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The manner of flight and its relation to the habits of certain birds

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THE

MANNER OF FLIGHT AND ITS RELATION TO THE

HABITS OF CERTAIN BIRDS.

A Thesis
Submitted to the Faculty of the Graduate
College of the State University of Iowa,
in Partial Fulfillment of the Require­ments for the Degree of Master of Science.

By

Dayton Eugene Merrill.

Iowa City, Iowa.

1910.
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INTRODUCTION.

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It is the ultimate purpose of this disquisition to show the relation between the habits and various manners of flight of representatives of all the orders and most of the families of birds. To do this it seemed best to give, first, a condensed, explanatory classification of the manners of flight, thus obviating any confusion as to the meaning of terms designating the type.

Second, descriptions of the flight of various birds are given, touching, in part, also, upon the alar adaptation for the particular type under discussion, these being taken up in systematic order. For the systematic classification, Ridgway's "Manual of North American Birds" was followed mainly, with a few departures as follows: Ridgway's orders Psittaci and Coccyges are given as sub-orders, Coccyges being changed to Cuculi, under an order Cuculiformes; the Strigidae and Bubonidae are placed, as a sub-order Striges, with the remainder of the Picariae, in an order Coraciiformes. These departures are according to the classification followed in "Birds of the World", Knowlton and Ridgway, 1909.

Succeeding this, is given a tabulation of birds according
to manner of flight, providing an easy survey of the comparative prevalence of each type.

The fourth part discusses the relation, proper, between the flight and habits. The discussion, concerning the relation between flight and habits, is based on the primary needs for flight, viz.; for migration, for securing food, and for protection from enemies. It has not seemed in the scope of this paper to touch upon the aspect of flight concerned, apparently, merely in courtship, this phase not being deemed vital.

Finally, is given an annotated list of references alluded to in this paper.
PART I.

AN EXPLANATORY CLASSIFICATION OF THE FLIGHT
OF BIRDS ACCORDING TO MANNER.

The flight of birds, according to manner, is classified under two main heads: Flapping and Sailing or Soaring. These two involve distinct, characteristic principles. There is a third class, an intermediate sub-head, Gliding. For our purposes the first two will be used for reasons to be seen from the definitions given below.

I. Flapping is the primary method of flight, in that neither Gliding nor Sailing can be accomplished entirely without it, except in ideal instances, such as pitching from a high perch, or starting in an excessive wind, when these might be accomplished.

In preparation for the stroke, from a condition of rest, the humerus is elevated and brought forward at an angle with the body, this same movement serving to extend the forearm and hand so as to bring the flight feathers automatically into position for the stroke. The wing, now expanded, moves forward, the anterior edge being higher than the posterior. When far enough forward, the distance varying as the power and amplitude of the stroke to be delivered, the wing strikes from above forwards slightly, then downwards, and finally slightly backward. This curved stroke gives, in order, elevating, sustaining, and projecting power. At the end of descent the posterior edge of the wing is slightly above the anterior. The variations in the amount of wing concerned in the active stroke
are great, ranging from the complete, open wing beats, as in Chaetura pelagica, to the open-shut movement, as in the Sparrows.

In preparation for the upstroke, the humerus is raised from below the horizontal, gradually up and in at the same time. This flexes the wing as desired and presents least resistance surface by changing the convex contour, presented at the end of descent, to the narrow edge forward. The remiges also separate to allow the air to escape more readily. The wing is now ready for elevation and extension as before.

However, the change in direction of the inferior surface, from slightly backwards looking at the end of descent, to forward looking in ascent, is made gradually and there must be some forward, if downward, projecting power in the upstroke, the forward element more than overbalancing the downward, since the elasticity of the air, partially compressed by the downstroke, would counterbalance, in part, the downward tendency.

Thus the trajectory of the body is wave-like, and of the wing tip a series of backward directed, open S's (Capital, script) thus: \[ \text{backward directed, open S's} \], whose upper portion is made in extension of the wing, and whose bases are made in flexion. The whole is inclined from the perpendicular, in proportion as more or less flexion is employed on the upstroke.

Note. The hovering of the hawk or the poising,
vertical or horizontal, of the Hummingbird, may be noted here in connection with Flapping flight. These differ from real flight, in that there is no translation horizontally, to add the effect of momentum to that of the expended muscular energy. In these, as well as in the vertical rising of the Lark, the wings must vibrate rapidly enough to counterbalance gravity in toto and exert sufficient lifting or sustaining power at the same time. There must also be a difference in the direction of the application of the stroke to prevent motion forward. The stroke, unflexed and usually short in amplitude, especially in hovering, in this case is applied downward with a very slight forward inclination. This gives sustaining or elevating force and checks horizontal translation. The strength, amplitude and rapidity of the vibrations determine if the bird shall remain stationary or rise vertically.

II. In Sailing or Soaring flight, the wings are kept outstretched and there is no flapping. The plane of the wings is inclined upward from the horizontal, from comparisons from 5° to 30°; the center of gravity travels forward or back as occasion demands; and, given an initial velocity and a breeze, minimum, at any rate, this manner of flight is sufficient to accomplish progression indefinitely.

The initial velocity may be acquired by flapping, running, jumping, or pitching from an elevation. If the wind be excessive,
Soaring flight may be started without any of the preceding preliminaries.

The ability of the bird to shift the center of gravity by changing the amount of surface exposed in different velocities of wind, is the envy and desire of the aviator. The bird accomplishes this by means of flexible wing tips, flexions of the hand, by moving the whole wing back and forth, and by varying the position of the head, neck and tail. The "ailerons" of the airship are in great part instrumental in subserving this purpose in case of man's winged machine.

A number of theories have been advanced in explanation of this manner of flight, but no one is wholly sufficient. In this paper these can only be named and a few observable data and fairly evident points given. Some of the theories are:

1. Theory of ascending currents.
3. Varying velocities of strata of air in
   a. Superposed currents.
   b. Collateral currents.
   c. Vortices.
4. Internal fluctuations of wind.
5. Hypothesis of the Unstable Equilibrium in the Lower Atmosphere.
7. Swell of Air Theory.

Recent explanations ascribe as necessary before Soaring Flight can take place, given the properly equipped bird, the two factors named above, viz.:

1. Initial velocity
2. Breeze, a minimum at least.

The start to soar is always made in the face of the wind and indefinite, ascending, rectilinear progression is impossible, unless the wind be very strong, the general course being in sweeping spirals, or in a series of U-shaped curves, and the whole usually inclined to the leeward. These two types are, of course, subject to great variation. In either type, usually (1) a part of the course is on an incline and a part on a decline, the former being made in the face of the wind, and the latter with the wind. The ascent may be steady, however, with no decline when going with the wind. The turns are made when the general direction of the wind is at right angles to the bird's axis of progression, and the angle of turn seems to coincide with the angle of lateral incidence of the general current to the longitudinal axis of the bird. This indicates that sailing could not be accomplished at right angles to the wind, since the horizontal resultant of the impinging force would cause

(1). See discussion of Archibuteo lagopus sancti-johannis, p. 38.
lateral translation direct, in place of direct or curved forward translation, the normal resultant not differing materially. This is not to say the bird could not float or drift with the wind for a time, and still have the body "crosswise" with the wind.

The source of the power of ascension is in the elasticity of the air when opposed by a plane, advancing at a certain rate, horizontally, and inclined at a certain angle - between 3° and 30° with the horizon. And this angle varies inversely as the velocity of progression and the strength of the breeze. All impact seems to be resolved into resultant forces of two kinds, normal and horizontal, whose ultimate effect is forward progression. Resistance is small but not to be disregarded and the initial velocity is maintained by the act of "sliding" down the decline, with the wind to assist in accelerating the velocity that was retarded by the preceding rise, in case the breeze be not strong enough for steady rise. That there is a balance in favor of the power of ascension, is indicated by the fact that the up sweep is longer, if anything, than the down and accomplishes, as well, a heightening of altitude. In a calm it is possible to sail for a time, on the same level, but the result will be, in time, loss of altitude or velocity, unless the initial velocity is maintained by occasional flapping.

The source of the initial velocity is given above and it is not in our province to try to demonstrate the exact effect of
the wind's pulsations, which, no doubt, play an important part in the preservation of the sustaining force by varying the inertia. And, finally, the reason for the circling or curved course, is that it is less fatiguing than a kite-rise, in that it requires less muscular energy to accomplish a given result and at the same time gives opportunity to utilize the potential energy of the wind's pulsations.

III. Gliding Flight is accomplished without flapping and on extended wings. The center of gravity is forward, generally, to overcome the increased resistance on the front edge of the wing, due to the horizontal translation, and to prevent tipping up in front. For the plane of the wing is horizontal or inclined downward with the horizontal in most cases. This manner of flight is marked in its continuance, by a loss in either velocity or altitude. An initial velocity of motion, or potentiality of the same, is necessary and may be acquired by a previous flapping or by descent from a higher to a lower level.

This method of aerial progression is not self-sufficient and is used only for inconsiderable distances, or in connection with one of the other methods. For this reason it is not placed co-ordinately with Flapping and Sailing.
PART II.

DESCRIPTIONS OF THE FLIGHT OF VARIOUS BIRDS
ARRANGED SYSTEMATICALLY.

These descriptions have to do only with the sub-class Neornithes.

ORDER I. STRUTHIONES.

The members of this order are all flightless.

Struthionidae.

In this family the wing is imperfectly developed and this, together with the loose texture of the wing feathers, renders the organ functionless. The few modified quills, or plumes, are worthy of notice as being one of the few extraordinary modifications of the remiges of birds, flightless or otherwise. In running, the wings are raised above the body and flapped somewhat. This aids in preserving the bird's balance, and, possibly, the wings act as sails in a slight degree but only when running with the wind.

Rheidae.

As in the Ostriches, the remiges are loose-barbed and drooping. Differing from the Ostriches, they run with both wings expanded and drooped or only one raised like a sail.
Dromaeidae.

Emeus have neither the plumes of the last two families nor even the spiny rudiments of remiges possessed by the next family, so are flightless entirely.

Casuariidae.

As hinted above, the Cassowaries have, in their quite rudimentary wing, from four to six stiff, rounded, webless quills, - rudimentary remiges of flying ancestors - from twelve to fourteen inches long. Needless to say they are flightless, since the only external evidences of a wing are these spiny quills.
ORDER II. APTERYGES.

Apterygidae.

In this family the wing is reduced to a slender humerus, about two inches long, weak, short, radius and ulna, and a single, fused digit. This is provided with a long external claw. The wing is feathered but there are no quills. It is flightless.
ORDER III. CRYPTURI.

Tinamidae.

The Tinamous have the wings functional, rounded and ample, though short, but the reduction of the pectoralis major (1) so deprives the bird of power to depress the wing that practically all ability to guide its flight is lost. Rhynchotus rufescens may be taken as a type. The usually low and absolutely rectilinear flight is started by rapid, noisy and violent flapping, followed by a glide of a few hundred yards. Only a few of these alternate periods of gliding and flapping serve to exhaust the bird for further flight.

Hudson (2) describes the flight thus. It "rises at a decreasing angle for fifty or sixty yards, then, gradually nearing the earth till, when it has got to a distance of two or three hundred yards, the violent action of the wing ceases and the bird glides along close to the earth for some distance and either drops down or renews the flight — " . He also states that they often dash themselves to death against obstacles if flushed unexpectedly. He gives further (3) a striking instance illustrating the inefficiency of its power to control the motion initiated by wing and wind. On being flushed in a high wind " the bird flew up into

(1) Standard Natural History, Vol. IV.; 52.

(2) F. H. Knowlton: Birds of the World; 78.

(3) Ibid; 79.
the air vertically, and, beating its wings violently, and with a swiftness far exceeding its ordinary flight, continued to ascend until it reached a vast height. Then it came down again, whirling round and round, striking the earth again a few yards from the spot where it rose, and crushing itself to a pulp by the tremendous force of the fall."
ORDER IV. SPHENISCI.

Spheniscidae.

These "feathered dolphins" of the Antarctic region furnish many departures from the conventional. They are flightless in air but use the wings entirely as means of propulsion under water, the feet being used only as rudders. In adaptation for this use the wings are short, blade-like; have practically no movement save at the shoulder joint; and are covered with very small, scale-like feathers. No quills are differentiated. The pectoralis secundus is "almost the largest of the three"(1) pectoral muscles. This is necessary in overcoming the resistance to the forward stroke under water. The alternate movement of the wings, like the blades of a screw-propeller, is peculiar to this group.

ORDER V. PYGOPODES.

The Pygopodes are most nearly pure flappers.

Podicipedidae.

With the Grebes the wing is short, concave, narrow and pointed, with about twenty secondaries and the exceptional number of twelve primaries.

Expert divers, they use only the lobed feet for sub-aquatic progression, never using the wings. In general the flight is strong, straight and rapid and accomplished by rapid vibrations of the wings. The head and feet are extended. They experience difficulty in rising from the water, it being necessary to run and "tread water" for some distance before getting under way. On descending they strike the water with a splash from full motion.

Centropelma micropterum, found only in Lake Titicaca, Peru, is flightless. The slight progress, outside of diving and swimming, is made by running on the water and flapping the rudimentary wings. (1)

Podicipes rufipes (2), of New Zealand, "flies with difficulty and only for short distances, skimming the surface with a very labored flapping of its little wings." (2)

(1) F. H. Knowlton: Birds of the World; 105.

