in nestling plumage, Oct. 27, Divala, October, November, and December.

**Arremonops conirostris** (*Bp.*). — Six specimens, both sexes, Divala, November and December.

**Sporophila aurita** (*Bp.*). — Five specimens, both sexes, Divala, October and November.

**Volatinia jacarina splendens** (*Vieill.*). — One adult ♂, Divala, November 17.

**Icterus galbula** (*Linn.*). — Two males, Divala, December 9.

**Sturnella magna inexpectata** *Ridgw.* — One ♀, David, October 16.

**Amblycercus holosericeus** (*Licht.*). — Nine specimens, both sexes, Divala, November and December.

**Cacicus microrhynchus** (*Scl. & Salv.*). — Five males, Divala, November and December.

**Ostinops decumanus** (*Pall.*). — One adult ♂, Divala, November 12.

**Zarhynchus wagleri** (*Gray*). — Three specimens, both sexes, Divala, November and December.

**Cassidix oryzivora mexicana** (*Less.*). — One adult ♂, David, October 15.

## THE CLASSIFICATION OF BIRDS.

BY HUBERT LYMAN CLARK.

THERE is a good old saying that "fools rush in where angels fear to tread," and the writer is aware that in approaching such a very complex subject as the classification of birds, without far more experience than he has had, he is laying himself open to a very prompt and simple classification under the above given rule. His only plea is that a simple classification of birds, one comparable with the classification of other animals, is greatly to be desired, and he believes that in the field of pterylography a way to such an end may be found. If one takes the trouble to examine the classifications of birds as given in the most recent elementary zoölogies, and compares them with classifications by ornithologists like Gadow or Sharpe, it will be perfectly obvious that general zoölogists prefer to cling to the old, worn-out 'orders' of Cuvier and his immediate successors, than attempt to introduce their students to the score or more 'orders' of present-day authorities. The belief is very general among zoölogists that the *orders* of birds

do not correspond with the *orders* of other classes, being based on far less important structural conditions. That there is good ground for such belief is shown by the fact that the class Crustacea, with as many species as Aves, is very generally grouped in a dozen orders or less; the Gastropod Mollusks, with nearly fifty per cent more species than Aves, are almost universally included in *three* orders; while the schemes for avian classification contain twenty orders or more, or, worse still, are divided into *gens*, *super-orders*, *super-families*, and other indefinite groups which, to an elementary student only makes "confusion worse confounded." That this is a real difficulty in giving ornithology its proper place in a course of zoölogy, other teachers besides myself can testify.

The cause of this trouble, it seems to me, is to be found in the importance that has been placed on characters which are by no means fundamental in the structure of birds. Originally the orders of birds were based on characters of the bill and feet; but it was long ago recognized that those characters are very unreliable, because so readily modified according to habits and food. In seeking more stable characters, ornithologists turned to the skull and other parts of the skeleton, the muscles, the wings, and even the viscera. But as our knowledge of avian anatomy has increased, we have been forced to admit that in all these points, changes of habit are soon followed by changes of structure, and it becomes a matter of great difficulty to trace real relationship. Owing to the large number of possible combinations of characters, which ornithologists regard as of more or less importance, the comparatively homogeneous group of birds has been split up into numberless orders. The remedy is to be found in a rearrangement of avian characters, with a careful estimate of their relative value, so that those that are least liable to change shall be accorded the most weight. In Gadow's well-known scheme for the classification of birds, published in 1892, he made use of more than forty characters, to determine the mutual relationship of the groups. A careful examination of this list shows a very large number which are of slight value because of their marked tendency to be easily modified, while others are omitted which ought to be of great value because of their slight tendency to vary. For example, there are no characters of which use is made, connected with the reproductive, ex-

cretory or central nervous system. It may be said that these systems are too uniform throughout the class to be of any value in classification, but it is very possible that a more intimate acquaintance with their structure will make them of very great value.

