A SYSTEMATIC STUDY OF THE MAIN ARTERIES IN THE REGION OF THE HEART—AVES XII

GALLIFORMES, PART 1[1]

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In this, as in several previous studies on the main arteries in the neck and thorax of birds, the writer presents the basic ordinal characteristic arrangement-pattern, along with some of the important family and specific variations within the limitations of this study. As has already been noted, specific deviation from the basic ordinal arrangement is generally but slight, although in certain orders of birds, especially the Coraciiformes (11) and Ciconiiformes (16), there may be extreme differences in the family arrangement-patterns. Where two carotid arrangements (1) characterize an order, it may be held that the different families have had different immediate ancestors and express certain of these primitive features while other features of anatomy have undergone developmental convergence, thus showing similar or identical characteristics. On the other hand, it may be held that, despite apparent wide differences in one or more important anatomical features, widely divergent species may have undergone rapid and radical monomorphic evolutionary changes with apparent polymorphic resultants in the form of extant species, all of which stemmed from a single common ancestral group or type. In either case, paramorphic development cannot be overlooked in any consideration of phyletic relations—based on morphological characteristics—since instances of paramorphism are to be noted in various major groups of organisms, and more particularly within a single class of animals and for any single characteristic. Such instances of paramorphic development as are especially notable may be due, in large, to the fundamental nature and structural limitations of protoplasm. There are, no doubt, many basic and primitive characteristics commonly inherent in many different, sometimes widely separated, orders of animals. The more closely related families and orders naturally tend to sharply present more basic and closely associated characteristics.

According to Beddard (1) and Garrod (3), the Galliformes are "bicarotidinae normales." In the former order GALLINAE the Pteroclidae, Tetraonidae, Phasianidae, and Cracidae are "aves bicarotidinae normales," while the Turnicidae and Megapodiidae are reportedly "aves laevo-carotidinae." Wetmore (23) places the Tetraonidae, Phasianidae, Cracidae, and Megapodiidae in the Galliformes, while the Turnicidae are assigned to the Gruiformes and the Pteroclidae are placed in the Columbiformes. Within the limits of the present study, Garrod's observations are substantiated. However, further studies, to include the Cracidae and Megapodiidae are necessary to discern whether or not these families have representatives which are not bicarotidinae normales.

The present study is limited to 10 species of the present order Galliformes. Difficulties encountered in obtaining adequate and satisfactory specimens has been the chief limitation in this study. As a result, this paper is of necessity brief, and conclusions based upon these findings can only be regarded as tentative and subject to change, based upon subsequent and more complete observations.

[1]Contributions from Blue Sea Lake Biological Laboratory, Messines, P. Q.

MATERIALS

The writer is indebted to the Royal Ontario Museum of Zoology, the Chicago Natural History Museum, and the Ohio Cooperative Wildlife Research Unit for materials used in this study. Except for the ring-necked pheasant, common barnyard fowl, and hoatzin, only single specimens were available for study.

Suborder GALLI

Superfamily **Phasianoidea**

Tetraonidae

Bonasa umbellus (L.), Ruffed Grouse

Phasianidae

Phasianus colchicus torquatus Gmelin, Ring-necked Pheasant
Chrysolophus pictus (L.), Golden Pheasant
Catreus wallichii (Hardwicke), Cheer Pheasant
Arborophila brunneopectus henrici (Oustalet)
Crossoptilon mantchuricum (Swinhoe), Brown-eared or Manchurian Pheasant
Gallus gallus domesticus Darwin, Common Barnyard Fowl or Chicken
Pavo cristatus L., White Pea Fowl (Indian)

