcula* of such a species as *Prosthemadera novæ-hollandiæ* is, as

we would expect, a larger bone than the *os furcula* of *Arachnothera magna*, yet the characters are identically the same, so much so that were the bone in the latter brought up to the size of the one in the former, I very much doubt that any ornithotomist could, with certainty, tell them apart. Indeed, the *os furcula* possesses in all the passerine birds here under examination the same form and characters. When we say it is U-shaped in outline, has a large, transversely compressed, and upturned hypocleidium, slender limbs, and expanded clavicular heads, we have said about all there is to be said in regard to it.

All these birds have *coracoids* and *scapulæ* of the shoulder-girdle very much alike indeed—that is, apart from the matter of size. The morphological variations are very insignificant and offer little or nothing of taxonomic value. It is interesting to note, however, that irrespective of the length or form of the beak, we find in all the Meliphagidæ that the lower external angle of the expanded part of a *coracoid* is produced outwards as a distinct, flattened process, best seen in the short-billed species, though also well-marked in *Acanthorhynchus*, which Dr. Richmond informs me is a genus belonging to the family Meliphagidæ. Now, in *Arachnothera*, and in all the Nectariniidæ and Cœrebidæ at hand, that angle of the coracoid is more or less *truncated*, but whether this points correctly to any existing relationships of the families named, it would be difficult to say*.

Representatives of all these families at hand, as in all true Passeres I believe, have at each shoulder-joint an *os humero-scapulare*, and it varies but very little in size and form in the species examined. When we come to examine the *sternum* of *Arachnothera magna* and compare it with the sterna of other species of Nectariniidæ, and with the other bird-forms enumerated in this paper, we once more realize that this part of the skeleton is likewise all passerine in its morphology, presenting only a few slight differences for the various species. Still, apart from the variations in size, these differences are more or less constant, and in any case unmistakable with respect to the sternum of the species possessing them—that is, the species which have thus far been named in this paper. The sternum in all exhibits a number of characters which all the sterna present in common, as the large, upturned trihedral *manubrium*, with its bifurcated free extremity; the lofty *costal processes* with the hæmapophysial facets on the posterior borders; the marked concavity of the

* Without going into details, and judging from the skeletons alone, I would remark that the Australian genus of birds named *Acanthorhynchus* which have been referred to the Meliphagidæ possess skeletal characters which in the main agree better with the corresponding ones in *Arachnothera* than they do with any of the same characters as seen in the short-billed Meliphagidæ. But two species of *Acanthorhynchus* are known to me, *A. tenuirostris* and *A. superciliosus*, and these I have never had the opportunity of comparing in the flesh with the meliphagidine birds of Australia and New Zealand.

dorsal aspect; the pair of "notches" in the xiphoidal extremity giving rise to an outer xiphoidal process upon either side; the deep "keel" with its prominent carinal angle, anteriorly; and, finally, the fact that the bone is more or less pneumatic. The coracoids never decussate in their sternal beds, though in some species they almost appear to do so. Again, the hypocleidium of the furcula never comes in contact with the manubrial process of the sternum, though in some species the approach is extremely close (*Entomyza cyanotis*). So much for the general characters, and *Arachnothera* has them all to perfection; and there are *a few* minute *pneumatic foramina* in the middle line on the dorsal aspect of the bone, anteriorly, in this species. If we designate the *length of the sternum* by a line extending from the apex of the carinal angle of the keel to the mid-xiphoidal point posteriorly where the keel terminates, then this distance in *A. magna* measures 2·3 centimetres. This same measurement will be applied in the case of the sterna of the other species—as, for example, in *Arachnothera longirostris*, the length of the sternum is but 1·5 cms., and we find the body of the bone *flatter*, the xiphoidal notches comparatively deeper, the carinal angle not so acute, and the keel of the manubrium conspicuous and produced well down upon the anterior border of the sternal carina. The pneumatic foramina are scarce and in the same locality. In *Leptocoma grayi* the sternum has a length of but 1·3 cms. In *Cyanerpes cyanea*, as representing the Cœrebidæ, it measures 1·7 cms., and here the bone is very thin and delicately constructed, with a small manubrium; deep notches and dilated extremities to the xiphoidal processes. These characters do not apply to the sternum of *Cœreba chloropyga*, another of the Cœrebidæ, a species having the bone only 1·2 cms. long.