The question now confronts us, What characters are of the most importance in determining the relationship between two birds, and what are of the least value? There can be little question that the least valuable characters are those connected with the form and external characters of the bill and feet. Somewhat more valuable, but still very uncertain, are the characters of the wings and tail, and hardly more valuable is the nature of the plumage, such as the presence or absence of down, aftershaft, tuft on oil-gland, etc. The arrangement of viscera, muscles, and blood-vessels, are of some value, but probably less than the characters offered by the skeleton. It must be borne in mind, however, that the skeleton, and especially the skull, would be very liable to marked changes, accompanying changes in the bill, feet or wings, so that skeletal characters are by no means as indicative of real relationship as many writers assume. Certain characters connected with breeding, as the condition of the young when hatched, are of considerable importance; but there is reason to believe that even these are rapidly modified under changed conditions. As already suggested, the structure of the urino-genital organs, and the central nervous system would probably be very slowly modified, and ought therefore to furnish some very valuable fundamental characters. It is the purpose of this paper to show that the arrangement of the contour feathers, that is, the *pattern of the pterylosis*, is a similar character, in that it is only slowly modified, and therefore serves as a most important clue to the relationship of the various groups of birds.

The general opinion among ornithologists at the present time is that the pterylosis offers us little assistance in determining the relationship of birds, because it is believed that the arrangement of the feathers is governed largely by the shape of the body, and that the distribution of the tracts depends to a considerable degree on the habits of the bird. It is hard to see how this opinion has arisen, for there is much evidence to the contrary. If one will compare a plucked Swift and Swallow, a Colie and Cuckoo, an

Auk and a Loon, it will at once appear that though the body shape is very similar, the pterylosis is strikingly different, while on the other hand, birds with very differently shaped bodies, sometimes have the pterylosis very much alike; for example, a Goose and Petrel, or (on the dorsal surface) a Loon and a Flamingo. That the pattern of the pterylosis is very slightly modified by changes in habit, is admirably shown in the Water-ouzels, where the feather tracts are similar to those of the Thrushes, although the habits of the bird have caused the development of a dense coat of down over the whole body, a condition unique among the Passeres. In the light of these facts it is clear that we cannot assume that the pattern of the pterylosis is a recently acquired and unstable character, and we must look for further evidence as to its value. An examination of some Hummingbird embryos, just before hatching, shows that the characteristic pterylosis is, even then, clearly marked out. This would seem to indicate a deep-seated character, for otherwise the feathers ought to appear uniformly on the back and underneath, and only assume the characteristic arrangement with the growth of the bird. A good illustration of the fact that the line of development of a special form of pterylosis would appear in the embryology of the bird is afforded by the Swallow, which, as is well-known, has a very characteristic and peculiar saddle-shaped dorsal tract. In a large series of young Eave Swallows (*Petrochelidon fulva*) from Jamaica, ranging in age from embryos which are just assuming the form of a bird up to those large enough to fly, I find that the dorsal tract as first marked out is much more like that of Swifts, than like the adult Swallow; that is, it is first a broad, dorsal patch with a small central apterium. Later on, it begins to assume more the condition characteristic of the adult, but that condition is not fully attained until the bird is able to fly. It seems to me that the young Hummingbirds, and the young Swallows together, show that the pattern of the pterylosis follows the same laws of heredity as other characteristics, and the later modifications of the pattern appear later in the development of the individual. Thus the Hummingbirds, being nearer the ancestral form in the pattern of the pterylosis, show that pattern from the start, while the Swallows, being more specialized, simply pass through that stage in the develop-

ment of their own characteristic pattern. A similar illustration is found in a comparison of the embryos of a Rail (*Rallus longirostris*) with those of a Heron (*Ardea tricolor*) which shows that the two, just before hatching, have very similar pteryloses, which are distinctly heronlike. A more important point shown by the Heron embryos, is that the powder-down tracts are a more recent acquirement than the pattern of the pterylosis, for only one of the three pairs is indicated at all, and the presence of that pair is shown only by the peculiar color and appearance of the skin. The pair present is the femoral. I thought I could find indications of the ventral pair, but those near the furcula are entirely wanting.