(2) Ibid; 104.
Urinatoridae.

The Loons, or Divers, have the wing as in the Grebes, except it measures a little longer proportionally and has but eleven primaries. They are divers par excellence, and swim under water, using feet and half open wings to propel themselves. They have the same difficulty in rising that the Grebes do, but after getting under way with much flapping and "treading", the flight is exceedingly swift, usually rectilinear, somewhat labored, and may be sustained for considerable time. The head and neck are outstretched and the descent to water is as with the Grebes.

Alcidae.

In the Alcidae the wings are short, narrow and pointed. Flight is accomplished by rapid vibrations of the wings and most species fly strongly and rapidly in straight lines, but not for great distances. The wings are also used in swimming.

Lunda cirrhata. The Tufted Puffin flies very swiftly, absolutely rectilinear, changing direction by angle and not curves, but does not rise very high (1).

Simorhynchus. The Auklets fly straight as an arrow and so rapidly that the wonder is collisions are not met with on every side where so many thousand birds are wont to fly at once and in all directions.

Cepphus. The Guillemots are most expert sub-aquatic swimmers, and present a condition of the pectoralis secundus similar to the Penguins (q.v.).

Uria. The flight of the Murres is rapid but labored and heavy. At St. George's Island, Elliott says (1) that the males form in a long procession a quarter mile wide and thirty miles long and circle the island every morning and evening for several hours, always flying quartering on the wind.

Alca torda. With the Razor-billed Auks the wings are well developed and flight is strong. They often fly in long, close single file with rapidly beating wings (2).

Plautus impennis, the extinct Great Auk, enjoys distinction as the only flightless bird of the Northern Hemisphere. The remiges were normal but the reduction in size of the entire wing made it useless for flight.

Alle alle. "The Dovkie has a 'hurried' flight, and, while flying can dive into the sea without any interruption of the action of the wings, and also emerge from beneath the surface flying" (3).

(2) Ibid, 404.
ORDER VI. LONGIPENNES.

In this order we come to the first soaring flight, possessed by all its members in varying degree. The wings are long and pointed, with eleven primaries and little or no concavity. The primaries are rapidly graduated. These birds swim, some of them dip into the water with a semi-dive, some feed from the surface and one species is said to pursue its prey a short distance under the water.

Stercorariidae.

The Skuas and Jaegers are adepts in the piratical soaring, being able to sustain the flight for long times and being enabled by the long tail to execute sudden turns and quick evolutions.

Megalestris antarcticus, the Antarctic Skua, is predaceous and its raptorial nature is reflected in its actions, which are all very hawk-like, both on the wing and in the choice of a vantage point for perching (1).

Stercorarius parasiticus. This Jaeger is a persistent pirate and its flight has all the elements of agility, ease, sustaining power and exceeding swiftness, necessary to enable it to overhauls Terns, especially, and parasitize upon their disgorged prey. It swims well but can not dive nor plunge (2).

(2) Ibid; 77.
Laridae.

The Gulls (Larinae) are powerful flyers and are tireless in their endless quartering back and forth, low over the water. Without apparent effort they float in the air with scarcely a movement of the wing, skim the tops of the wave, down into the troughs, shoot upward, again wheel and turn in endless variations, and all with a distinct air of purposeful steadiness. When food is discovered, the din of fluttering wings and noisy cries gives the birds a different character as dozens of them try for the food of one. Satisfied in this quarter, they again resume the pendulum swing over the water. They feed from the surface of the water mostly, some species feeding partly in air on insects.

*Larus delewarensis*, the Ring-billed Gull, often is seen quartering over freshly plowed fields. It alights often to feed on food thus upturned but does not have so much difficulty in rising, experienced usually by soaring birds. It also flaps more on the wing.

The Terns (Sterninae) have proportionally narrower wings than the other members but their flight is hovering and irregular. They seem to float at times at random, unlike the steady Gulls, and flutter occasionally to set themselves right. They have, on the other hand, a buoyant dash and are rapid and graceful. On the whole, they are a strange mixture of the fluttering, uncertain flight of a
large butterfly and the dashing skim of a swallow. They dive headlong after fish from a considerable distance, often disappearing under water and even swimming a short distance. Then they shake off the spray and rise again(1).

**Rhynchopidae.**

*Rhynchops nigra*, or Black Skimmer, has a broader wing than the other members of the order, because of its habit of flying low over the water with its lower mandible skimming the surface, thus increasing the resistance. They fly back and forth Gull-like, measured and sweeping, but twisting and turning at times with extreme rapidity in their zig-zag course. The usual flight is the characteristic sailing of the order but the body is held with the foreparts inclined downward(2) to clear the wings above the water, thus differing from other birds. Darwin says, "occasionally, when leaving the water, their flight was wild and irregular" and that their habitus resembled the conventional artist's depiction of marine birds in air(3).

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(2) Elliott Coues: *Key to North American Birds* (1864); 772.
(3) Charles Darwin: *Voyage of a Naturalist Around the World*; 137.
ORDER VII. TUBINARES.

The Tubinaires are all sailers, except Pelecanoides, from the typical and far famed Albatross to some of the less proficient Petrels. They swim but do not dive, save in the above exception. Diomedeidae.

With the Diomedeidae the wings are normally very long, narrow and pointed. The length of the wing is due to the great proportionate lengthening of the humerus and the narrowness is due to the rapid graduation of the eleven primaries and the shortening of the numerous, forty or more, secondaries. A wing expanse of some ten feet yielding only seven square feet of surface must be very narrow, the average width being about nine inches. Yet these few square feet support eighteen pounds tirelessly!

The pectoral muscles are small, showing little need for power of depression as is necessary in flapping flight, but the coracoid is short and stout, an efficient brace against the resistance of the greatly lengthened wings. The adequacy of this arrangement as an aeroplane is seen from the prolonged flight of birds of this type.

*Diomedea exulans.* Prof. Hutton (1) describes the flight of the Wandering Albatross thus: "With outstretched, motionless wings he sails over the surface of the sea, now rising high in the air and

(1) A.H. Evans: Cambridge Natural History, Vol. IX.; 63.
now with a bold sweep, and wings inclined at an angle with the horizon, descending until the tip of one almost touches the waves as he skims over them. Suddenly he sees something floating on the water and he prepares to alight. He raises his wings, his head goes back, his back goes in, down drop two enormous, webbed feet, straddled out and he falls 'souse' into the water. To rise, he stretches out his neck, and with great exertion of his wings, runs along the top of the water for seventy or eighty yards until, at last, having got sufficient impetus, he tucks up his legs and is once more fairly launched in the air.

W.B. Barrows says the Albatross can "soar out of sight." (1) I have never seen the statement elsewhere. F.A. Lucas (2) says it rarely rises over one hundred and fifty feet. Another observer (3) says "If they be closely watched, very short but extremely quick motions of the wings may be detected. ---- the movements can not be seen at all unless the bird is exactly on a level with the eye." Judging from the consensus of opinion this explanation on these birds' flight is incorrect.

Diomedea nigripes. The flight of the Black-footed Albatross is described by W.K. Fisher (4). "As is well known, the

(2) F.A. Lucas: Smithsonian Report, 1901, Pt. 1; 654 - 659.
(3) Richard Lydekker: Royal Natural History, Vol. IV; 522.
(4) W.K. Fisher: Birds of Laysan and Leeward Islands; 22 - 23.
Albatrosses are past masters at soaring and sailing. If the wind is favorable they are able to skim over the water for a long time without once flapping their wings. Diomedea nigripes is no exception to the general rule. The long slender wings with long humeral bones are eminently fitted for this sort of existence, and their construction renders flapping laborious, for in proportion to its size, the Albatross is not a very muscular creature, and could not fly a great distance if obliged to do so by wing beats. When a stiff breeze is blowing, albatrosses can sail only against the wind or with it, and are able to quarter a breeze or go directly across it only for a short distance and when under great momentum. When we were steaming directly against the wind they had no trouble in following us, and they would fly all around the ship without flapping their wings, except when the breeze was strong, and they were obliged to give a few vigorous beats when turning into the wind. When, however, our course lay at an angle with the wind, they followed us by sailing in a series of ellipses. They would, in this case, sail directly against the wind, approaching us on the starboard quarter, go over the stern a short distance to port, then wheel and scud before the breeze perhaps a hundred yards off the starboard quarter, when they turned and approached us as before. Their speed was so superior to ours that they were able to keep up without any trouble, and their frequent trips astern and rapid overhauling again made our cumbersome gait all the more apparent. Of course as they
neared the turning point each time they had to quarter the breeze a little and for a moment sail directly across it." At such places they were obliged to flap rather frantically to keep their equilibrium.

"The position in which the wings were held when sailing against or with the wind is quite characteristic in either case. When coming against the breeze, the carpal segments and primaries are bent downward, as if to catch the wind; but when the bird turns and goes with the wind, the ends of the wing are bent up. When sailing against the wind they often gradually rise, but they are likewise perfectly capable of descending, and when going swiftly with the wind they not infrequently, in fact usually, make a long sweep downwards and skim over the water, rising a little as they turn to come to windward. The position of the wings in the two cases seems to be constant. In the first case they catch more wind, and the fact that the birds generally rise a little shows that the wings act on the same principle as a kite. On the other hand, when sailing with the breeze, the position is such as gives less resistance to the wind. The first position is, as suggested by Dr. Gilbert, one of great muscular rigidity.

One is impressed, when watching these birds, with the fact that there is a tremendous amount of muscular tension brought into play to preserve an equilibrium. We are told that wind is not a
constant movement, but is made up of a series of lulls and gusts following each other. With consummate skill the bird seems forever balancing itself and taking advantage of these blasts. When there is very little breeze albatrosses cannot sail far and during a dead calm they progress by a series of flaps and short sails.

"The albatrosses frequently settle on the water, and their actions when doing so are very ludicrous. As they are about to alight both feet are sprawled out on either side, and they strike the water with a splash. The wings are held high over their heads till the birds are safely settled, when they are folded with extreme care so as no to become the least wet."

Procellariidae.

The wings in this family are very long, save in Pelecanoides where they are very short, and are strong and pointed. Primaries ten; secondaries short, varying in number in the genera, but less numerous, much, than in Diomedeidae. Humeral segment lengthened. The flight, on the whole, is less strictly confined to sailing and usually less even than in Diomedeidae.

Ossifraga gigantea, the Giant Fulmar, is a very close rival of the Albatross in point of flight. It is said to be unable to fly when gorged. (1).

Puffinus. The Shearwaters are graceful and strong flyers, often dashing through the crests of waves with no visible motion of the wings. Brewster says (1) "at times, especially during a gale, their evolutions compare in grace and spirit with the Mississippi Kite."

Puffinus cuneatus. Of the Wedge-tailed Shearwater, Fisher says (2), "at sea they are expert flyers, sailing with immovable wings rapidly and readily close to the water, as well against as with the wind and they can go across the breeze much more easily than can the Albatross."

The Petrels, according to Coues (3), have a "peculiarly airy and flickering flight, more like that of a butterfly than of ordinary birds." They flit with more or less flapping close to the water and paddle on it, evidently assisting themselves thus.

The Diving Petrels, Pelecancoides, have very short wings and their flight is rapid and fluttering. They can not rise easily from the level but are good divers. Darwin describes the action of P. urinatrix(4). "It dives to a great distance, and on coming to the surface, with the same movement takes flight. After flying by the rapid movement of its short wings for a space in a straight line, it drops as if struck dead and dives again."

(2) W. K. Fisher: Birds of Laysan and Leeward Islands; 24.
(3) Elliott Coues: Birds of North America; 776.
(4) Charles Darwin: A Naturalist's Voyage Around the World; 290
ORDER VIII. STEGANOPODAE.

The flight of the various families of this order is less homogeneous than in the preceding. The wings are long and pointed, most greatly developed in Fregatidae, shortest in Phalacrocorax, and very ample in Sulidae and Pelecanidae. There are eleven primaries and a varying number of secondaries; Phalacrocorax has fifteen; Fregata, twenty-four; Pelecanus, twenty-nine. The humeral and ante-brachial segments are elongated and in Fregata and Pelecanus the wing is further elongated by lengthened manus and primaries.

Phaethon and Fregata swim but little, the latter least of all water birds, very rarely alighting on the water.

Phaethontidae.

The Tropic birds are flappers. Fisher (1) says they "Progress by short, nervous wing beats, never attempting to sail." The flight is sweeping and rapid and they often rise to a great height to plunge into the water, perpendicularly. After a plunge they float awhile upon the water and rise with great difficulty. They are capable of protracted flight and are met with hundreds of miles at sea.

Sulidae.

The Gannets have a vigorous and protracted flight, though it is performed by alternate flapping and sailing, the wings never

(1) W.K. Fisher: Birds of Laysan and Leeward Islands; 27.
(2) A.H. Evans; Cambridge Natural History, VOL. IX.; 73.
being brought close to the body and the head, neck and tail outstretched. They fish by diving like plummets or by an oblique dash into the water. When fishing "in single file, each bird, when it comes over the shoal, closes its wings and dashes perpendicularly into the waves, whence it emerges after a few seconds -- and mounts in a wide curve, and orderly takes its place in the rear of the string to repeat the headlong plunge." (1). Before the plunge they set the wings and sail up a few feet on a slight curve. This checks the impetus. Then they wheel round, turn half over, bringing the head down pointing to the sea. After an almost imperceptible pause, they drop sheer with wings tight closed and are wholly submerged, sending up water eight or ten feet (2). The coracoids are articulated nearly parallel with the long axis of the breastbone, thus more effectually aiding in reducing the shock of the plunge.