Anthreptes malaccensis has a sternum which is the counterpart of that bone in *A. magna*, only it is much smaller, having a length of but 1·4 cms.

Among the larger forms of the Meliphagidæ we meet with characters in the sternum that are absolutely diagnostic, as, for example, there is no such a thing as mistaking the species had we but this bone to help us in such a bird as *Acanthogenys rufigularis*. Here, although it is of the usual passerine type, it is peculiar in having the anterior border of the sternal body very much thickened and rounded; this thickening is continued across the base of either costal process and up on to the mesio-posterior margin of the same. Such a thickening also defines the limits laterally of a deep mesio-longitudinal groove, deepest anteriorly, that is found upon the dorsal aspect of the body of the bone. For its anterior moiety, thickly crowded together at the bottom of this groove, we find some thirty or forty pneumatic foraminal openings. Between the coracoidal grooves there is another single pneumatic foramen, and the external angles of the mid-xiphoidal prolongation are pronounced. The carinal angle is

not prominent and is to some extent slightly rounded off. Thus it will be observed that this meliphagidine species possesses a very characteristic sternum, quite different from the bone in *Arachnothera*.

In *Entomyza cyanotis* the sternum, of course, is somewhat larger, and in it the anterior border of the body is thickened and the mesial groove with its pneumatic foramina on the dorsal aspect is confined to the anterior third of the bone. The *carinal angle* is sharp again and rather prominent, while the most distinctive character of this sternum is the unusually short manubrial process, though its bifurcations are conspicuous. In this bird I should have noticed above that the *coracoids* are very long and particularly slender.

In *Prosthemadera novæ-hollandiæ* the sternum is likewise distinctive, in that the above-described mesial groove on the dorsal aspect is *absent*, and the pneumatic foramina in that locality are reduced to a very few minute and hardly noticeable ones. Very little thickening of the anterior sternal border is to be observed, and the carinal angle is not produced anteriorly. As compared with other Meliphagidæ, however, the sternum of this species may be easily recognized by the remarkably thickened free anterior border of the manubrium, which is extended more than halfway down upon the anterior border of the keel. Then, posteriorly, the external lateral xiphoidal processes are unusually slender and long. Distally, on either side, they almost touch the greatly produced outer angle of the mid-xiphoidal prolongation, thus giving the much elongated "notch" upon either side the appearance of a foramen.

Posteriorly the keel terminates in a conspicuous triangular area, and, as usual, there are *five* hæmapophysial facets on the posterior border of either costal process.

Entomyza cyanotis has the sternum 3·2; *Acanthogenys rufigularis* 2·6; and *Prosthemadera novæ-hollandiæ* 3·1 centimetres long.

So far as any characters go, the sternum of the last-named species is most like the bone in *Arachnothera magna*, and this seems to be true with respect to some other parts of its skeleton. Whether this circumstance carries with it the fact that these two species are more nearly affined than either of the other two meliphagidines just named remains to be seen. It would require more extensive and varied material, I must believe, to be certain of such a point as this.

Of the Appendicular Skeleton: the Pectoral Limb.—With great care I have examined and compared the bones of both the pectoral and pelvic limbs in the birds named in the list presented in the first part of this paper. This part of the osseous system has likewise been studied by me in a very large number of passerine species from various parts of the world. The

forms here being examined are from Mexico, South America, South Africa, Asia, East India, New Zealand, and Australia, or, in other words, very widely separated countries, yet there is no mistaking any of the characters of the skeleton of the limbs in any of the birds,—they are all distinctly passerine, we might say "typically" passerine, had there ever been selected as a reference standard a species anywhere, the skeleton of which was to be universally considered as the *type* in this respect for all Passeres. It would be interesting to know what species would be selected upon a consensus of opinion of ornithotomists everywhere, on this point—*Merula* perhaps. Typically passerine or otherwise, however, one would be surprised to note the variations in form in some of these bones among these oscine honey-birds, creepers, and their kin. To appreciate this to the full extent, the skeleton of the limbs of the several species would have to be brought up, either in drawings or plastic models, to many times the size of the original, and *then* compared one with another. Take the *humerus*, for example: had we models of this bone from all the species in our list each twenty centimetres long, and the other proportions correctly reproduced, we should be surprised at the differences which exist in them, which by this means could easily be recognized at a glance, but which otherwise must be studied by passing from one to the other with a good lens to assist you.