Meleagrididae

Meleagris gallopavo L., Domestic Turkey

Suborder OPISTHOCOMI

Family **Opisthocomidae**

Opisthocomus hoatzin (P. L. S. Muller), Hoatzin

OBSERVATIONS

The basic ordinal arrangement-pattern of arteries in the neck and thorax of the Galliformes, included in this study, is reasonably characteristic. The aortic root (*1*) arises in the left ventricle and passes diagonally to the right before dividing to form the innominate arteries (*2*). The right systemic arch (*3*) arises from the right innominate artery almost immediately after bifurcation of the aortic root and, after passing dorsally in an arch over the right pulmonary artery, passes posteriorly and diagonally toward the median line as the right radix aortae (*4*) to the dorsal aortae (*5*) where the embryonic left radix aortae persists as the ligamentum aortae (*6*). The ligamentum aortae may maintain its proximal connection with the left pulmonary artery (*8*), or may remain as a white, imperforate cord in the supporting connective tissue with only the distal connection. The right ligamentum botalli (*7*) is present, either completely or in part, and may fuse with the ventral face of the right radix aortae. Anteriorly the

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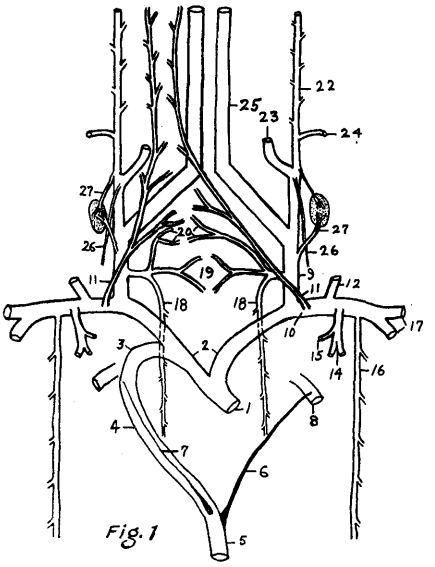
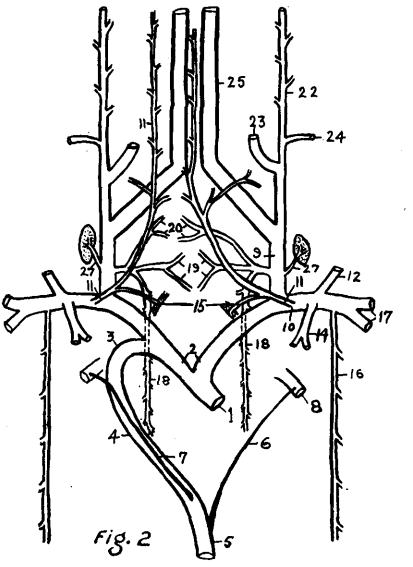
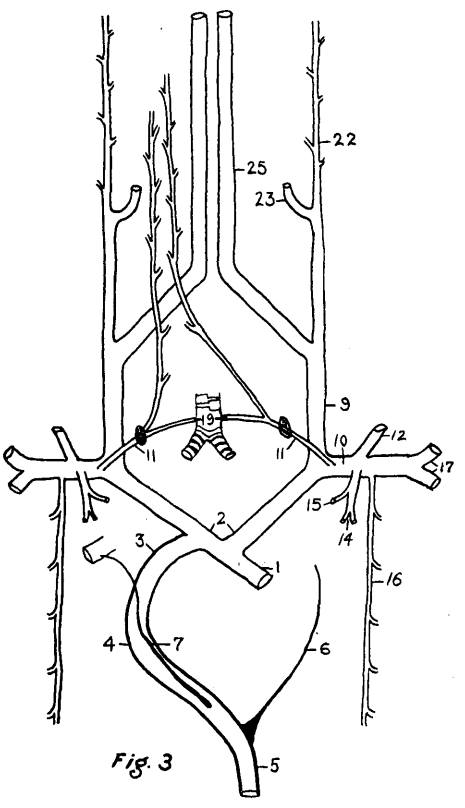
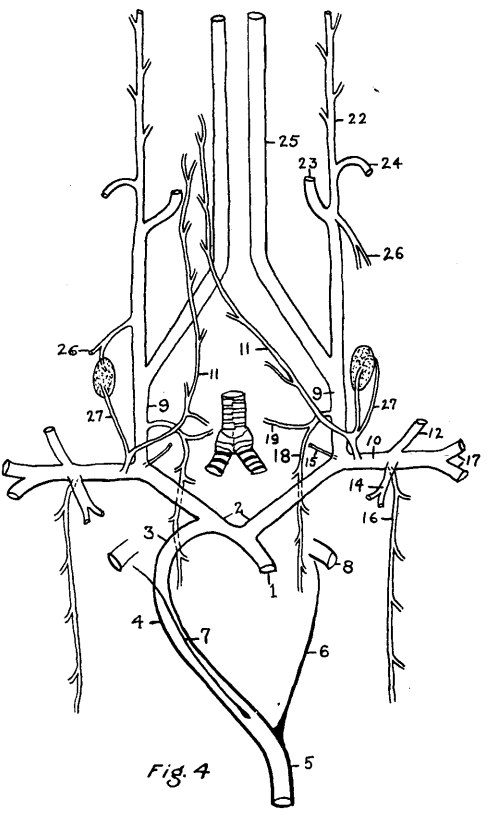
KEY TO NUMBERS USED IN FIGURES