Anhingidae.

The Anhinga has the wings only moderately long, pointed, On the wing, the neck is drawn back upon the shoulders and the flight is mostly by flapping, though these birds sometimes rise to a considerable height and soar in circles for a time. Their flight is swift but a trifle labored and they are more at home in the water where they swim beneath the surface with ease and rapidity.


(2) Living Age: 252; 758-60.
using the wings but little. They do not plunge after prey.

Phalacrocoracidae.

Cormorants have short wings for this order. The wings are concave, stiff and strong and are used in swimming beneath the water in pursuit of prey. "The heavy (flapping) flight is strong, steady and rapid, bearing a certain resemblance to that of the Duck Tribe, while the birds experience considerable difficulty in starting and laboriously flap their wings until fairly launched in the air (1)."

Their flight is short and usually low, the outstretched neck adding to the labored appearance. To offset the difficulty they have in rising from the level, they always, if possible, light on crags so they can jump off and the fall will give the proper impetus. They dive from the surface and do not plunge as Gannets do.

Phalacrocorax harrisi. Harris's Cormorant is found only on Narborough and Albemarle Islands of the Galapagos group. It is flightless, having very small wings with eleven soft primaries, about the size of those of the Great Auk. The first two are much reduced (2).

Pelecanidae.

The Pelicans fly after the manner of the Gannets, though more buoyantly for such large birds, adding, moreover the accomplish-

(1) A.H. Evans: Cambridge Natural History, Vol. IX.; 78.
(2) F.H. Knowlton; Birds of the World; 130.
ment of circling high in the air on set wings for long periods of time. The head is carried with the neck kinked and the head drawn well back between the shoulders. This is necessary to preserve the equilibrium when fish are carried in the pouch as is often the case. The first five primaries are widespread at the tips on the upstroke, as is the case with a soaring Vulture. The furcula are fused with the sternum.

F.M. Chapman (1) further describes the flight of the Brown Pelican, *Pelecanus fusca*. "They travel in parties of six to twelve, flying diagonally, one behind the other, all flapping and sailing in unison; traveling high in air, before the wind, or low over the curling breakers when going to windward. From a height of thirty or forty feet they plunge headlong with a resounding splash on their prey."

Prof. C.C. Nutting testifies personally that they turn a complete somersault on plunging into the water. Considerable difficulty is experienced in rising.

*Pelecanus erythrorhynchos*, the White Pelican, does not dive but scoops up its prey while wading or swimming.

**Fregatidae.**

Of the Steganopodes, the Frigate Bird is the only sailer, pure and simple. The wings are exceedingly long and pointed, the ten (1) F.M. Chapman: Century, 71; 198-211.
primaries being very long and very strong. The antebrachium is one third longer than the humeral segment, which is itself only slightly lengthened. Add to this the long primaries and the wing length becomes disproportionate, apparently, to the size of the body. The long, scissor-like tail aids in balancing the whole and in guiding the quick turns and sudden evolutions.

In the pectoral bones is found a more complete soldering than in the Albatross. The wishbone is very strong and fused to the breast bone and to the short stout coracoid. The breast muscles are weak.

To rise it is necessary for the Frigate Bird to flap and struggle along on the level in a most ineffective and awkward manner. Once sufficient impetus achieved, and it rises, airy as a feather and floats away on pinions that never flap and move only to meet the exigencies of the pulsations of the breeze or to execute the fantastic manoeuvres of this monoplanist par excellence. It sails straight away into the teeth of the wind or scuds, like an arrow, before a gale that would compel others to leave the air.

"To maintain any continuous sailing the Albatross needs a fresh breeze, and they always move with considerable rapidity. Not so with the Frigate birds, however: On comparatively calm days they are able to rest on motionless wings or slowly to describe circles high in the air. Some wind or motion of the air is of course always necessary, but they seem to be able to do with a minimum amount."
They frequently rise so high that one can scarcely detect them against the shimmering blue of the tropical sky. Suddenly some individual aloft takes a notion to descend, and promptly does so by a series of leaps or swoops that fairly make one dizzy."(1)

I. Lancaster(2) says, "At the minimum velocity the bird's wings are stretched to their extreme limit and the angle of inclination is the greatest. As the breeze stiffens, the bird, if it remains in the same place, flexes its pinions and reduces its incline. The Frigate Bird will float in a storm with not more than one quarter of its wing surface exposed. Sometimes it bends the points of its wings till they meet underneath."

For speed it is unsurpassed, being able to overtake easily the Gulls, Terns, and Jaegers. As aerial gymnast it is incomparable but it can not dive nor scarcely swim nor walk.

(1) W.K. Fisher: Birds of Laysan and Leeward Islands; 31.
ORDER IX. ANSERES.

In general, the Anseres are typical flappers. The wings are only moderately long (very short in recently extinct *Cnemidornis calcitrans* and in *Tachyeres cinereus*), stiff and strong. The ten primaries are graduated so as to form a pointed wing, and the secondaries are not lengthened so the wing is, on the whole, narrow and has a small ratio of surface to body weight. By regular vibration of this wing a rapid, vigorous, sustained and often whistling flight is achieved. Ninety mile an hour is often given as a maximum rate for Anatidae.

Palamedeidae.

The Screamers of South America have the wings rather ample and somewhat rounded and their flight is quite different from the typical Anserine. Some species have one or two spurs on the wing, one at the bend and one farther up on the radius. *Palamedea cornuta* and *Chauna chavaria* have two spurs.

Of *Chauna cristata* Evans says (1), "The flight is slow with powerful strokes of the wings, the birds being greatly addicted to soaring in spiral circles until they are hardly visible, and at times floating lazily upon the breeze. They rise noisily from the ground with labored action." He also attributes eleven primar-

ies to them. They are waders and swimmers rather than divers.

Anatidae

*Cnemiornis calcitrans*, of New Zealand, recently extinct, had the keel aborted and the wings very short and useless for flight.

*Plectropterus gambensis*, the Spur-winged Goose of tropical Africa, has one spur at the wing bend. Flight slow and heavy.

*Chenoplax jubata*, the Knob-winged Goose of South America, has "wings long, broad, each armed at the end with a small knob"(1).

With a few exceptions, the Merginae, Anatinae and Anserinae have the typical Anserine flight, varying in slight degree as to rapidity, dependent in part upon the extent of migration. When a flock is on the wing it maintains the chevron formation or the oblique file. They rise rather awkwardly with much noisy flapping and splashing, but, withal, rather quickly. When under way the flight is strong and easy, considering the incessant flapping that tends to give a labored appearance. In descent they come to water often with exceeding rapidity and many erratic twists and turns, in the case of the Teals, before the final ploughing splash. The neck is stretched straight in front. All are good swimmers, and the Sea Ducks (Fuligulinae) dive to great depths.

*Anas boschas*, the Mallard, rises quickly with a spring, and

obliquely. It gets under way at once and its quills whistle loudunder the rapid vibrations that speed the bird so quickly.

Anas discors and Anas carolinensis. The Blue- and green-winged Teals turn and twist rapidly in air on rising and on settling.

Aix sponsa, the Wood Duck, is more efficient at guiding its flight, picking its swiftway easily and with grace, among the trees. It needs to use more care in alighting in trees than its relatives do in splashing down into the water. The longer tail is a better rudder.

The Sea Ducks, Aythia, Somateria, Erismatura, Oidemia, Histrioicus, Glangula, Glaucionetta, Charitonetta, Tachyeres, are characterized as deep sea divers.

Somateria, the large Eider Ducks, have a very labored flight and usually fly low.

Tachyeres cinereus, the Steamer Duck of the South American coast, is a rather large duck some thirty inches long. It flies well when young but loses the power when it grows older, due to increase in size and weight and deposition of mineral in the bones. It then paddles with wings and legs. Its progress thus is rapid and it dives expertly. (1)

Nesonetta aucklandica, from the Auckland group, adds one

(1) F.H. Knowlton: Birds of the World; 193.
more to the flightless birds from the Australian region.\(^1\)

Chen, Anser and Branta, fly with regular measured flaps and execute no unnecessary manoeuvres, such seeming beneath their ponderous dignity of progress.

The Cygninae have a powerful flight, "a composite of beats of small amplitude, alternated with rectilinear gliding", coming to water with an oblique plunge that sends them far along leaving a watery furrow behind. Little variation from rectilinear is noted in their course. The inner secondaries are widened somewhat and act as sails when the wings are partly raised in swimming, as they usually are. Their rate is more rapid than the Goose's when flying with the wind as they are wont to do. Against the wind or across it, they fly more slowly.

\(^{1}\) A.H. Evans: Cambridge Natural History, Vol. IX.; 125.

\(^{2}\) Mouillard; Empire of the Air; Smithsonian Report, 1892, Pt. I; 436.
ORDER X. ODONTOGLOSSAE.

Phoenicopteridae.

The Phoenicopteridae have eleven primaries and about twenty-two secondaries, giving a fairly long wing and quite ample. To rise, they flap strongly and take a series of gallops to give the proper momentum. Under way the long neck and legs are stretched straight out before and aft and, in cuneate or oblique catenulate formation, they progress "gracefully, with alternate flapping and gliding motion or circle around ---." (1)

ORDER XI. HERODIONES.

In the Herodiones, the wings are consistently broad and ample, rounded and moderately long. The rounding is due to the shortening of the first three or four primaries. Usually there are eleven primaries, while the secondaries vary from fourteen to twenty-five. When the wing is expanded the tips of the first four or five primaries are separated and curved upward.

On the wing, the legs are stuck out straight behind, while the neck is thrown into a curve bringing the head back nearly between the scapulae in Ardeidae, and is held out straight in other families.

To alight, the long legs are dangled down and the shock is broken by vigorous strokes before the final settle.

Plataleidae.

The Spoonbills fly with "easy flapping action and with the legs and neck outstretched, now and then rising spirally to float aloft." (1)

Ibididae.

The Ibises fly moderately high and rapidly with extended neck and legs, most species habitually sailing or circling aloft, although Plegadis rises with a whirr and skims along at no great

(1) A. H. Evans: Cambridge Natural History, Vol. IX.; 103.

(2) Ibid; 100.
elevation." The wings are more pointed in this family.

Guara alba, the White Ibises, Prof. C. C. Nutting relates personally, often rise in a flock with slow flaps and then soar on stately, motionless wings out of sight, their calls only, giving indication of their presence. After a time they gradually circle down in the same way.

Ciconiidae.

The Ciconiidae have ample wings with twelve primaries in all save Ciconia. The flapping flight is graceful and noiseless, but powerful and rapid, the neck and legs going carried in line with the body, and immense heights being attained by soaring and circling (1). In passage they fly in V-formation and usually at great heights.

The Wood Ibises of Southern United States have the same characteristic flight. (2) Coues says of Tantalops loculator, "Flight is performed with alternate flapping and sailing; at times it mounts high and performs the most beautiful evolutions, with motionless wings like a Turkey Buzzard."

Ardeidae.

The Herons proper have a quite rounded wing, but broad and of relatively large area. They fly noiselessly with labored action,

(1) A. H. Evans: Cambridge Natural History, Vol. IX.; 95.
the wide wings moving measuredly, and at a comparatively slow pace. The slender neck is bent so that the head rests almost between the shoulders and the long legs stick straight out behind. Soaring aloft is not resorted to and flight is usually not for long distances at a time except in migration.
ORDER XII. PALUDICOLAE.

Heterogeneity fits this order in so far as manner and ability of flight, as well as appearance of its members, are concerned.

Gruidae.

The Cranes have rather long, broad wings, the inner secondaries being longer than the primaries and often composed of long drooping plumes of more or less dissociated webs. To get under way they take a few preliminary gallops. Their flight is powerful and long sustained to accomplish the long migrations. The V-formation is preserved in passage. At times the progression by slow beating wings, forceful and contained as if possessed of great reserve ability, is changed to soaring, and on motionless wings, with legs and neck outstretched, they circle steadily upward till lost to view.

I. Lancaster (1) states that Grus mexicana may rise to a height of from one to three miles, approximately, and then glide uninterruptedly from Winnipeg to Florida! This statement would be hard to demonstrate until we are able to follow with the airship.

Rallidae.

The Rallidae have short, rounded and concave wings and the family contains flightless forms. None of the Rails have very

(1) I. Lancaster: Scientific American Supplement, Apr. 23 1904.
efficient flight. With head and neck outstretched, their progress is labored, of short duration usually, neither swift nor vigorous. Yet their quick-beating wings accomplish, in some way, extensive migrations. Chapman has noted Porzana carolina at night flying at considerable elevation.

Ocydromus, of New Zealand, is flightless.

Porzanula palmeri, of Laysan, is flightless, the wings being very rudimentary, indeed.

The Gallinules have a short, flappy flight, rising by violent flaps and running, and they usually drop at the first opportunity. The legs dangle more or less in flight.

Notornis mantelli, of New Zealand, practically extinct now, is flightless, the wing being very short and rounded and the feathers soft.

Fulica americana is a very good swimmer and diver. To rise it flaps vigorously for several rods, the while running on the water and paddling with the lobed toes. Then it lifts from the water at an increasing angle and finally flies off in a labored fashion and with continuous action of the wings. It flies only as a last resort, preferring to swim noiselessly out of sight.