In *Arachnothera magna* the *humerus* has a length of 2·2 cms., and its smooth shaft is nearly straight, presenting hardly any of the usual sigmoidal curve from whatever point we may view the bone. In form it is subcylindrical, being somewhat compressed, from its anconal aspect palmad. The *radial crest* is short and not very prominent, while the ulnar tuberosity is conspicuous, and the *pneumatic fossa* surrounded by a distinct raised margin, which between this concavity and the head of the bone on the anconal side is raised into a thin and projecting process. What is most peculiar is that the head of the humerus is *hollow* and the entrance to the concavity is seen on the anconal side, next to the pneumatic fossa, being separated from it by the aforesaid thin projecting process. A few small, scattered, pneumatic foramina are found at the bottom of the fossa, where they usually occur. At the distal end of the bone we find the oblique and ulnar tubercles much produced with the olecranon fossa circumscribed and well marked. It is confined to the ulnar side of the shaft. The ecte- and entepicondylar processes are both distinct though not large apophyses. In all these birds there is to be found a *free sesamoid* at the elbow-joint.

Arachnothera longirostris has a humerus resembling the bone in *A. magna*, but in it the *caput humeri* is not hollowed out in the manner described above. In both species there is a distinct and circumscribed pit at the distal end of the shaft on the palmar surface right next to the ulnar tuberosity. This humerus has a

length of 1·7 cms. Considering its size, the proximal end of the bone is expanded in *Leptocoma grayi*, and the processes at the distal extremity conspicuous; otherwise the characters are quite identical with those in the humerus of *A. magna*. It has a length of 1·3 cms.

Cinnyris chalybeus has the caput humeri but very slightly hollowed out, and the bone has almost the appearance of being non-pneumatic. In any event, by the aid of a strong lens, I failed to find pneumatic foramina at the base of the fossa. The radial crest is considerably aborted, and a long shallow notch cuts out a portion of its free continuity. The bone is 1·2 cms. long.

Among the Cœrebidæ, *Diglossa baritula* has a non-pneumatic humerus, measuring in length 1·2 cms. Its distal processes and tuberosities are made conspicuous by their distinctness—clean-cut and produced, as it were. There is not a little hollowing out of the head of the bone next to the pneumatic fossa, the concavity being fairly well separated from the latter by a thin osseous partition, as in *A. magna*. These two cavities practically merge in such a form as *Anthreptes malaccensis*, and the partition between them in other species, though well produced, has withdrawn toward the proximal end of the bone. It has a length of 1·6 cms. and appears to be non-pneumatic.

In *Cyanerpes cyanea* this mergence of the pneumatic fossa and the very profound excavation of the *caput humeri* is practically complete—the merest vestige of an osseous partition existing between them. The radial crest is very short; and this humerus, too, appears to be non-pneumatic or very largely so. It has a length of 1·5 cms. Without particularly examining this bone in other Nectariniidæ, Cœrebidæ, or Certhiidæ—though it may be said with respect to the latter that in *Climacteris scandens* the humerus presents very different characters, for in it the *caput humeri* is not hollowed out at all, the pneumatic fossa is very open, the foramina large, the entire bone pneumatic, and the shaft somewhat curved (length 2 cms.)—we may pass to a study of the bone in the Meliphagidæ. Here in *Acanthorhynchus*, *Entomyza cyanotis*, and *Acanthogenys rufigularis* the *caput humeri* never exhibits the slightest indication of any hollowing out or any cavity leading in to it next to the pneumatic fossa. The latter is large, deep, with its free margin much thickened, and the pneumatic foramina at its bottom big and more or less numerous, as the bone in these birds is highly pneumatic. The subcylindrical shaft displays to same degree the sigmoidal curve and in some species is stout for its length, as in *Prosthemadera novæ-hollandiæ*. The radial crest is short and not very prominent, while the tubercles and processes at the distal end are so.