1. aortic root
2. innominate arteries
3. right systemic arch
4. right radix aortae
5. dorsal aortae
6. left ligamentum aortae
7. right ligamentum botalli
8. pulmonary artery
9. common carotid artery
10. subclavian artery
11. arteria ventralis gallinae
12. axillary artery
13. coracoid minor artery
14. coracoid major artery
15. sterno-tracheal artery
16. intercostal artery
17. pectoral arteries
18. ductus shawii
19. syringo-trachael artery
20. meso-oesophageal artery
21. accessory ascending oesophageal artery
22. superficial cervical artery
23. vertebral artery
24. subscapular artery
25. internal carotid (trunk) artery
26. basi-cervical artery
27. thyroid artery
28. arteria pericardia
29. accessory superficial cervical artery
30. basi-oesophageal artery.









Diagrammatic representation of the arteries of the neck and thorax of: (Ventral view).

FIG. 1. *Bonasa umbellus.*
FIG. 2. *Chrysolophus pictus.*
FIG. 3. *Phasianus colchicus torquatus.*
FIG. 4. *Catreus wallichii.*

innominate divides to form the common carotid (*9*) and subclavian (*10*) arteries. The latter then gives rise to the arteria ventralis gallinae (*11*) before giving rise to the axillary (*12*), coracoid major (*14*), intercostal (*16*), and two pectorsal (*17*) arteries. In the Galli, the common carotids give rise to the ductus shawi (*18*) which send off branches to the syrinx and trachea (*19*) and the oesophagus (*20*) before passing posteriorly. The ductus shawi and its branches (*18*, *19*, *20*) were not observed in either *Phasianus colchicus torquatus* or *Opisthocomus hoatzin*.

In *Bonasa umbellus* (Fig. 1), arteria ventralis gallinae serves as the accessory oesophageal arteries and the vessel of the left side likewise sends branches to the trachea. A short basi-cervical artery (*26*) arises from the superficial cervicals (*22*) near the point of origin of the vertebrals (*23*). The thyroids receive two short arteries (*27*): one from the common carotid and the other from the superficial cervical. The axillary (*12*), coracoid major (*14*), intercostal (*16*), and two pectoral (*17*) arteries arise from the subclavian artery in order. The sterno-tracheal artery (*15*) arises as a branch of the coracoid major.

Chrysolophus pictus (Fig. 2). The sterno-tracheal artery (*15*) arises as a branch of the ventral galline artery in contrast to the otherwise normal origin from the coracoid major (*14*); the thyroid artery (*27*) arises as a branch of the common carotid artery (*9*); the ductus shawi (*18*) is present along with proximal branches supplying the syrinx and trachea (*19*) and the oesophagus (*20*) locally.