Otididae.

The Bustards have moderately large, rounded wings, with primaries and secondaries almost equal. They fly powerfully and
rapidly, usually low, with a regular and quite rapid flapping of the wings. Their appearance is heavy and the outstretched neck and legs do not add to the grace of movement.

*Otis tarda* has a prolonged, often rapid, though invariably heavy, flight. It rises slowly\(^1\).

*Otis tetrax* rises to a great height, flutters and twists about in the air. Sometimes it flies rapidly and straight. It rises with a pat-pat of wings\(^2\).

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\(^1\) A. H. Evans: *Cambridge Natural History*, Vol. IX.; 263.

ORDER XIII. LIMICOLAE.

The Shore Birds in general have long, thin, flat, pointed wings with stiff, narrow primaries which are graduated rapidly from the tip in. The secondaries are graduated in the reverse order, the inner ones being of nearly equal length to the outer primaries. This arrangement gives an almost falcate tip with a broad base and posterior re-entrant angle.

Of slight build, usually, these birds get under way quickly from a short run. On the wing they progress by flappings of various rapidity, a "whirr" in Philohela, and are capable of long sustained flight, as is attested by their extensive migrations. They are easy and quite agile in the air, considering the short tail. To alight, they flutter to a short distance above the place selected and then drop easily, the slender legs dangling and both wings held straight above the back ready to "back air" in a moment if the lighting place does not prove suitable. Once on foot and the wings are brought down and folded without wetting. This latter does not apply to the Jacanidae.

Phalaropodidae.

The Phalaropes swim well and their migration zone extends from Arctic regions far southward, past the Tropics, in case of Phalaropus tricolor.
Recurvirostridae.

The members of this family have very long legs and these, with the head and neck, are outstretched in flight to counterbalance the light body. In Recurvirostra the wings are rather short for a wader and a short glide is made before alighting with the wings raised. Himantopus often hovers with the legs dangling.

Scolopacidae.

In this family a few interesting variations in flight are found. The wings are the usual type save for being somewhat shorter and rounded in Philohela and Gallinago.

*Philohela minor*, the American Woodcock, rises abruptly with a "whirr" and darts away rapidly and steadily usually, though at times it zig-zags somewhat after the fashion of *Gallinago*. It does not fly far at a time, dropping out of sight among the bushes, and when tired, flaps more slowly. In the open it flies along close to the ground. In the spring it sometime rises high in the air in the mornings.

*Gallinago delicata*. Wilson's Snipe, has a strong, rapid and long sustained flight. Its zig-zag dartings when flushed are characteristic. Rising abruptly - old hunters assert, probably incorrectly that it uses its bill as a projecting lever - , with little if any "whirr", it dashes helter skelter a few yards in one direction, turns
half over, showing the under white, and darts away at right angles. In a moment it changes course again and angles away quartering, then settles into a steady, swift flapping. In the mating season the male may fly high and pursue a course in undulating, concentric circles, then partly close the wings and drop, recover himself and drop again. On alighting he almost hurls himself down with wildly gesticulating wings and, when near the earth, backs air stiffly, raises the wings and settles in Limicoline fashion. Often when he takes a plunge, a curious drumming noise is heard. It is attributed to various causes: vibrating wings, voice plus vibrating wings, and buzzing of the webs of remiges and outer rectrices. The latter seems more probable.

*Totanus pugnax*, the Ruff, breeds in Northern Europe and Asia and migrates to South Africa, Indian region and Japan. Other species of this genus also have a very wide migratory zone.

*Numenius* has a swift, firm, direct flight. It may be very protracted and is accomplished by regular, continuous, rather rapid, wing beats.

*N. tahitiensis* breeds in Alaska and spends the rest of the time in the Hawaiian Islands. This necessitates a straight journey of some twenty-five hundred miles. This were not difficult if these birds had the surprising rate of two hundred miles an hour that Herr Gätke attributes to the two genera *Limosa*,...
in this family, and Charadrius, of the next!(1)

**Charadriidae.**

Charadrius dominicus, the Golden Plover, migrates from Arctic breeding grounds to Hawaiian Islands and far past the tropics into South America.

Vanellus vanellus, the Lapwing, has a spur on its wing bend. "The flight is very erratic and peculiar. Its wings are very long and broad, and it flaps them in a regular, sedate manner. Now it soars upward for a few yards, seemingly without effort, then, flapping its broad and rounded wings, it wheels round and round; then it darts rapidly down as if hurling itself to the ground, and then, mounting the air again, with easy grace flies in ever changing course, darting wheeling, trembling and reeling, as though beating time with its pinions to its wailing and expressive cries."(2)

**Aphriziidae.**

Arenaria interpres has a very swift flight and accomplishes cosmopolitan migrations. It also accompanies Numenius tahitiensis.

**Haematopodidae.**

These birds are flappers.

(1) Herr Gatke: Smithsonian Report, 1893; 475.

Jacanidae.

*Jacana gymnastoma.* The Jacanas are provided with a spur on the wrist of the narrow wings. They are expert divers and sub-aquatic swimmers and are difficult to flush, preferring to dive and swim out of sight. When they do fly, they progress by alternate flutterings and glidings, low over the water, the feet dangling.
ORDER XIV. GALLINAE.

The Gallinae have short, stout, markedly concavo-convex, bilobed wings, which fit close to the body. In the order, flight is quite consistently in straight lines, by alternate flapping and tense-winged gliding. The rapid vibration appears labored and often produces a "whirr". On account of the rapidity of their progress, the angle of inclination on the glide is very low. As a usual thing, flight, at any one time, is not protracted. The rise and settle are quick.

Tetraonidae.

Colinus virginianus, the Quail, flies characteristically but is soon exhausted, flying only short distances and dropping into cover, usually with a sidewise turn from its general course.

Bonasa umbellus, the Ruffed Grouse, rises with a startling whirr and flies away straight and swiftly, at the same time deftly avoiding branches in its path.

Tympanuchus americanus, the Prairie Hen, is an exceptionally good example of the combination flight of this order. The rise is steady but sudden and the whirr of the wings of a large flock is very loud indeed. On the glide, the wings are tense, tips spread and decurved and the direction of progress seldom deviates from the rectilinear. The settle is made with a flutter of wings after a curved, descending glide.
**Centrocercus urophasianus.** Coues(1) describes the flight of the Sage Grouse as "extremely vigorous and at times greatly protracted, with wings so widely expanded that the tips of the primaries stand apart; the course, rapid and steady when the bird is once fairly on the wing, is accomplished with a succession of quick energetic wing beats, alternating with sailing with stiffly motionless wings until the impulse is spent."

**Phasianidae.**

The Pheasants fly in the composite fashion, though more labored on account of the tendency toward great development of the tail and, in case of the Argus Pheasant (*Argusianus argus*), of the secondaries. In the male of this bird the secondaries are very long and wide while the primaries are very short, being graduated from a long inner to a short outer. This makes a wing unfit for effective flight.

*Pavo cristatus,* the Peafowl, is a poor flyer on account of its extraordinary tail.

*Gallus,* the Jungle Fowl, "flies steadily with rapid beats and alternate sailings."(1)

*Meleagris gallopavo mexicana,* flies with steady, vigorous, sweeping beats, alternating with glides. Flight not protracted.


ORDER XV. OPISTHOCOMI.

Opisthocomidae.

The members of this family have the pectoral girdle an­chylosed as in the Fregatidae; the furcula anchylose with the cor­acoids and the manubrium of the sternum(1). The keel is cut away in front and is slight on the hinder portion. The praesocial young can dive well and have a claw on the index and one on the pollex. In the adult these are rudimentary. The wings are ample but Opisthocomus cristatus flies only "awkwardly some forty yards at a stretch with violent flapping action."(2)

(2) A.H. Evans: Cambridge Natural History, Vol. IX.; 242.
ORDER XVI. COLUMBAE.

The wings in flying Columbae are commonly long, but flat and not concavo-convex as in the Gallinae. In Columbigallina they are short and are aborted in the recently extinct Dodo and Solitaire.

Columbidae.

Ectopistes migratorius, the Passenger Pigeon, is a model for flapping flight. The long, pointed, trm but ample, wing furnishes adequate propelling force, by its regular, powerful stroke, for the shapely body, built to cleave the air, and guided in its evolutions by the long tail. The sustained speed on a long journey is reckoned variously from sixty to one hundred miles an hour. The powerful driving of the pinions causes the whistling so characteristic of most birds of this group.

Zenaidura macroura, the Mourning Dove. When rising hurriedly the wings strike above and often below adding the flapping noise to the whistling. At full speed and seeking a place to light the wings are held flexed and almost parallel to the body and the strokes are slower with a glide for the space of two or three strokes while the wings are being slowly raised again. About to alight, these birds often sail in circles with wings extended and one depressed, then alight from a flutter. When flying among trees,
they twist and turn most adroitly as they hurtle among the branches.

**Columbigallina.** The Ground Pigeons fly but little

**Dididae**

**Didus ineptus,** the Dodo, was extinct by 1691. It was confined to Mauritius Island. The wing was nearly completely aborted and the power of flight lost.

**Pezophaps solitarius,** the Solitaire of Rodriguez Island, extinct by 1761, had a knob the size of a musket ball on the end of its wing, which was itself much reduced and flight rendered impossible.
ORDER XVII. RAPTORES.

The Raptores possess the ability to soar but they can also flap. The necrophagus members of this order have little carrying capacity as flappers, and little endurance while the more strictly predaceous or raptorial members have a powerful flapping flight when occasion requires. In all, the wings are of moderate length and ample; primaries eleven, secondaries various. This shape of wing, for soaring is much different from the typical Frigate Bird's wing, but its utility under governing conditions is sufficient.

To get under way the necrophagous members run some distance and flap, while the predaceous members give one or two powerful jumps and initiatory flaps. They perch from a short, upward soar that checks the momentum and breaks the jar almost entirely.

Cathartidae.

The American Vultures come under the first head mentioned above. The distal segment of the wing is flexed back, except in Catharista where the anterior outline is nearly straight. The primary tips, except in Catharista again, are widely separated and bend up. In high winds these birds repair to seclusion.

Cathartes aura, the Turkey Buzzard, rises slowly after several running jumps and with vigorous flapping of its wings. Under way, it sails away easily and gracefully, with motionless wings,
and may rise out of sight or circle for hours without flapping. To alight on the ground it circles down to within a few feet of the chosen spot then gives a few vigorous strokes and settles with wings extended. Once on foot, the wings are taken in. If the perch be a lofty spot, the bird will descend below it and then swoop upward to alight, thus checking its momentum.

*Catharista atrata*, the Black Vulture, is less trimly built and has to flap often when sailing.

*Sarcorhamphus gryphus*, Condor. Darwin describes the Condor's flight (1). "Except when rising from the ground, I do not recollect ever having seen one of these birds flaps its wings. Near Lima, I watched several for nearly half an hour; they moved in large curves, sweeping in circles, descending and ascending without a single flap. As they glided close over my head, I intently watched from an oblique position, the outlines of the separate and great terminal feathers of each wing; and these separate feathers, if there had been any vibratory movement would have appeared as if blended together; but they were seen distinctly against the blue sky. The head and neck were moved frequently, and apparently with force; and the extended wings seemed to form the fulcrum on which the movements of the neck body and tail acted. If the bird wished to descend, the wings were for a moment collapsed, and when again expanded, with an altered inclination, the momentum gained by the rapid descent (1) C. Darwin: A Naturalist's Voyage Around the World; 186.
scent seemed to urge the bird upward with the even and steady movements of a kite."

The Condor can not raise its own weight adequately enough by flapping so as to rise without a run of some thirty yards if on the level. It usually acquires momentum by pitching from a crag. It can then soar to vast heights.

_Pseudogryphus californianus_, the California Vulture, rivals the Condor in ease and grace on the wing.

**Serpentariidae**

*Serpentarius secretarius*, the Secretary Bird, has ample wings but differs from other Raptore in having long legs and neck. It can "fly well and strongly, although in a somewhat heavy manner. It may be seen soaring high in the air, with motionless, outstretched wings after the manner of a vulture, and may always be recognized by having its head stretched straight in front and its legs extended backward below its tail." (1)

**Falconidae.**

The Vulturinae, Old World Vultures, are not closely related to the New World Vultures in structure but their manner of flight is practically the same and they belong in the necrophagous group. The primary tips are separated and also widened, seeming to serve

the same purpose as the "ailerons" of the airship.

*Gyps fulvus*, the Tawny Vulture, is unrivaled for ease, beauty and duration of soaring. It also hovers easily. Mouillard (1) says that it can not rise twenty yards at an angle of 45° and can not lift itself ten yards vertically. To alight, it soars down, dangles the feet, and then gives a few strokes to check the impetus.

*Vulture monachus*, the Arabian Vulture, is reported very swift for this kind of soaring.

*Gypaetus barbatus*, the Lammergeier, flies evenly with gliding motion and occasional flaps of the wings. (2)

The Falconidae other than the Vulturinae are more various in their manner of flight than the preceding sub-family and have considerable carrying capacity.