Passing to the bones of the *antibrachium*, *carpus*, and *manus* we find that they present among these families, including

Arachnothera magna, fewer distinctive characters than do the humeri for the species examined. All are essentially passerine and more or less typically so. *Radius* and *ulna* of the fore-arm are invariably straight, and present the characters common to the group. On the shaft of the ulna the papillæ for the quill-butts of the secondary feathers of the wing may be very well pronounced (*Entomyza*) or entirely absent (*Arachnothera*, *Prosthemadera*, and most others).

The *middle metacarpal* is always produced beyond the main bone of the metacarpus—the index metacarpal,—and I have never met with any *claws* on any of the terminal phalanges. There is always present a triangular, flattened process at the proximal end, ulnar side, outer aspect of the index metacarpal which is directed backward and rests flat against the proximal end of mid-metacarpal.

Radiale and *ulnari* of the wrist are invariably well-developed and present the usual passerine characters.

The Pelvic Limb.—Upon comparing the bones entering into this extremity in *Arachnothera magna* with the corresponding ones as we find them in the legs of the cœrebidine, certhidine, and meliphagidine species at hand, it is to be observed that the characters upon the whole are more uniform than they are for the bones of the pectoral limb. Osteologically, the limb is of a strictly passerine type throughout, and when compared, bone for bone, with the limb in any of the non-passerine suborders, presents more or fewer differences. As a rule, in the former the long bones of the thigh, leg, and metatarsus are quite straight, and in the case of the femur and tibio-tarsus have cylindrical shafts. *Entomyza cyanotis* offers an exception in the case of the latter bone, for instead of its shaft being entirely straight it is seen to curve away from the fibula above the fibular ridge and approach it again proximally to articulate with the latter and the femoral condyles. This condition is not usually seen or is much less marked among other meliphagidine species. As in the case of the bones of the antibrachium and manus, all the bones of the pelvic limb are non-pneumatic, and the nutrient foramina that enter them are very minute.

In the *femur* the semi-globular head is sessile, and the pit for the *ligamentum teres* generally very feebly marked. Distally, the summit of the bone includes a part of the head, the great trochanter, and the valley between the two, thus forming one surface, which is articular, and lies in a plane to which the longitudinal axis of the shaft of the bone is perpendicular. Distally, the condylar end of the femur is well-developed and presents the usual passerine characters. The depth of the *rotular channel* varies in different species and families, being rather deep in *Arachnothera* and generally shallower in the Meliphagidæ.

As in the majority, if not in all, oscine passeres, the species

here under examination possess a well-developed osseous *patella*. As we would naturally expect, it varies in size for the species, but very little with respect to form. In *Arachnothera magna* it is of a cordate outline, with the much rounded apex below, convex anteriorly, and decidedly concave on its upper and posterior aspects. Posteriorly, the concavity is double, the surface between being intended to accommodate itself to the femoral condyles. In *Prosthemadera novæ-hollandiæ* the patella has a transverse diameter of half a centimetre, and is two millimetres deep at the centre.

Tibio-tarsus supports the usual pro- and ectocnemial processes, and these have their common passerine form, varying but slightly for any of the species here being examined. In all cases they rise but slightly above the summit of the bone; they extend only a very short distance down the shaft, and both are always turned slightly fibulawards. Their antero-inferior angles may be sharp-pointed (*Arachnothera*, *Cœreba*, and *Diglossa*) or they may be rounded off as in the Meliphagidæ. They are very conspicuous and far apart, and produced almost directly to the front in *Climacteris scandens*. Always feebly developed, the *fibula* is but rarely produced beyond, or much beyond, the fibular ridge on the tibio-tarsus in articulation. It is a weak bone, of but slight importance in all small passerine forms.