Phasianus colchicus torquatus (Fig. 3): As in the other members of the family Phasianidae, the coracoid major and axillary arteries arise from the subclavian shortly after the origin of the arteria ventralis gallinae (*11*); the intercostals arise just lateral and posterior to the coracoid major; sterno-tracheal muscles are supplied by a branch (*15*) from the coracoid major; the thyroids receive their supply from the arteria ventralis gallinae which then gives rise to a syringo-tracheal branch (*19*) before passing anteriorly to send off branches to the oesophagus and crop. The internal carotid (trunk) artery (*25*) enters the hypapophysial canal to pass anteriorly to the head. The ductus shawi could not be located.

Catreus wallichii (Fig. 4), presents several minor differences in origin of basal cervical vessels: the sterno-tracheal artery arises from the dorso-medial face of the subclavian artery at the base of the common carotid artery; thyroid supply is variable; the left thyroid gland receives two vessels from the arteria ventralis gallinae which then passes diagonally and medially to supply the oesophagus and crop; the right thyroid receives a branch from the right ventral galline artery and another branch from the right basi-cervical (*26*) which sends a branch to the skin and connective tissue near the base of the neck; a notable subscapular artery (*24*) arises from the superficial cervical; the intercostal arises dorsal to the coracoid major from the posterior face of the subclavian.

Arborphila brunneopectus henrici (Fig. 5), presents an accessory cervical vessel (*29*) which arises from the common carotid artery and sends off the thyroid artery; the sterno-tracheal artery arises as a branch of the coracoid major. The trachea is medial anteriorly, but about half-way down the neck it passes diagonally to the left and then posteriorly.

Crossoptilon mantchuricum (Fig. 6): Like *Meleagris*, an accessory oesophageal artery arises from the base of the left superficial cervical; as in *Meleagris*, *Phasianus*, and *Catreus*, the thyroid receives a branch from the arteria ventralis gallinae near the latter's point of origin. A short basi-cervical artery arises as a branch of the small accessory superficial cervical artery which arises as a branch of the primary superficial cervicals near the bifurcation of the common carotid; the accessory oesophageal artery (*21*) sends off a basi-oesophageal branch (*30*); a coracoid minor (*13*) arises from the ventral surface of the subclavian just lateral to the coracoid major and axillary arteries and medial to the point of origin of the intercostals. The sterno-tracheal artery arises as a branch of the coracoid major;