*Elanoides forficatus*, the Swallow-tailed Kite. "It was to me a beautiful and exciting sight to watch the various motions and coquetting evolutions, sailing high in the air, swooping down with partially closed wings, skimming along the prairie --- ascending in spiral flight, gliding from slow to swift and from swift to slow, without a flit or break, like Swallows." (3)

*Ictinia mississippiensis*, the Mississippi Kite, sails for

(1) Mouillard, L.P.: Smithsonian Report, 1892, Pt. 1; 416.
(2) Richard Lydekker: Royal Natural History, Vol. IV.; 252
(3) N.S. Goss: History of the Birds of Kansas; 249.
hours, swoops down to catch its prey, and usually devours it on the wing.

**Circus hudsonius.** The Marsh Harrier is very light on the wing, sailing slowly but buoyantly, low and quartering the ground, or flapping slowly occasionally. It never swoops but hovers above its unsuspecting prey and then pounces. It can hover several minutes at a time over almost the same spot. In spring the males often rise high and then, with wings over their backs, fall several yards, turning over and over, only to catch themselves and circle up again to repeat. I have seen a half dozen of them tumbling at once.

**Accipiter.** The members of this genus are exceedingly agile on the wing, due to the long tail, and swift. They flap often with quick strokes.

*A. atricapillus,* can kill and carry away a bird nearly its own weight.

**Buteo.** The members of this genus are stoutly built and fly slowly with measured, powerful beats. They are excellent soarers as well, circling easily and steadily to great heights in continuous spiral ascent and with no flapping.

*B. latissimus,* the Broad-Winged Hawk, lives more in the woods and stalks its prey more and so is on the wing less.

**Archibuteo** has flight not essentially different from *Buteo,* though perhaps more labored when flapping. I have watched, on a
level with it, *A. lagopus sancti-johannis* soaring in continuous ascent with no loss of altitude when going with the wind.

*Aquila chrysaetos*, the Golden Eagle often soars for hours almost perfectly. It can drop like a plummet for yards and recover itself on its strong wings, fitted for a strong, regular, flapping flight as well, with great carrying capacity.

*Haliaeetus leucocephalus*. The Bald Eagle flies as well as the Golden save a little more labored. A.K.Fisher(1) says "it is capable of carrying a weight exceeding its own."

*Tharsaetus harpyia*, the Harpy, has broad, compact wings that enable it to "wheel in circles with slow, heavy flight" (2) or dash swiftly after its prey, the long tail steering the course in all its sudden turns. Or it can dive several hundred feet sheer into the forest and recover itself with its strong wings.

*Falco* has more pointed wings and its members are very efficient stoopers.

*F.peregrinus anatum*, the Duck Hawk, is likely our swiftest hawk, rivaling the Wild Duck in speed, and stoop with fearful onslaught upon a prey much larger than itself.

*F.columbarius*. The pigeon Hawk's "flight is very rapid and resembles that of the Wild Pigeon quite closely."(3)

(1) A.K.Fisher: Hawks and Owls of the United States; 101.
(2) A.H.Evans: Cambridge Natural History, Vol. IX.; 159.
(3) A.K.Fisher: Hawks and Owls of the United States; 112.
F. sparverius. The Sparrow Hawk chooses to hover rather than circle and it rarely soars. Its flapping flight is irregular and usually not protracted, though often swift, and accomplished by quick beats. It may flap rapidly for a short way and then sail, but not in a typical flap-and-glide manner. Its preference is to watch a chance and pounce.

Micraster semitorquatus comes nearest of the Raptores to being flightless. It has short, rounded wings and a long tail. Living in woods, it flies little and jumps from bush to bush. (1).

Polyborus cheriway, Audobon’s Caracara, "frequently carries its food in its beak while flying--" and "the flight is strong and elegant and closely resembles that of a Turkey Buzzard." (2)

Pandion haliaetus carolinensis. The American Osprey has long wings and tail, making a different figure from eagles. It flies usually slowly and a trifle labored but can soar equally as well as the Eagles, the legs straight behind, and can also accomplish many aerial evolutions. When fishing it "poises itself aloft, vertically, descends with terrific dash and splashing plunge to rise again with its captured prey--." (3) It hovers easily. The dive is often made from a great height, the wings closed, and the catch is made with the wings open above the head. The victim seized, the Osprey shakes off the water from its compact plumage and flaps away again.

(1) F. H. Knowlton: Birds of the World; 224.
(2) A. K. Fisher: Hawks and Owls of the United States; 129.
(3) A. H. Evans: Cambridge Natural History, Vol. IX.; 181.
ORDER XVIII. CUCULIFORMES.

Sub-order Cuculi.

The members of this sub-order are in no way endowed with any remarkable powers of flight, all being flappers of only a mediocre degree of excellence.

Cuculidae.

For the most part the wings are long, pointed, flat and do not fit closely, but hang lazily.

*Coccyzus*. The American representatives of this genus, the Blackbilled and the American Cuckoo, fly noiselessly, waveringly, rather unsteadily and stealthily, but rapidly and in a gliding manner usually among trees. Flight is not protracted.

*Geococcyx* has the wings short and more concave. The Road-runners prefer to run, rising to fly with difficulty, often jumping from the top of a scrub tree to start. Under way it progresses for a short way near the ground, easily and swiftly, and then drops to hide or run again. It is easily tired out, on the wing.

*Crotophaga ani*. The Black Ani's flight is "slow and gliding, somewhat labored and of little duration, the birds often appearing to fall short of the point originally aimed at." (1)

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(1) Charles Bendire; Smithsonian Contributions to Knowledge, Vol. XXXII.; 8.
Sub-order Psittaci.

Psittacidae.

The flight of the Parrots is flapping, usually undulating, slow and measured and not of long duration. Some species rise high in the air at times.

**Nestor notabilis**, of New Zealand, has developed a raptorial nature. Small companies rise high in air.

**Gonurus carolinensis**. Flocks of the Carolina Paroquets "move in the manner of the Wild Pigeon, darting in swift and airy phalanx through the green boughs of the forest." (1)

**Stringops habroptilus**, the Owl Parrot, has short, rounded wings; no furculum; and a rudimentary keel. The chief function of the wing is to assist in jumping, alighting from a jump, or as a balance.

**Callocephalum**. The members of this genus fly high often and even out of sight.

(1) F. H. Knowlton: *Birds of the World*; 469.
ORDER XIX. CORACIIFORMES.

Sub-order Coraciidae.

The many and various members of the sub-order Coraciidae are primarily flappers.

Coraciidae.

Coracias garrulus, the Common Roller of Southern Europe, is typical of this family. It often rises high, unsteadily, by not very well sustained flapping, and drops sheer, turning over in the air like a tumbler pigeon and throwing himself here and there. (1) Its regular flight is strong.

Momotidae.

The Motmots fly with slight undulations, and for short distances. The wings are rather short and rounded.

The Todies have Flycatcher characteristics, perching on a twig and darting out to catch an insect and then returning. Wings are short.

Alcedinidae.

The Alcedinidae have eleven primaries, the wing being short, rounded, but powerful.

Ceryle alcyon, the Belted Kingfisher, is a proficient

(1) F.H. Knowlton: Birds of the World; 485.
plunger for short distances. On distance flights it flies slowly with steady, nearly full-arm, beats and, on preparing to dive, hovers, brings the body vertical and drops with the wings closed, but strike the water obliquely and shoots out and up again. It dives as well from perch. When prospecting, its strokes are slow and mainly with the hand, the humeral segment not being expanded. The strokes flex and extend the hand principally, the extension being slow and the flexion quick. The result is a series of sharp undulations, the rise short and the decline long, a kind of glide on half open wings.

Bucerotidae.

The Hornbills "have powerful wings, but their heavy bodies oblige them to use much exertion in flight, which is, therefore, not rapid, though often of considerable extension — too heavy to dart after fruit — cannot even fly quickly from branch to branch." (1) They fly with rapid wing beats and then sail, gradually rising to greater elevation. (2)

These birds have the greatest pneumaticity yet they are not most excellent flyers. The great noise produced in flight is thought to be due to the air rushing between the bases of the quills which are not made tight by the under coverts.

(1) J. S. Kingsley; Standard Natural History, Vol. IV.; 405.
(2) F. H. Knowlton; Birds of the World; 504.
Rhinoplax vigil, the Solid-casqued Hornbill, has the bill solid and heavy and is a very weak flyer. (1)

Upupidae.

The Hoopoes have ten primaries, short, rounded wings, and their flight is "strong, undulating, though seldom protracted." (2)

Sub-order Striges.

The Striges have only moderately long, broad and rounded, concave wings of eleven primaries. They have feathers of a loose texture which causes the flapping flight to be noiseless.

Strigidae.

The Barn Owls (Striginae) have longer and more pointed wings. They quarter the ground like a Harrier but noiselessly and by flapping instead of sailing.

The Buboninae vary in flight from the jerky Glaucidium to the stately Bubo.

The larger genera Syrniun, Bubo, Asio, Nytea, fly buoyantly but not steadily, with slow, regular, noiseless beats. They, as well as other Owls, usually pitch from perch on starting to fly and light from a short rising glide. Flight Sustained while hunting.

(1) F. H. Knowlton : Birds of the World ; 507.

(2) A. H. Evans : Cambridge Natural History, VOL. IX. ; 396.
Surnia ulula caparoch, the Hawk Owl, flies very swiftly for an Owl and the long tail aids in securing quicker movements.

Megascops. Wavering and fluttering. It flies usually only for short distances though it can fly farther.

Speotyto flies only a few rods then glides to rest upon a Prairie Dog's mound. Wings short.

Glaucidium passerinum, the Pigmy Owl of Southwestern United States, has a "rapid, jerky flight very different from that of the more slowly flapping, crepuscular species." (1)

Sub-order Caprimulgi.

The Caprimulgi have long, pointed wings of ten primaries and rather lax plumage, in Caprimulgidae especially. Flapping is characteristic.

Caprimulgidae.

The Caprimulgidae are expert in the uncertain chase after insects, their flight being buoyant, swift, noiseless, and characterized by sudden stops and starts and unexpected turns, accomplished by aid of the well-formed tail and wings.

Chordeiles virginianus, the Night Hawk, is most expert. It may flap lightly, yet swiftly along, unconcernedly and suddenly dash upward almost vertically, pause as suddenly to secure an in-

(1) A.H. Evans: Cambridge Natural History, Vol. IX.; 407.
sect, and then float on, with motionless wings for a space, the wings held at a rather large angle above the back. Or it may drop to earth, pick up an insect with hardly a pause in its easy course. In the mating season the male rises high and then drops sheer like a bolt, the vibrating primaries causing a booming noise, only to catch himself with a single easy flap and sail away up again to repeat or to journey on.

_Natrostromus vociferus_, the Whip-poor-Will, flies not quite so well as the Nighthawk but very similarly. Its course lies nearer the ground and it has a more halting and erratic flight, stopping to alight often. If flushed in the daytime, it flies in a zig-zag fashion for a few yards and drop into concealment. The Nighthawk will do the same.

Some of the South American species furnish examples of extreme modification of some of the primaries.

_Heliothreptus anomalus_ has the first six primaries incurved and the seventh, eighth and ninth elongated, especially the eighth.

_Macrodipteryx macrodipterus_ has the ninth alone elongated, with long, bare shaft and racquet-like tip. (1) This seems to be a secondary sexual character as it is confined to the breeding period. Probably it hinders flight.

(1) A.H. Evans: Cambridge Natural History, Vol. IX. ; 418.
Sub-order Micropodii.

The Micropodii have a high keel on the breast bone, short humerus, longer forearm and extremely long hand. This arrangement gives a short leverage for the quicker action of the large pectoral muscles, sacrificing ease of motion to rapidity in case of the Humming Birds. The tensor patagii brevis has no slender tendon distally, the fleshy belly connecting with a special tendon that runs from the distal portion of humerus parallel with forearm on the radial margin to the hand. (1) This shortening lends quickness of motion.

Only six or seven secondaries are found, very short, and ten primaries, long and graduated, forming a narrow and almost falcate wing in Trochilidae, and a long, narrow wing in Micropodidae.

Trochilidae.

The Hummingbirds are the pigmy aerial acrobatic experts. Their flight is accomplished by almost incredibly rapid vibrations of the wings which give great speed. The wings make a blur in vibration and the eye can hardly follow the bird as it darts through any distance. From the shortness of the humeral leverage there is not great power in the wings, and were it not for the minute size of the birds such flight were absolutely impracticable. If a Condor

were to vibrate its wings so rapidly, an immense body of strongest steel and great weight would be necessary for the attachment of the mammoth muscles and probably material could not be made strong enough for the wings. The noise could hardly be imagined.

In motion each wing moves in a half circle, the two nearly meeting above and below. With the tail as an aid, extreme control is had over the movements. The Hummingbirds can dart away swift and straight as an arrow and stop like a shot before a flower or in poise in mid air. Or they can hover with the body in any angle from horizontal to perpendicular, rise or fall with a tilt of the tail, or back away from a flower with a forward and downward motion of the tail. This last point has been disputed but personal observations bear it up.

The poising requires much more rapid and shorter strokes, for, in such case, the body is immobile and the full gravity needs constantly to be counteracted by the vibrating wings, while, when in motion, the inertia of the body counteracts part of gravity, the vibrations overcoming the rest. And where the velocity is so great, gravity becomes much less.

The vertical poising requires still more rapid beats as here the body has to be maintained in a position out of the natural equilibrium of flight.

The larger the species of Trochilidae, the less swift and
expert are its movements in all respects.

*Patagona gigas*, nine inches long, "whilst hovering over a flower, flaps its wings with a very slow and powerful movement, totally different from the vibratory one so common to most of the species, which produces the humming noise." (1) "Its flight resembles somewhat that of the martin, often, though, keeping the wings immovable." (2)

The long rectrices of some species do not seem to retard the flight.