Tarso-metatarsus presents nothing of marked departure from the ordinary form of the bone among all small passerine birds. Its *hypotarsus* is always reduced to a small subcubical apophysis vertically pierced for the passage of tendons. The shaft is always more or less flat anteriorly, and longitudinally grooved behind. The three distal trochlear processes are found in nearly the same transverse plane, with a large, free *accessory metatarsal* directed backward.

As to the skeleton of the *pes* it is purely passerine in its morphology, with the joints of the toes on the usual plan. All of these species have the *ungual joints* large and much curved, especially is this the case with respect to the *ungual phalanx of the hallux* in the larger species of the Meliphagidæ.

Ossification in these birds, and probably in others, may normally extend to some of the tendons of the muscles at the back of the tarso-metatarsus between the hypotarsus and the accessory metatarsal of the hallux, which is markedly the case in *Entomyza*.

Conclusions.

It is clear from what has been brought out in this paper that none of the species of birds here osteologically passed in review, employing *Arachnothera magna* as the type, has any especial affinity with the Trochili. Even the morphology of the tongue in quite a number of the forms has no significance when taken in

connection with the rest of the anatomical structure, which in the Humming-birds is so decidedly non-passerine, while in all the families here investigated the osteology at least points most distinctly to the Passeriformes.

There are a few faint cranial resemblances to be seen upon comparing that part of the skeleton of a Humming-bird with the corresponding structures in certain Cœrebidæ, or even Nectariniidæ, but they amount only to resemblances and no more. These are interesting, but they have no bearing whatever upon affinities.

As to the probable relations of these several families—the Nectariniidæ, Cœrebidæ, Certhiidæ, and Meliphagidæ—to each other and to other groups, we are confronted with an entirely different question, and one by no means easy of settlement. In my paper on "An Arrangement of the Families and the Higher Groups of Birds" my provisional opinion has already been presented. There the Meliphagidæ stand between the Nectariniidæ and Certhiidæ—the three families being kept together and placed between the Dicæidæ and Mniotiltidæ. From these the Cœrebidæ are well separated, being placed between the Drepanidæ and Tanagridæ, with several families intervening, including the Larks and Finches. I do not know that this opinion has in any way been shaken or disturbed by the examination of the material Mr. Beddard has so kindly placed at my disposal; still before my convictions come to be any firmer or more settled, I would prefer to investigate the anatomy of a great many more species of families evidently related, than I have up to the present time. Were I to propose a change in my arrangement I would say perhaps that the Cœrebidæ should hold a place in closer relationship to the Creepers and Warblers, which I am rather inclined to think that they do. As a family, however, the Cœrebidæ are undoubtedly very distinct, certainly from the Nectariniidæ, here made to include the former family Cinnyridæ. The examination of the skeleton of such a form as *Diglossa baritula* would be quite sufficient to establish that fact, and this has been done in the present contribution. A few more Sun-birds and Honey-suckers should be examined, especially of the genera *Drepanis* and *Meliphaga*, which I have not as yet seen. *Cinnyris* is a genus of the Nectariniidæ, though not typical of that family. I have in former years examined many of the Sittidæ—the Honey-creepers (*Cœreba*) are quite distinct from them.