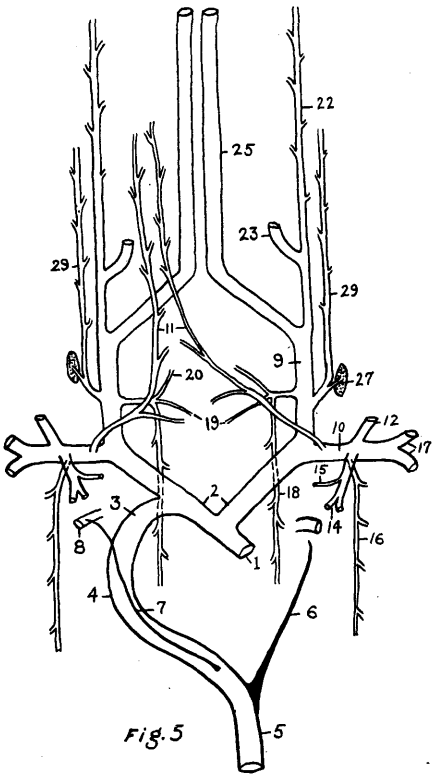


Fig. 5

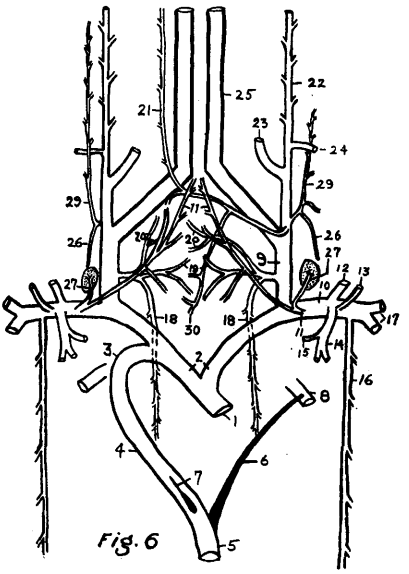


Fig. 6

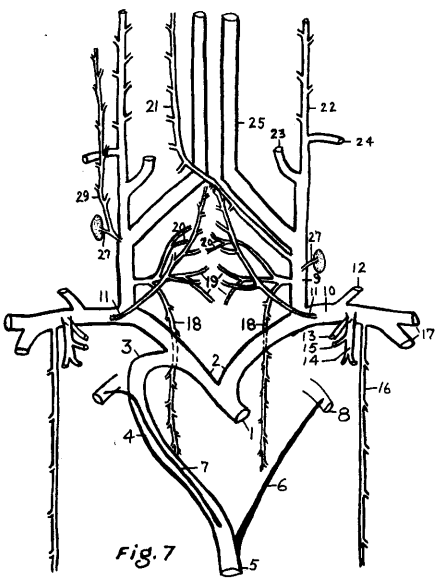


Fig. 7

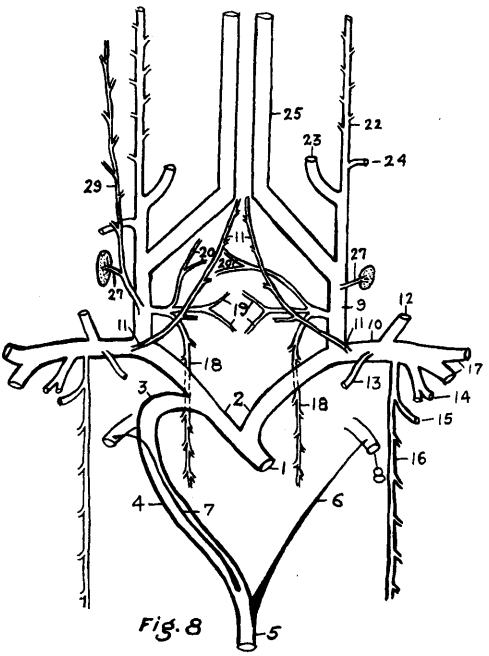


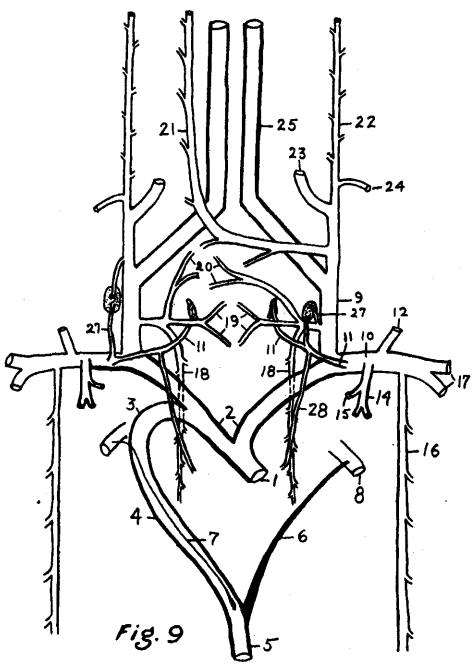
Fig. 8

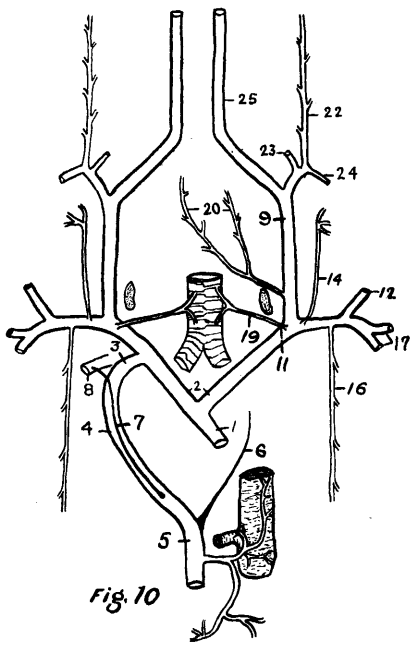
Diagrammatic representation of the arteries of the neck and thorax of: (Ventral view).

FIG. 5. *Arborophila brunneopectus henrici.*
FIG. 6. *Crossoptilon mantchuricum.*
FIG. 7. *Gallus gallus domesticus.*
FIG. 8. *Pavo cristatus.*

the ligamentum aortae is very large and prominent, whereas the ligamentum botalli is reduced to little more than a "button," or is fused in part with the right radix aortae.

Gallus gallus domesticus (Fig. 7), presents a pattern somewhat comparable to that of *Crossoptilon* except that the left accessory cervical artery is absent, and the thyroid receives its supply from a branch of the common carotid; the right accessory superficial cervical is present and sends off a branch to the thyroid of that side; the coracoid minor (*13*) arises from the subclavian near the base of the coracoid major which gives rise to the sterno-tracheal artery as its first branch. Origin of the coracoid minor is in all probability a more variable vessel, with respect





Diagrammatic representation of the arteries of the neck and thorax of: (Ventral view).
FIG. 9. *Meleagris gallopavo.* FIG. 10. *Opisthocomus hoazin.*

to point of origin, than are the other more commonly found vessels, and may not be found in some individuals.

Pavo cristatus (Fig. 8): Very similar to *Gallus* except for minor details: the coracoid minor arises from the subclavian medial to the axillary; the sterno-tracheal arises as a branch of the intercostal which lies medial to the coracoid major and lateral to the axillary. It would appear that *Pavo* is the most atypical of the Phasianidae, thus far studied, in the arrangement of the arteries of the neck and thorax.