*Loddogesia mirabilis* has the two lateral rectrices long, with spatulate ends, and curved so as to cross twice. When flying, these are raised, the spatulae being brought together flatwise, forming an efficient rudder. The flight of this species is inconceivably rapid, changing the course every second to escape running into obstacles. (3)

**Micropodidae.**

In this family, flight is of almost indefinite duration, since the members rarely alight save to roost or brood. Rapid progress is made by alternate flapping and sailing, the impetus for the

(1) A.H. Evans: Cambridge Natural History, Vol. IX. ; 430.
(3) Ibid ; 447.
latter given by only three or four strokes of the long wings. The wings are held quite rigid and the quick beat is full-armed, as if the wings were ears of whale-bone working swiftly up and down with no change in the anterior contour which is as the arc of a large circle, the curve being made more pronounced by the primaries being incurved at the tips. The sail is made with the wings rigid, slowly and on a very slight inclination. The quick turns to capture insects are made by tilting the wings on an angle.

Though so free in the air and often flying very high, these birds have difficulty in rising from the level. "The Swift, Cypselus apus -- can not rise vertically six feet." (1) Chaetura pelagica experiences the same difficulty.

Sub-order Trogones.

Trogonidae.

The wings of the Trogonidae are rather pointed, of moderate size, and of ten primaries. Their flapping flight is rapid but rather weak and not extended. If continued for any distance it is undulatory after the nature of the Woodpeckers. (2) They capture fruit much as a Flycatcher captures an insect.

Pharomacrus mocinno, the Quezal, has a "noiseless flight,

(1) L.P. Mouillard: Empire of the Air, Smithsonian Report, 1892, Pt. 1; 416.
(2) F.H. Knowlton: Birds of the World; 572.
rapid but short, jerky and with occasional undulations." (1)

Sub-order Pici.

Rhamphastidae

The wings of the Toucans are rather weak though fairly ample, with eleven primaries and twelve secondaries. Yet their flight is "easy, direct, graceful, accompanied by occasional noisy flaps of the wing, the bill being carried horizontally." (2).

Picidae.

The Woodpeckers have a moderate sized wing of ten primaries and pointed. Their flight is flapping but not sustained, being a series of undulations on whose incline three or four full openings and closings of the wings are given and on whose decline the wings are closed against the body. This is characteristic if the flight is for any distance. When passing from one tree to another, they usually describe an arc by pitching from the one tree with wings closed, flapping three or four times in the trough, and sailing up on open wings to perch on the other.

In summer Sphyropicus varius and Melanerpes erythrocephalus perch on the top branches of dead trees and sally out, or up, on quick beating wings, snatch an insect, wheel in mid-air with wings extended, and sail back to perch in their usual fashion.

(1) A. H. Evans : Cambridge Natural History, Vol. IX. ; 442.
(2) Ibid ; 453.
The flight of Passéreses is characterized as flapping with only minor variations, save in a few cases to be noted later. None of them are flightless. The wings present only limited modifications from rather short, either pointed or rounded, to long, pointed, as in the Hirundinidae, where the modification consists in a shortening of the humerus and lengthening of the distal segment and primaries. The number of primaries varies from nine to eleven, but gives no index to ability in flight. In general the flight may be said to be adaptive to a more or less varying environment.

Menuridae.

The Lyre-birds are the poorest flyers in the order. Their wings are short, rounded, of eleven primaries, and very rarely used, trust being placed in the legs to find hiding.

Tyrannidae.

The flight of this family is strong and aggressive, varying, in the nature of the encounter, from short sorties after insects to swift-winged pursuit of intruding Hawk or Crow. The wing beats are quick, nervous, rather quivering, the stroke being mainly with the digital and antebrachial segments while the humeral segment is more or less shrugged.

Milvulus and Pyrrocephalus hawk for insects in buoyant
sweeps and graceful curves, often stopping to drop or rise several feet almost vertically on quivering wings, then dashing on again.

The most of the other genera perch on a limb and make dashes out for passing insects.

_Empidonax_ usually seeks its prey Kinglet-fashion, going from one tree to another with short undulations.

**Alaudidae.**

_Alauda arvensis_, the Skylark of Europe, and our Horned Lark _Otocoris alpestris_, often rise nearly perpendicularly on quivering wings, the body being horizontal, until out of sight. Then they descend in like manner, until near the ground, when they give a headlong dart to alight.

**Paradiseidae.**

With all the fantastic modifications of feathers in this family, the wing remains normal in contour, though short. "The brief flight is undulating and often heavy." (1)

**Corvidae.**

The Crows and Ravens are excellent examples of regular, sustained, rather slow flappers and they seldom fly otherwise. Their only departure is a short sail before alighting or perhaps on a

downward turn. The Jays spread the primary tips widely. The Magpies are slow and awkward.

Icteridae.

On a distance flight, the course, save in Sturnella, is undulatory, the closed-winged dive alternating with several open-shut strokes.

Quiscalus and Agelaius often rise from perch, describe short curves with set wings and settle again. When dropping from a tree, for instance, to ground to feed, they are beautiful examples of the gliding flight, the wellformed tails aiding them to rise and fall in graceful undulations in their sloping course until they finally come to ground with a flutter.

Dolichonyx rises vertically some twenty or thirty yards on nervously quivering wings, during the mating season, singing incessantly, and flutters down in like manner.

Sturnella rises with a flutter and on occasion varies the rapid vibrations with a tense-winged glide for a short distance, in the manner of the Quail.

Fringillidae.

This family, for all its great size, is quite consistently semi-undulating flapping in distance flight. The few open-shut strokes alternate with a short closed-winged dive in almost any
direction, giving a marked variability and irregularity in the course

Serinus and Astragalinus are very markedly undulatory, after the manner of the Woodpeckers.

Coccothraustes and Habia have nearest a sustained flight, their flight being by rapid, continued strokes that describe nearly a half circle.

Calamospiza "soars (Not in the technical sense) and descends with outstretched wings."(1)

Tanagridae.

The Tanagers' flight is Sparrow-like and not long continued.

Hirundinidae.

The Swallows' flight is the most radical departure from the common flight of the order.

Chelidon erythrogaster, the Barn Swallow, may serve as an example of the family. Its flight is a complex of flapping and sweeping, curved glides, on wings of more or less expansion, varying inversely as the velocity, the anterior contour being always an arc of a circle. The motion of the wing in the strokes seems to start at the shoulder and ripple to the end of the long, supple wing. These strokes give the initiatory speed, then a pendulum-like, sweeping glide, then flaps again to regain the momentum lost during the

(1) A.H. Evans : Cambridge Natural History, Vol. IX. ; 586.
glide. The turns at the end of a sweep are usually very abrupt. The bird glides up to check the impetus, at the same time turning half over. At the end of this shoot the long axis is directed in the opposite direction. Then beats are employed to gain equilibrium and accelerate the diminished velocity. In pursuit of insects it often makes sallies out with a quick turn and back to its course. While hawking high, in evenings generally, it is common for them to glide up, catch the insect, then slide a short way downward tail foremost, then proceed on their way.

This flight is capable of long duration. It cannot be classed as sailing because the sailing periods are not self-sufficient. The body is too light to overcome the inertia of the air sufficiently to allow soaring indefinitely after the proper momentum is acquired. On straight, distance flight, the beats are of slow, full, open-shut type and have great driving power.

Ampelidae.

Grace and ease characterize the sustained flight of the Waxwings.

Laniidae.

The Shrikes’ flight is strong, rapid, undulating, but not long continued.
Vireonidae.

The Vireos are flappers only very slightly undulating. They often dart out after insects, as do the Flycatchers, but stay mostly among the branches unless in migration.

Mniotiltidae.

The Wood Warblers' flight tends more toward the undulatory than is the case with the Vireos. All are more or less quick, flitting in action.

Protonotaria. The flight is more firm and decided, swift, but brief and, if prolonged at all, undulating.

Motacillidae.

The Wagtails fly easily, though usually short distances and jerkily.

Neocorys spragueii rises aloft as does the Lark.

Cinclidae.

In the Dippers is found a variation in the opposite direction from the Swallows. Their wings are short, almost broad as long, stiff and concavo-convex. These birds fly beneath the water, using wings and legs both, and, since their specific gravity is less than water, some effort is necessary to perform this feat. They fly little in the air but strongly and rapidly.
The Wrens fly rapidly and directly with rapid vibrations of the wings.

The Thrashers and Mockers have an unsteady, bobbing flight, the appearance of unsteadiness being increased by the long, drooping tail.

Certhiidae.

The Brown Creeper darts down from one tree bole and skims or flits to another lower down. On a longer flight it undulates.

Paridae

The Paridae are undulating in flight. While the Nuthatches (Sitta) dart from one tree to another in Woodpecker fashion, the Tits have a weak flight made more undecided by the long, drooping tail.

Sylviidae.

Turdidae.

The flight of the Turdidae is strong, rapid, slightly undulating and, on migrations, extended. It is not protracted when located.
PART III.

A TABULATION OF BIRDS ACCORDING TO MANNER OF FLIGHT.

In a tabulation of birds according to manner of flight, a few arbitrary definitions are necessary. Of the three main heads, Flightless Birds, Flappers and Sailers, the first is used to denominate birds incapable of lifting themselves from the earth and sustaining themselves in the air effectively by means of their wings.

Under Flappers are placed all birds whose most stable means of progression is by flapping. Two sub-heads are given: Pure Flappers and Flap-and-Gliders, or those that habitually progress by alternate periods of flapping and gliding.

Under Sailers are placed all birds that are able to sustain themselves by sailing flight. Two sub-heads are given under it as well, to indicate, first, if sailing is primary to the complete, or almost complete, exclusion of other means and, second, if sailing is secondary, an adjunct to other means. In case a bird has more than one variety of flight, it will be so shown under the appropriate sub-heads.

In so far as dealt with in this paper, birds may be tabulated according to manner of flight as follows: -
I. FLIGHTLESS BIRDS.

1. Struthiones.
2. Apteryges.
4. Pygopodes.

1). Podicipedidae
   a. Centropelma micropterum.

2). Alcidae.
   a. Plautus impennis.

5. Steganopodes.

1). Phalacrocoracidae.
   a. Phalacrocorax harrisi.

6. Anseres.

1). Anatidae.
   a. Cnemiornis calcitrans.
   b. Tachyeres cinereus.
   c. Nesonetta aucklandica.

7. Paludicola.

1). Rallidae.
   a. Ocydromus.
   b. Porzanula palmeri.
   c. Notornis mantelli.

8. Columbae.
1). Dididae.
   a. Didus ineptus.
   b. Pezophaps solitarius.

   1). Psittacidae.
      a. Stringops habroptilus.

II. FLAPPERS.

A. Pure Flappers.
   1). Pygopodes. See I. 4. 1)&2).
   2). Tubinares.
      1). Procellariidae.
         a. Pelecanoides urinatrix.
   3). Steganopodes.
      1). Phaethontidae.
      2). Phalacrocoracidae. See I. 5.
      3). Anhingidae.
   4). Anseres.
      1). Palamedeidae. See III. B. 2.
      2). Anatidae. See exception II. B. 3.
   5). Herodiones. See II. B. 5.
   6). Paludicola.
   8). Opisthocomi.

10. Raptorens.
   1). Falconidae, except Vulturinae, III.A.4.2).
   2). Serpentariidae.


12. Coraciiformes.
   1). Coraciae. See II.B.8.1).
   2). Striges.
   3). Micropodii.
      a). Trochilidae.
   4). Trogones.
   5). Pici.


B. Flap-and-Gliders.
   1). Crypturi.
   2). Steganopodes.
      1). Sulidae.
      2). Pelecanidae.
   3). Anseres.
      1). Anatidae
         a). Cygninae.
   4). Odontoglossae.
      1). Phoenicopterae.
5. Herodiones.
   1). Ciconiidae.
      a. Tantalops loculator.

   1). Jacanidae.

7. Gallinae.

8. Coraciiformes.
   1). Coraciae.
      a. Bucerotidae.

2). Caprimulgi.
      a. Caprimulgidae.

3). Micropodii.
      a. Micropodidae.

   1). Icteridae.
      a. Sturnella.

2). Hirundinidae.

III. SAILERS.

A. Primary.

1. Longipennes.

2. Tubinares. See II.A.2.

3. Steganopodes.
   1). Fregatidae.
4. Raptores.
   1). Cathartidae.
   2). Falconidae.
      a. Vulturinae.

B. Secondary.

1. Steganopodes.
   1). Anhingidae.
   2). Pelecanidae.

2. Anseres.
   1). Palamedeidae.

3. Odontoglossae.
   1). Phoenicopterae.

4. Herodiones.
   1). Plataleidae.
   2). Ibididae.
   3). Ciconiidae.

5. Paludicolae.
   1). Gruidae.

6. Raptores.
   1). Falconidae, except Vulturinae.
   2). Serpentariidae.
RELATION OF THE MANNER OF FLIGHT TO THE
HABITS OF BIRDS.

I. The Flightless Birds.

In a discussion of the relation between manner of flight and the habits of birds, it seems best to begin with a consideration of those members of the class that are flightless.