These facts, though few in number, seem to me to indicate very strongly that in the pattern of the pterylosis we have a character which has changed but slowly, and is liable to little variation, and is therefore of primary importance in seeking the proper classification of birds. Indeed there is little reason why the *general pattern* should change, for necessary differences in the thickness of the feather-coat would naturally be brought about simply by widening or narrowing the main tracts. That this is the case is readily seen by comparing the tracts of a Goose and a Petrel, where the pattern is essentially the same, but the tracts of the more active bird are much narrower. In the taxonomy of the Crustacea, a class characterized by a segmented external skeleton and jointed biramose appendages, the division into orders is based on the number and arrangement of segments and appendages; and in other classes of animals the primary divisions are based on variations in the principal character of the class. It is both fitting and desirable, therefore, that the great class Aves should have its orders based on variation in its striking character, — the body covering of feathers. Such orders would be clearly equivalent to the orders of other groups.

But is it possible to adopt any such standard and arrive at any definite results in the classification of birds? After a careful study of Nitzsch's work, and a review of my own in connection with it I find there are eight distinct, and, in general, easily recognized patterns of pterylosis in the class of birds. There are, besides, two very distinct groups of birds which have no apteria, but have

the body uniformly covered with feathers. It would be possible, therefore, to divide birds according to the pterylosis into ten orders, nine of which belong in the subclass generally known as Carinatæ. The group Ratitæ have so many characters in common which distinguish them from other birds, it is a convenience to regard them as a subclass, of equal rank with the Carinatæ. So far as the pterylosis is concerned, they comprise, however, only a single order. This type of pterylosis may well be called

STRUTHIONIFORM.

Adult without apteria or oil-gland; plumage soft and lax, intermediate between down and contour-feathers.

In the Carinatæ, the adults all have contour feathers, the pterylæ are generally clearly defined, and the oil-gland is usually present. If distinct apteria are wanting, the oil-gland is well developed. The following are the patterns of the pteryloses of the Carinate birds.

SPHENISCIFORM.

Adult without apteria, but with oil gland; plumage dense.

This style of pterylosis is characteristic of the Penguins.

COLYMBIFORM.

Upper and lower cervical tracts not separate until near shoulder.
Upper cervical tract deeply forked but branches not diverging.
Dorsal tract broad, separate from cervical, and without any apterium.
Humeral tract broad and distinct.
Femoral tracts small, mostly separate from dorsal.
Sternals broad, directly continuous with branches of the lower cervical, which is quite deeply forked; and with no side branch.
Ventrals *very* broad, directly continuous with sternals; ventral apterium narrow but broadest behind.

This style is characteristic of the Loons and Grebes.

### ANSERIFORM.

Upper cervical tract not separated from lower until near shoulder; forked, branches diverging somewhat.

Dorsal tract directly continuous with upper cervical, thus enclosing a more or less elongated apterium.

Humeral tracts broad and strong, sometimes connected with the dorsal.

Femoral tracts large, united with dorsal.

Sternals directly continuous with lower cervicals, and usually with a prominent side-branch.

Ventrals very broad, directly continuous with sternals; ventral apterium very narrow, and not notably broader behind.

This style characterizes the Petrels, Albatrosses, Pelicans and other totipalmate birds, Auks, Geese, Ducks and Swans.

### FALCONIFORM.

Upper cervical tract well-marked, usually narrow; strongly forked between the shoulders; slightly or not at all connected with the dorsal tract; branches diverging.

Dorsal tract very variable, either broad or narrow, forked or solid.

Humeral tracts strong but not very broad.

Femoral tracts wanting or very weak; the feathering of the tibia is usually very full and a strongly marked patch sometimes crosses the head of the tibia and runs along the femur a distance.

Lower cervical tract considerably forked.

Sternals very strongly marked.

Ventrals narrow but widely separated on belly; wider on the breast and more or less fused with the sternals; sometimes united only at the furcula (*Asio*), sometimes also touching at edge of sternum (*Strix*), and sometimes united the full length of the breast (*Pandion*).