Meleagris gallopavo (Fig. 9), varies considerably from members of the Phasianidae, although it follows closely the basic ordinal arrangement-pattern: the accessory oesophageal (*21*) arises as a branch of the left superficial cervical or it may arise from the common carotid near the origin of the superficial cervical; the arteria ventralis gallinae is reduced in function and sends off a branch to the thyroid, and an arteria pericardia (*28*) before supplying the trachea anteriorly; branches of the subclavian are the same as in *Bonasa* except that the coracoid major arises somewhat medial to the axillary. Oesophageal supply of the ventral galline

artery (*11*) was not observed, although it cannot be entirely excluded as a possibility, since these vessels are extremely small, and at times hard to follow unless the vessels are properly injected.

Opisthocomus hoatzin (Fig. 10), presents an arrangement-pattern quite different from that presented by the other gallinaceous birds: the coracoid major arises from the subclavian near the base of the common carotid and passes somewhat more anteriorly to supply the coracoid muscles; the intercostals arise medial to the axillary arteries, and the arteria ventralis gallinae, usually of considerable extent in the other gallinaceous birds, is short and, in so far as could be determined, did not supply the oesophagus and crop; a branch (*20*) from the left common carotid serves as a basal oesophageal supply. No ductus shawi could be found in either specimen which was examined. The cervical branches of the common carotids are the same as in other Galliformes. The ligamentum aortae is much reduced as is the ligamentum botalli.