It is not within the scope of this paper to attempt to trace the prehistoric connections of birds, but in the case of the keelless birds, STRUTHIONES and APTERYGES, there is need of a few words in regard to their probable development, as far as flight is concerned. The rudimentary wings are, no doubt, considering the evidence offered by the vestigial remiges in several forms, reductions from lower forms that possessed better developed wings. The absence of the sternum has occasioned more discussion. Some of the flying reptiles had no keel, and some of them had only a small one; **Archeopteryx** had a very small keel; yet flight was possible among these, so it seems the keel is not indispensable to flight. Further on we find **Ichthyornis** a powerful flyer with a well-developed keel. Also if the keelless condition is not regarded as a reduction, it argues two separate lines of descent for the Ratitae and Carinatae from the reptilian ancestry, which is not probable. And, since we have examples of Carinates becoming almost keelless by
reduction, (Didus, Pezophaps, Stringops), it seems reasonable to suppose that the Ratitae may be evolved from keeled, flying ancestry, since they are not primitive enough to be directly in line of descent with keelless flyers, and, since flight was achieved before their time both with and without a keel. Our tentative conclusion is, then, that the flightless birds and the keelless condition in STRUTHIONES AND APTERYGES are the results of a reductive evolution, brought about through natural selection.

Nine orders are represented in the list of flightless birds; three orders entire and twelve species divided among the other six orders. Of these Plautus impennis is the only member that was the least migratory. This species, before becoming extinct, performed a strictly aquatic, seasonal migration, ranging from its sub-arctic home, southward as far as Virginia.

With Plautus impennis, the SPHENISCI, Centropelma microptera, Phalacrocorax harrisi, and Tachyeres cinereus, are strictly aquatic in their search for food and frequent land chiefly to breed. Terrestrial enemies are absent from their habitats. Centropelma inhabits Lake Titicaca only and enjoys isolation. The SPHENISCI are most strictly aquatic and their adaptation for such life and their ability as sub-aquatic flyers have been mentioned in Part II. p. 13. Wings sufficient for aerial flight with these birds would be prejudicial to their welfare as so much extra ma-
So the aquatic members of the flightless group, there being occasion for flight, neither for food, migration, nor escape from enemies, are the result of reductive selection in varying degrees.

The APTERYGES, Cnemiornis calcitrans, Ocydromus, Porzanula palmeri, Notornis mantelli, Didus ineptus, Pezophaps solitarius and Stringops habroptilus are all insular in habitat where the climate is such as to occasion no need for migration. Cnemiornis and Stringops are vegetarians; Didus, Notornis, Ocydromus, Porzanula and Pezophaps are chiefly so; while the APTERYGES find their sustenance in the insects, worms, snails, etc., inhabiting the ground. Porzanula, moreover, parasitizes on the eggs of other birds of Laysan, its island home. Wings would hinder its skulking among the vegetation and slipping easily in and out of small crevices for hiding. Space on the island is so thickly populated that this bird has a most perfect adaptation for utilizing room not available to its winged neighbors. Stringops and the APTERYGES are nocturnal feeders, remaining in hiding in holes, under rocks or in similar places, during the day. Wings here would be detrimental to birds with such elusive habits.

An important factor to be noticed is the absence of carnivorous animals in the regions inhabited by these birds. The Dingo (Canis dingo), of Australia, is the only one and it is thought to
have been introduced by man, so natural enemies are nothing. The result among these members is the same as in the last group. Many species under similar conditions have paid the penalty of extinction, when the balance of environment was disturbed. And, where nature has provided a creature for an almost passive existence, giving it means of escape from danger, if, indeed, it knows what danger is, only in defenceless concealment or elusion, with no swiftness, the end of such a creature is not hard to guess, in case conditions are disturbed. Extinction will come to all, as it has, very recently, to a few mentioned here, because this radical specialization, accomplished in so long a time, permits of no adaptations in another line.

The STRUTHIONES are just as helpless as the preceding on the wing, but their enlarged legs give them a chance to seek safety in swift escape or in flight.

The Struthionidae, Rheidae, and Dromaeidae live in the open where their height commands a wide view of the horizon. Thus they can detect an enemy at a distance or, if surprised, their escape is more sure by their powerful legs than enable them to get up terrific speed at once, than it would be if wings were trusted to convey so large birds. The lax plumage renders the heat more tolerable and the plumes of the Ostriches also aid in this since the wing can not be shut close.

The Casuariidae live more in the forests and trust to concealment for safety.
Where there was food in plenty and a congenial climate to afford perennial residence, Nature could find no easier method of escape from enemies for these large birds, than by enlarged legs. Wings to support such large birds would need to be enormous. Considering the seventeen pound Condor has some nine feet expanse, what would a one hundred and eighty pound Ostrich need? It is very probable that the flying ancestors of these birds were much smaller in size and that a strictly terrestrial life has given opportunity for increase in size. This latter is true in case of Didus and the older Moas. The thirty pound Ornithostoma with its twenty-five square feet of wing appears to have been Nature's winged maximum. (1)

So, passive environment and a degree of isolation, have produced among the flightless birds, giants, pigmies, sluggards, imbeciles and the physically ugly and awkward among the feathered kind.

II. The Flappers.

A. Pure Flappers.

Were the term "pure" not used relatively, the PYGOPODES and Pelecanoides urinatrix would be the only real members of this class with Anatidae and Phalacrocoracidae as eager aspirants.

The short-tailed PYGOPODES find their food under water so need small wings for diving for food and out of danger, or swimming with greatest ease. With such small wings, flapping flight is most efficient. They can rise from water more easily and quickly thus, compared to other manners of rising, and they have no need for flight save as a means of transportation and their swift, direct course is most expedite, in migration with Podicipedidae and Urinitoridae and in shorter flight in all the families. The short tail and small wings render control of the flight difficult so that alighting under other conditions than those in which they live would be dangerous. The Podicipedidae and Urinitoridae always alight in the water, so their abrupt descent needs no check and it makes for the most sudden escape from view.

The Alcidae spend the greater portion of their lives on the open ocean, are pelagic in fact, and the benefits of small wings are evident. Their only need for flight is during the nesting season and then merely to enable them to reach the precipitous cliffs on the island shores where they breed. Alighting on water they de-
scend as abruptly as the two other families and on land they alight from an ascent to the cliffs, thus rendering extra check of impetus by the wings unnecessary. Their flight back and forth in straight lines over the rookeries appears aimless, unless it be to keep up practice in flight. The curious morning and evening parade of Uria appears unexplainable if it is not after the nature of the Wild Duck's evening patrol before settling for the night.

So in all three families the tendency is toward a reduction of wing size, looking to sub-aquatic progression, and at the same time toward a conservation, making rectilinear, flapping flight efficient.

Pelecanoides urinatrix is more strictly aquatic than the Alcidae, though it remains all the time in quiet waters of sounds. Thus it has but little need for flight, save to evade a sub-aquatic enemy. The tendency of adaptation is the same as in PygoPODES.

Phalacrocoracidae are one step beyond the Alcidae, inasmuch as they spend less time on the water. Their wings are insufficient for a steady rise from the level, yet they suffice for the same purposes as do those of Alcidae and evidence the same tendency.

The Anatidae, excepting the Cygninae, illustrate the tendency, evidenced in the PygoPODES, only to a less degree. Their food is more often in shallow water and mostly vegetable, obviating, largely, sub-aquatic pursuit, though deep diving is common to certain
genera of the Sea Ducks in Merginae and Fuligulinae. Moreover, the Anatinae and Anserinae often alight on the ground to feed, while certain species frequent trees. Among all these it is a noticeable fact that the farther the species gets away from purely aquatic life, the more control it has over its flight and the less are the limitations of its manoeuvres. These members being brought from under water to its surface, and some even to land, have larger wings, but since some diving or ducking is common and their habitat in many cases secluded, and not allowing detection of an enemy in time for a slow start to soar, small wings and flapping flight are retained but in a better regulated condition than in the Pygopteres.

The migrations in this family are long and the great speed in flight counteracts the greater expenditure of energy in a given time, so the result is the same, as far as the birds are concerned, as though more time were consumed under lower pressure.

The Phaethontidae, in point of the extent of their flight, might well be sailors but, since they secure food by plunging, flapping serves better in order to make the rise, difficult enough as it is, easier. Their small size gave no need for the flap-and-glide flight of the Sulidae. That sailing might be a benefit to them in their long journeys, is deduced from the fact that they sometimes become exhausted.

The Anhingidae surpass the Ducks in relative wing size
and are expert divers as well. They also swim under water but the size of the wing precludes its use greatly as an organ of propulsion under water and also precludes rapid vibrations. These birds are equipped for unobtrusiveness, since they dive or sink noiselessly, and they rise on wing slowly and quietly, trusting to quiet and seclusion for safety, rather than to speed as in the case of the Ducks. By their long tail their rather swift flight among trees is rendered controllable in their swampy home. This tail also aids in augmenting the sustaining surface and, in connection with the slender body, makes soaring possible on this type of wing. Soaring allows a survey of the field for intruders undetectable otherwise in the swamp. They are thus doubly safeguarded.

The Rallidae, being inhabitants of regions of dense vegetation, need flapping flight in order to progress advantageously. Their wings are fairly ample and they trust to concealment for safety since their rise is slow. On migration their speed is not great, the slighter bodies and relatively larger wings precluding the great driving power of the Anatidae. Their migrations are less direct and more halting than Anatidae, so the great speed is not necessary. *Fulica* swims under water but uses the lobed feet as the means of progression.

In the LIMICOLAE is found a transition between the Anser-
ine type and the Heron type to be discussed later. The flat, narrow wing tips give means for a driving flight rivaling the Anatidae in speed. Since the body is slighter, the vibrations are less rapid, due also to the broad base, and this gives a more enduring flight. This character of a broad base renders more buoyancy to their flight to allow a successful lighting on the ground with the slender legs. These birds live only partly in the open and so need a ready rise and, for their remarkable migrations, great speed and endurance.

*Philohela* lives more among trees and underbrush and its rise is after the nature of the Ruffed Grouse (*Bonasa umbellus*). Apparently this is a case of approximation through community of needs. *Gallinago*’s erratic flight serves most admirably for an elusive rise from its marshy home with a wide horizon. It would be of interest, if data were available, to see if the pursuit of the Snipe by men has had any influence on its manner of flight.

To finish the flapping water birds, the *HERODIONES*, Gruidae and Palamedeidae may be considered much in conjunction. All are waders, the Palamedeidae being good swimmers as well, and, to allow a lighting as mentioned for the *LIMICOLAE*, the wings are broad. The Palamedeidae are not completely away from the Anserine rise but their soaring ability is markedly a departure and so is the settle. They are not migratory and, being large birds not easily concealed, rise to survey their marshy home for enemies and, possibly, as a
means of escape from pursuit. Soaring is practiced by all others in
this group save Ardeidae. These latter circle by slow flapping.
This soaring or circling as the case may be, besides being an avenue
of escape from imminent danger, in the migratory species, is to al­
low these birds to acquire easily a height to warrant safety from
inimical Raptore to their rather slow passage. They often need to
soar thus in light winds, hence another reason for the broad sus­
taining surface of the broad wings. The long legs in these species
act to a limited degree as rudders, though they are not indispens­
able, nor do long legs in a sailor indicate a short tail, as is ev­
idenced by the Serpentariiidae. The pose of the neck in Ardeidae,
differing from others, is from anatomical causes. The center of
gravity being naturally farther forward with them, the head is car­
rried farther back to give the proper balance.

So these birds flap slowly and with good control because
the abrupt flight of the Anserine type would be prejudicial to the
long legs, and these same long legs would be equally incompatible
with a gulf's alar equipment. As a recompense for their slow gait,
necessitated by the broad wings and light bodies, on a straight
flight, they are enabled to circle easily on these wings up to alti­
tudes seldom reached save by the boldest enemy. These species that
soar, do so in smaller circles than the pursuing Raptore and
often escape thus.
The Otididae are essentially terrestrial and their legs are stronger, being fitted for running instead of wading. Thus the wings are less ample than in the Gruidae and a more rapid flight possible. In habits and habitat they approach to a certain degree the Tetraonidae, so their flight approximates that of this family except they do not glide.

The OPISTHOCOMI have the weakest flight of the flying flappers. This is to be expected in the light of their leaf eating habits and jungle habitat. There is little need for flight and great need for climbing, hence the claws, weak wings, and reduced keel.

Of the COLUMBAE, the terrestrial species are non-migrants and poor flyers, there being little need for food in search for food and their inconspicuousness being a better protective means than flight could give.

The vast numbers of Ectopistes that were found formerly necessitated a swift, powerful flight in order that these hordes might go miles to and from feeding grounds during the breeding season and that they might wander at other times. Zenaidura is migratory but not found in such great flocks. The wings of these members are perfect for the easy and rapid propulsion necessary. The peculiar method of feeding of Ectopistes requires strong flight.

The flapping Falconidae are endowed with a sustaining
and carrying power to enable them to carry away their prey. Since a rapid flapping flight could not accompany great carrying power and since the food consists of live animals, means must be found to counterbalance this tardy pace. In most of the species, those really predaceous, the power to soar high in the air and hover is given by the broad wings. Furthermore they can close the wings and plunge headlong with the speed of an arrow for hundreds of feet, then regain control with the powerful wings at once and either grasp the victim or, with greatly increased speed, finally overtake the prey. The soaring ability furthermore increases the field under survey and facilitates the chase. Where the hunter seeks smaller prey the noiseless quartering on expanded wings is most efficacious. Among smaller Hawks that feed mostly on insects the need is for agility rather than power so the wings are narrower and tail longer.