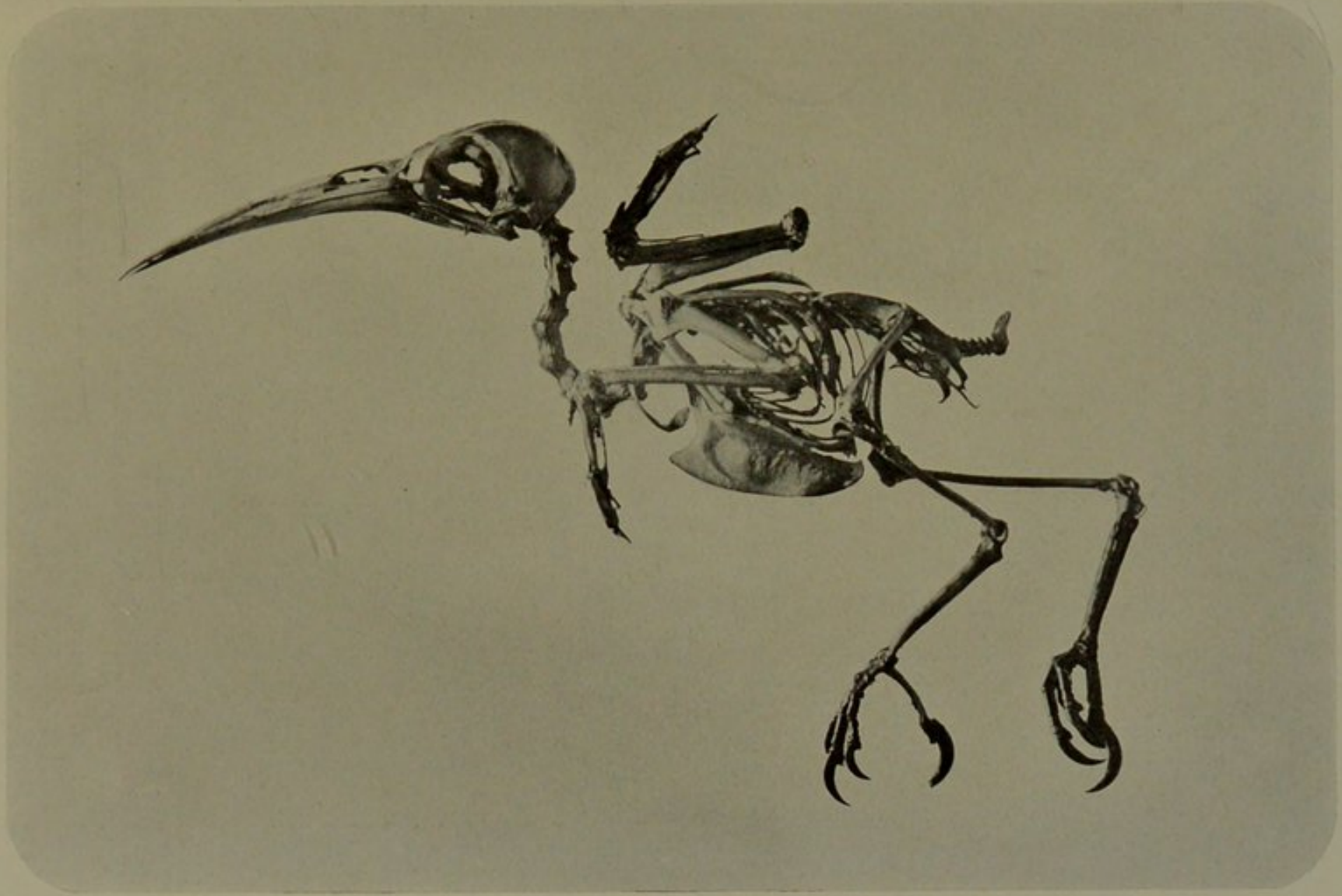
Climacteris scandens as a representative of the Certhiidæ clearly points to the fact of the distinctness of that family, but I should like to examine the skeletons of other species of Wall-creepers.

A far greater number of the Meliphagidæ need investigation, and the genera here examined do not point, in so far as their skeletons go, to any very close relationship with the Nectariniidæ, as exemplified in the genus *Arachnothera* and others. Especially

does this required research apply to the subfamiles *Myzomelinæ*, *Melithreptinæ*, and *Meliphaginæ*. Possibly the representatives of some of these are more nearly affined to such a species as *Arachnothera magna* than some we have seen. In any event my labour will not have been in vain if what has here been brought out with respect to the osteology of the four meliphagidine genera examined proves to be of any assistance in that direction.

EXPLANATION OF PLATE LXVIII.

Left lateral view of the skeleton of *Arachnothera magna*. Adult. Natural size. Right ulna fractured at its proximal third. Preparation partly ligamentous; podothecæ not entirely removed. Reproduced from photograph of the specimen by the author.



SKELETON OF ARACHNOTHERA MAGNA.

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