This style is shown by Vultures, Hawks, Owls, and other birds of prey; and probably Parrots also.

### PELARGIFORM.

Upper cervical tract divided very deeply on the neck but the branches not diverging.

Dorsal tract solid or deeply forked (toward rear), more or less connected with cervical.

Humeral tracts well marked.

Femoral tracts long but narrow, and not very strong.

Lower cervical tract similar to upper but the division is not so deep, and the branches tend to diverge.

Sternals broad (compared with the other tracts), continuous with or separate from the lower cervical.

Ventrals broad and continuous with the sternals, sometimes separated from the latter, for some distance, joining near the furcula.

This type characterizes the Rails, Cranes, Storks, Herons, Bustards, and Flamingoes.

### CHARADRIIFORM.

Upper cervical tract sharply defined, not very deeply forked, the branches diverging.

Dorsal tract more or less forked (toward rear), slightly if at all connected with forks of upper cervical.

Humeral tracts narrow.

Femoral fairly strong, usually narrow and distinct.

Lower cervical tract very deeply forked, continuous with sternals.

Sternals moderate in size but strong.

Ventrals narrow or only moderately wide, well separated on the belly, joining the sternals on the breast usually near the furcula.

This type is shown by the Gulls, Terns, Plovers, Snipes, Sandpipers, etc.

### GALLIFORM.

All the tracts broad, but usually well defined.

Upper cervical tract usually more or less merged with the dorsal, but sometimes more or less distinctly forked.

Dorsal tract broad, sometimes very broad posteriorly; often with a mid-dorsal apterium; occasionally connected with the femorals.

Humeral tracts broad and very strong.

Femoral tracts very large, sometimes uniting with the dorsal.

Lower cervical tract rather deeply forked, the branches continuous with the sternal tracts.

Sternals very strong, widest anteriorly, connected with ventrals near furculum or not at all.

Ventrals narrow, not widely separated on belly, narrowest anteriorly, united posteriorly in front of anus.

This type is shown by the Gallinaceous Birds, Curassows, and Tinamous.

### COLUMBIFORM.

Upper cervical tract wide, strongly forked between shoulders, often united with lower cervical, until near the shoulders.

Dorsal tract very broad and diffuse, fairly separable from cervical, but inseparable from femorals.

Humeral tracts very broad and strong.

Femoral tracts large, not distinct from dorsal.

Lower cervical tract slightly or not at all forked, continuous with the sternals.

Sternals broad, completely united with the ventrals.

Ventrals broad, not widely separated, but not united posteriorly.

This type is clearly shown by the Pigeons and Sand Grouse.

### PASSERIFORM.

Upper cervical tract narrow, well-defined, and continuous with the dorsal tract.

Dorsal tract not clearly distinguished from the cervical, more or less widened (often enclosing a prominent apterium), generally narrowed as it approaches the tail. The dorsal tract is frequently distinctly divided into two parts, the anterior of which is usually forked; less commonly the posterior part is forked.

Humeral tracts moderate, frequently narrow.

Femoral tracts usually weak and small, sometimes wholly wanting, and sometimes quite clearly defined.

Lower cervical tract more or less forked.

Sternals usually strong and well-marked.

Ventrals rather narrow, widely separated on belly, and not reaching the anus; usually not separated from sternals, but sometimes partly distinct.

This type is shown to a greater or less degree by all those birds, usually classed as Cuculiformes, Coraciiformes and Passeriformes. Its varieties are fairly constant and may assist in the arrangement of these groups in suborders and families.

The following table will help to make the character of the ten types more easily grasped, but it must be borne in mind that this arrangement is very artificial and is in no sense a 'Key.'