Serpentariidae have come to feed chiefly on snakes living in the long-grassed plains, and the legs are elongated to facilitate pursuit on the ground in case the first attack is unsuccessful. They also need carrying power since the snake is often carried high in to the air and dropped. Soaring broadens the field as in case of the Falconidae.

Of the CUCULIFORMES the Psittacidae are non-migrant and dwellers, largely, in forest regions, some species frequenting open places. Safety for them lies in concealment and, since there is no
need for flight in migration, they fly mainly to secure their food which is in most part fruit and seeds. The various degrees of efficiency in unsustained flapping or undulatory flight is sufficient unto their needs. *Crotophaga* of the family Cuculidae comes in this group.

Of other Cuculidae, *Coccyzus* includes migratory species and the flight, though adapted to arboreal selection, slow, noiseless and easily controlled, is adequate for the journeys taken in easy stages.

*Geococcyx* is terrestrial. Open flight in its sagebrush home could make only for exposure, for its food and shelter are terrestrial and it is not migratory. Its protective coloration and swift legs avail more for safety than the rare attempts at a low, short flight.

The members of the order CORACIIIFORMES furnish some rather wide variations on the adaptations of flapping. Of the Coraciidae, the Coracidae are largely migratory, arboreal and insectivorous, requiring a strong flight. The Momotidae are non-migratory and denizens of the deep forest so fare very well with their unsustained flight in waylaying insects. The Alcedinidae need the short, powerful wings in diving and these furnish means for the rather extensive, though indirect, migrations.

The Upupidae are mainly terrestrial, inhabiting waste
places, so need no great powers of flight.

The Striges have an easy noiseless flight to comply with their nodturnal invasions. As the habits of the species tend more toward diurnal, so the flight is less typical and becomes more like the smaller RAPTORES, as shown by Surnia and Glaucidium. The semi-parasitic, terrestrial habits of Speotyto have reduced its powers of flight.

Nocturnal Caprimulgidae have the noiseless flight of the Striges but their flight is modified for a light, nimble pursuit of insects. The diurnal or crepuscular Chordeiles needs a still more agile flight it has, to catch its elusive prey successfully.

The bullet-like flight of the Trochilidae is the maximum in flapping. The diminutive size of these birds gives cause for an adequate safeguarding in swift flight and their blossom exploring habits occasion the deft poisings. So these ornithic torpedo boats are able to maintain a prolific existence under the very eyes of their hostily inclined neighbors and this even where their actual rate of reproduction is slow. The larger species are less at the mercy of possible enemies so their flight is less rapid. With the small species of such light weight, wings and pectoral equipment, fitting for a slow, flapping flight would make little more than feathered butterflies of these creatures and put them at the mercy of any inimical passerby.
The Trogonidae are denizens of the tops of the deep forest, rarely leaving such places. Their food is mainly fruit, with a few insects. They are non-migratory. These factors call for no extraordinary powers of flight.

Of the Picidae, the Rhamphastidae, light of build, fly easily to get the fruit that comprises their food but they need no strong nor protracted flight. The arboreal Pisciidae do not have need of a protracted flight, and the undulatory type provides transit without constant flapping and consequently, with less expenditure of energy. It also makes lighting on a vertical surface easy by providing a rise. The wings are ample enough to provide sustaining surface for a curved glide in passing from tree to tree. In certain species mentioned, the insect catching habit carries with it an approximation to the sallying flight of the Flycatchers.

A few of the Passeres have specialized flight, in families. The Hirundinidae are adapted for insect hawking on the wing, thus having a field practically to themselves and they approach the sailing type of flight. The Cinclidae pursue their food under water and their wings are shortened to serve sub-aquatically and at the same time are broad enough to serve for propulsion in the air, thus differing from the purely aquatic type. The near-terrestrial Menuridae are non-migratory and free from natural enemies. There being no need for much flight, the wings, in place of degenerating, as is usually the case, have attained a rather neutral char-
acter and are nearly as equally useless.

The typical Passerine flight is one fitting for life of keen competition in the densely populated mid-region between water below and air above. It is admirable in its all-aroundness, furnishing adequate transportation to the migratory species; ready means for obtaining food; as well as ever present and quickly utilizable ability for escape. Calms do not affect it and storms are usually easily evaded. In short, this type of flight, not dependent on fixed conditions, fits the variability of surroundings encountered by the majority of PASSERES and, viewed from the standpoint of the struggle for existence, is compatible in rank with the place accorded its possessors in classification. The quick wings furnish a ready start, or a sudden, fluttering stop and are broad enough to allow short glides on curves, or for easy settling. From the shy Thrushes to those domineering tyrants, the Flycatchers, the flight varies, not in nature, but merely in point of fitness for only slightly varying habits.
B. Flap-and-Gliders.

The CRYPTURI are terrestrial and non-migratory, living on the open plains. Since their legs serve mainly for progression, flight is resorted to only in an emergency. Then rapidity with least expenditure of energy to transport the bulky body is paramount. This is achieved by the imperfect pectoral equipment, by a short period of flapping and a subsequent resting glide. There is little choice of lighting place in its habitat, usually no obstacle, and these factors, together with the little need for flight at all, have brought about this condition of flight equipment.

Among the non-migratory GALLINAE, the flight approximates that of the above order but is necessary stronger and more enduring, since they are not inhabitants of exactly the same kind of habitat. Their horizon is smaller and competition keener, making the quick rise just as essential. Some species are wood dwellers also. So, on the whole, more control of flight is needed. But, being heavy bodied and terrestrial, the wings must be broader than in the heavy bodied, aquatic forms, in order to furnish sufficient sustaining force for a successful light on ground or tree. The glide furnishes a period of rest necessary after flapping the broad wings, if the flight is to be continued any distance. Without the glide, either the wings must be made smaller or the pectoral equipment increased disproportionally, else alighting were disadvantageous,
or bulk unwieldy.

The species living in open country fly farther at a time than those living in covered regions. *Colinus* rarely exceeds a quarter of a mile as a maximum, while *Centrocercus* may have a flight of some miles.

*Sturnella* of the family Icteridae, approximates the above type through a similarity of habits and habitat.

In Sulidae and Pelecanidae the wings are long and pointed but ample as well. The small relative wing area of the Anserine type would not insure buoyancy sufficient for the poise before a plunge, nor render accurate enough control of the direction of flight in these fishing birds. The larger wings meet these demands and occasion a glide for the reason given under the discussion of the GALLINAE. Since the flight in these birds is of long continuance, in their quest for food, a lighter and easier flight is in this manner secured and it still meets the conditions necessary for plunging. Equipment for sailing flight would be of little avail after such plunges.

*Pelecanus erythrorhynchos* does not dive but needs the ample wings to assist in circling to a high altitude to perform its long migrations. *P. fuscus* is not so given to circling, since it is not so widely migratory.

The Cygninae, of America, at least, are more widely migra-
tory than the Anserinae and fly at greater heights, so a trifle more buoyancy is needed to enable them to attain these altitudes. The short, rapid strokes give great speed when the bird is under way and, by flying with the wind as it usually does, the glide keeps up the speed well and relieves the muscular strain, so allowing an easier and more protracted flight.

In the Phoenicopteridae the flap-and-glide flight allows a broad wing for soaring on inspection and for the proper sustaining surface found in the long legged birds. So ease and safety are secured.

Tantalops loculator, of HERODIONES, may be considered with Phoenicopteridae. No reason can be given for its flight being different from other Ciconiidae.

The aquatic Jacanidae have little need for flight and the flutter and glide combination seems to be the easiest means of accomplishing their flights, short and close to the ground.

Bucerotidae are non-migratory, arboreal in deep forests, or nearly terrestrial. Food, fruit and nuts, with reptiles added in case of the terrestrial species, is easy of access. The large bill, enlarged for feeding, and heavy in Rhinoplax, and heavy body would require too great exertion for continued flapping, so gliding is introduced to obviate any unnecessary development of muscle and still allow a facility of progression compatible with
their habits.

Mention was made of the Hirundinidae in the discussion of Passerine flappers. The Micropodidae may be considered here with them. The flight in these families departs considerably from the typical flap-and-glide but is closer to it then to the sailing flight. It is the nearest approach to the latter that is found in such small birds, whose bulk is too small to furnish inertia of motion sufficient for successful sailing. So flapping is resorted to oftener. Yet it suffices to bear these birds for hours in the air in most agile and efficient pursuit of insects. Their habits call for enduring, agile flight. Long continued flapping is too fatiguing nor would it give proper agility, due to increased bulk in birds of this size, if humming flight were attempted. And sailing is precluded, from the small bulk of the birds, so the needs are met equally as well by the dashing skims of the Swallows or the gentle glides of the Swifts. In connection with the above may be considered Chordeiles, as representative of the high hawking species of Caprimulgidae. Its flight is possibly not so rapid, though just as nimble as the above. However the approach to sailing flight appears for the same reason as in the two families just discussed and thus the manner of flight is similar in these otherwise widely different birds.
III. Sailers.

Since it seemed best to consider the soaring ability of the Secondary Sailers in the discussion of their flapping powers, there are left to be treated only the few groups of Primary Sailers.

The LONGIPENNIES are pelagic feeders and need a rapid, accurate and enduring flight to search for and capture food. The great numbers of sailing birds is another factor calling for enduring flight. This is best accomplished by sailing of the narrow-winged type. The broad-winged Vultures have an enduring flight but it is slow and efficacious only in light winds. The flap-and-glide type also furnishes too broad a surface. These sea birds can not wait for favorable weather so the long narrow wings obviate this necessity by giving great sustaining power in motion with little surface for unfavorable winds to act against. So this type of wing is found, not only in LONGIPENNIES, but in Fregatidae and the sailing TUBINARES as well, all being forced to hunt in various conditions of weather and all being practically surface feeders. A sudden rise is impossible with this type of wing but the breadth of the horizon and freedom from terrestrial or raptorial enemies, makes a sudden rise unnecessary.

The long, narrow wings would be of little use after a plunge in Gannet fashion. To feed, these birds, excepting the pirate
members, patrol the seas on tireless wings, comparatively close to the surface, till they sight food, when they usually alight to get the morsel desired. However the Petrels and Terns may dabble over the surface with wings outstretched or even dart through waves. In these members, though, much more flapping is employed in flight than in the larger members that feed as above.

Megalestris evidences raptorial traits in its feeding habits and the effect is noted in the sharp, curved claws and in the resemblance of its flight to the raptorial type. All the members of Stercorariidae have complete control over their flight fitting for raptorial or parasitic feeding. Extreme agility is needed where the bird is to overhaul a victim and catch his disgorged prey before it strikes the water.

The surface feeding Gulls need only the even, endless, contained flight. In Larus delewarensis is seen a case of adaptation, partly, to terrestrial feeding grounds, in that it flaps more. The lighter Terns must flap oftener, due to smaller bulk. Indeed they might almost as well be classed with the Swallows.

Rhynchopidae need accurate control in skimming the surface for prey. The increased area and position of the wings have been noted previously.

The Diomedeidae, due to large numbers, journey far for food during the breeding season and must be independent of storms.
or wind, so the long, narrow wings are preeminently fit. Since their journeys are so long, the practice of regurgitation in feeding the young is found, as in the Pelicans. Outside the breeding season they disperse far and wide to render the search for food easier, resting on the wave or cleaving the air with motionless wings.

In the Procellariidae, the Fulmars and Shearwaters are essentially Gull-like in flight and food habits, while the Petrels approach the Terns in needs and appointments.

In **Fregata aquila**, as typical of the Fregatidae, is found the acme of sailors in so far as accuracy of control, speed, and ability to sail in most variant kinds of weather are concerned. The long, narrow wings and long tail, with a light body, give a less steady, majestic tone, but such a habitus with its parasitical, piratical habits, were out of harmony. It is superbly fitted to hang in the air, or float lazily about, till it sees a more ambitious hunter raise a fish from the water, and then give piratic chase, frightening the victim into disgorging, then catching the morsel for its own. The high altitudes attainable give a wide field of survey and the meteor-like plunge puts it in swift pursuit at once. And here the lightness of the body is necessary and the narrow wings of another use. If the wings were broad and the body heavy, with the weak pectoral muscles of this bird, the wings would double back, if an attempt to check a plunge through the air were made, and the bird
would plunge on with no control. But the narrow wings do not furnish such a broad surface to yield a large resistance suddenly, and the light body has its momentum more easily checked, so the bird can open its wings and turn its dive into sailing flight at any point. The admirable powers of flight have brought this bird to live in the air and feed on aquatic food, fished almost entirely, by slower and more amiable flyers.

The Cathartidae and Vulturinae are necrophagous and so do not need the carrying capacity of the other RAPTORS, nor do they need to plunge after prey as do the Eagles, for instance. Indeed, with their weak muscles, such a plunge would mean death. The broader wings furnish a better sustaining surface for the heavy bodies, since they need to fly slowly. These wings are not serviceable in high winds or storms but such are the exception and not the rule in their habitat. A search for carcasses would not be very fruitful in a storm at any rate. So they sail high on broad, easy wings, even with little wind, and closely scrutinize any signs of their unholy food, discovering which, they circle or glide slowly down. Their inability to rise quickly, is offset by the careful survey of the field for enemies before alighting. The smaller species rise more quickly, not only because smaller, but since they live in less waste places and need more versatility.
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