The coeliaco-mesenteric artery gives rise, in *Opithocomus*, to two main branches, the first of which passes to the posterior end of the proventriculus. The first branch of this vessel recurves around the reduced ventricular valve while the other branch ascends the proventricular wall to the junction with the oesophagus. The second major division of the coeliaco-mesenteric sends off a branch to the liver, and to the gastro-intestinal tract. This latter vessel divides into two branches, the first of which goes to the ventriculus and the other serves as the anterior mesenteric artery.

DISCUSSION

Of the species studied, the most notable feature is the diversity in secondary arrangement of the cervical arteries. Except for the wide deviation from the basic ordinal pattern as found in *Opisthocomus*, the Galliformes included in this study appear to show fairly close relationships in their arterial arrangement-patterns. It would appear, too, that there are at least minor differences in the arterial arrangement within the families of the superfamily PHASIANOIDEA.

Such diversity in arrangement is probably indicative of a long and continuous evolutionary history. It would appear that the several families of this order, though showing certain fundamentally common characteristics, are far from being terminal in nature. This is especially notable in the diversity noted in the Phasianidae which are included in this study.

Whereas uniformity in all major (non-specific) characters is found in some orders of birds which appear to be terminal evolutionary forms, this does not appear to be the case in the gallinaceous birds. In a few orders of birds, the different families do not present uniform ordinal arterial arrangement-patterns. This is notable in the Coraciiformes (11), Colymbiformes (19), Ciconiiformes (4 & 16), and Psittaciformes (1 & 3). Furthermore, in addition to family variations within an order, several large and important families of birds show wide differences in numbers and distribution of the cervical and thoracic supply, as in several families of Passeriformes, Anseriformes (12), Psittaciformes, Ciconiiformes, and to a lesser extent among other orders of birds. On the other hand, there are several families of birds, such as the Picidae (6), Parulidae (Compsothlypidae) (21), Paridae (20), Indicatoridae (6), Phoeniculidae (11), Upupidae (11), Trogonidae (9 & 10), and Coliidae (13), and to a lesser degree in the Rhamphastidae (6), Fringillidae (5), Tinamidae (15), and Spheniscidae (7 & 8), and in members of the Charadriiformes (17 & 18) in which the family patterns are quite uniform with but little or no generic or specific variations of importance. Since in some of the orders there is but one family, the above conclusions may be drawn with respect to the order as well.

Although very few species of this order were examined in the present study, subsequent investigations should further clarify the matter of differences and

similarities within the families and more especially yet within the order. Such additional information may serve as an aid in establishing the natural groups by establishing apparent affinities within the families.

It would appear that the extant members of the Phasianidae, at least, are in a state of divergent evolutionary flux. The Phasianoidea present at least a single pair of vessels (arteria ventralis gallinae) which appear to be singularly characteristic of the Galliformes.

The presence of a large vascular supply to the crop and oesophagus may be correlated with crop-function and the feeding habits of these birds. Increase in size of this structure draws upon or requires increased blood supply.

Greatest differences in the vessels of the neck and thorax are found in the origin of vessels arising from the subclavian artery, and in the origin of the thyroid and sterno-tracheal arteries.

Pavo cristatus, while placed near the end of the Phasianidae, presents an arrangement-pattern which is quite different from the otherwise basic family pattern, and this might be interpreted as indicative of separate evolution, somewhat removed from the central pheasant line of evolutionary development, especially with respect to the organization and supply of the derivatives of the aortic arches and their associated vessels.

Further anatomical evidences to substantiate the position of *Meleagris* are presented by the arterial arrangement-pattern, as contrasted with that of the Phasianidae. In *Meleagris* the coracoid major artery tends to be medial to the axillary artery, while in *Bonasa* it is lateral to the axillary artery, and in the Phasianidae it tends to be opposite to the axillary artery.

The Phasianidae present a problem in grouping due in part to diversity in individual arrangement-patterns, but they tend to show at least close basic and major characters common to the several species studied. It is evident that the Phasianidae do not represent a terminal or end-line group as yet, and may still undergo further important changes in structure before arriving at a point of evolutionary termination.

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