- Apteria wanting.
  - Oil gland wanting . . . . . *Struthioniform.*
  - Oil gland present . . . . . *Sphenisciform.*
- Apteria present.
  - Upper cervical tract deeply forked, the branches not diverging.
    - Ventral tracts very broad, diverging on the belly . . . . *Colymbiform.*
    - Ventral tracts much narrower than sternals, converging on the belly . . . . . *Pelargiform.*
  - Upper cervical tract not as above.
    - Femoral tracts very broad, often united with the dorsal tract.
      - Dorsal tract directly continuous with the cervical and containing a more or less elongated narrow apterium . . . . *Anseriform.*
      - Dorsal tract not as above.
        - Ventral tracts not directly continuous with sternal tracts, narrow and united posteriorly . . *Galliform.*
        - Ventral tracts wide, continuous with sternals, and not united with each other . . . *Columbiform.*
    - Femoral tracts narrow, weak, or wholly wanting.
      - Upper cervical tract directly continuous with dorsal and not forked . . . . . *Passeriform.*
      - Upper cervical tract forked and branches diverging.
        - Femorals narrow but clearly marked . . *Charadriiform.*
        - Femorals very weak or wanting . . . *Falconiform.*

These ten types are so constant and in general so easily recognized, it seems to me they might well be made the central characters of ten orders; and we should find that such orders are not unnatural groups, but are characterized by many other important features. For example, the birds with the charadriiform pterylosis are nidifugous, schizognathous, with two carotids and aquincubital wings. There are, perhaps, other characters, but I have not attempted to determine them all. Such a group might well be called the Charadriiformes. Or the birds with the falconiform pterylosis are all nidicolous, desmognathous, with aquincubital wings, two carotids and epignathous, cered bill, and may well be designated as Falconiformes. That it is not unnatural to associate the Parrots with raptorial birds, will appear to anyone who will examine Gadow's comparison of the two groups, which shows that out of forty characters they have twenty-nine in common, including those which seem to me must be granted to be of the most significance.

It is of interest to see how basing classification primarily on the pterylosis will affect the position of certain doubtful forms. As is well known, the Tinamous will belong with the Galliformes and the Sand Grouse with the Columbiformes. The Flamingo is distinctly pelargiform. *Opisthocomus* is not at all galliform, but, curiously enough, is quite distinctly falconiform. The Bustards are clearly pelargiform and thus quite separate from the Charadriiformes. *Psophia*, on the other hand, is apparently more like Plover than Stork. The Auks are not nearly related to the Gulls and Terns, but are not far from the Petrels, and very possibly the Penguins are merely a further specialized shoot of the same branch.

It would give a very wrong impression, were I to close this paper without referring to any of the difficulties which lie in the way of making such use of the pterylosis for a primary character, as I have suggested. The number of orders would not be reduced thereby as much as was to be hoped, but ten is certainly better than twenty. More important than this, however, is the fact that the orders are by no means equally well-defined. The Anseriformes, for example, are difficult to characterize except by the very distinctive pterylosis, while the Colymbiformes and Galli-

formes are quite easily defined, with many important characters. A greater difficulty still is found in the fact that certain birds, such as *Buceros* and *Colius*, have a pterylosis so peculiar it is hard to compare it with any of the types. Moreover, various birds show a pattern of pterylosis, which at first glance is more like some totally different group, than like their admittedly nearer allies. Such, for example, are the Albatross, *Opisthocomus*, and Goatsuckers, all of which are strikingly falconiform!

These difficulties, however, are none of them insuperable, when we consider three important facts. First of all, our knowledge of pterylography is very deficient; Nitzsch's work is based so largely on dried skins that his figures are often faulty, and conclusions drawn from them are liable to error; for example, his statements regarding *Podargus* and the relationship between the Goatsuckers and Swifts, are not borne out by examination of better material than he possessed. Secondly, the study of the development of the tracts has not yet received any attention, while, as I have already shown, it is a most important factor in determining the type of pterylosis and the value of the pterylographical characters. Finally, the pattern of the pterylosis must not be regarded as an infallible guide, but must be followed with caution. Although it is a deep-seated character, it is by no means beyond modification and even radical change, and where its leading is dubious, it must be controlled by the evidence offered by other characters. Some use in taxonomy has been made hitherto of certain pterylographical characters, but only in a small way, and it is my desire to call the attention of ornithologists to the great value that the *entire pterylosis pattern* has in classification.