PATTERNS OF THE AORTIC ARCH IN AMERICAN WHITE AND NEGRO STOCKS, WITH COMPARATIVE NOTES ON CERTAIN OTHER MAMMALS

By CHARLES F. DE GARIS, M.D., Ph.D.,
IRBY H. BLACK, S.B., M.D.,
and EDWIN A. RIEMENSCHNEIDER, S.B.

Anatomical Laboratory, The Johns Hopkins University, Baltimore

The present report treats in a statistical way the varieties of branches associated with the aortic arch as found in dissecting-room material of this laboratory between the years 1925 and 1932. This material comprises 314 specimens, distributed as follows according to race and sex: white males 98, white females 13, total whites 111; negro males 138, negro females 65, total negroes 203. These totals include the following numbers of infants: 3 white males, 8 white females, 13 negro males, 9 negro females. For completeness of the record entry is made of the distribution of male and female adults and infants according to the various patterns, even though only gross totals are required for expressing incidence as to race.

In addition to this human material, a large number of aortic arches from other Mammals has been collected and dissected by one of us (C.D.). This comparative material is in the main from Primates, but also includes samples from other Mammals, the largest series being 42 specimens from the domestic cat. Separate reports will doubtless be made as this material accumulates, but here brief notes are introduced where comparisons with the human patterns are apposite.

With few exceptions the present report offers no new or extreme anomalies of the human aortic stems. Most of the patterns in this series have been figured by Tiedemann (1822), Bourgery (1836), Quain (1844), Dubrueil (1847), Le Double (1901) or other commentators, whose works depict many bizarre arrangements of aortic arches and branches, in part cited from sources so remote as to be now inaccessible. The excellent review of aortic patterns available in the work of Poynter (1916) renders the historical treatment of this subject unnecessary here. The interest of the present report then centres neither on a comprehensive survey of the subject nor on the novelty of the specimens described, but rather on the comparative frequency of normal and diverse patterns of aortic stems in the American white and negro races, thus bearing on the important question of racial variability.

For each of the patterns described below the relative frequencies will be

compared, wherever possible, with results obtained by other workers in this field. A previous report on aortic stems (De Garis (1923), hereafter designated Report I) has in some recent literature been misquoted for reasons largely inherent in the undue brevity of the report itself. Thus the failure to express pattern frequency in some customary fashion, i.e. per centum or per mille, has doubtless led to misquotation.

Since the records of Report I are still on file, it seems desirable to canvass them again and express their data according to the standards of the present report. Among these previous records it is found that 4 white males, 9 negro males and 1 negro female had an arrangement of aortic stems now accounted outside the normal, namely that in which the anonyma and carotis communis sinistra arise by a common root, as distinguished from a common trunk (see pattern B, figs. 1 B, 2 and 4). Since the adjusted frequencies of Report I are based solely on graphic records and notes, wherein no account is taken of the exits of stems viewed from the interior of the aorta, it is altogether probable that these frequencies are still far too low. Further, in keeping with the present standards, deduction from the number of normal patterns should include cases of the thyreoidea ima arising from the anonyma, this variant having been accurately set forth in Report I as present in 1 white female, 3 negro females and 1 negro male. The foregoing amendments to Report I are effective in the citations per centum given below.

PATTERNS AND INCIDENCE

The patterns of aortic branches are, with some exceptions, described and figured here in the order of their frequency. Arbitrarily, but as a matter of record, cases of the thyreoidea ima arising from the anonyma are accounted among anomalies associated with the aortic arch, as are cases of the vertebralis sinistra arising from the subclavia sinistra very near the arch. In the several line-drawings of patterns (fig. 1) a conventionalised stencil of the aortic arch is employed throughout, since attention is here directed solely to the arrangement and diversity of the branches. Photographs of certain specimens acquired during the past two years are shown in Plates I and II (figs. 2–12), where again no attempt is made to indicate the relative dimensions of the specimens.

Pattern A

The usual text-book sequence of aortic branches (pattern A, fig. 1 A) is the one most frequently found both in the whites and in the negroes of our series. Therefore it is taken as the normal from which variability is measured. No special comment is required as to the general disposition of this pattern. However, it should be noted that here, as in other patterns, the branches show much diversity as to spacing and occasional diversity as to alignment. The prevailing tendency among negroes is for the anonyma and carotis com-

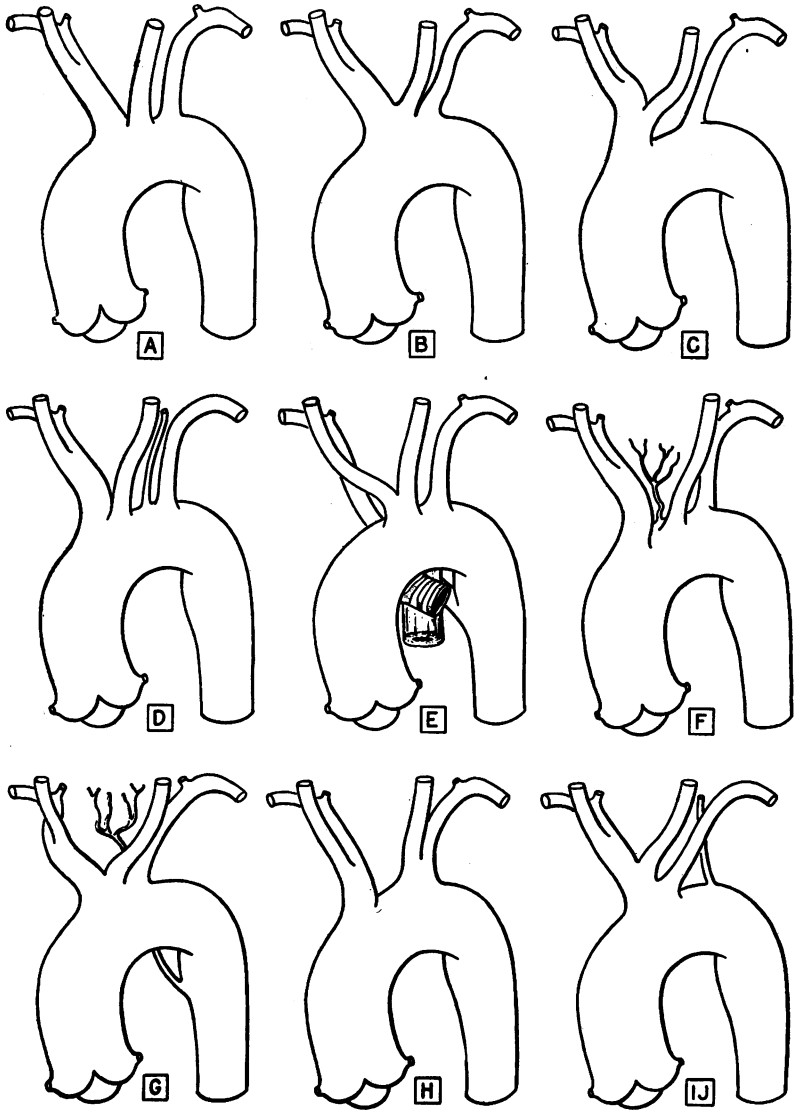

Fig. 1. Diagrammatic ventral views of aortic patterns. A, the normal pattern. B, radix communis for anonyma and carotis communis sinistra. C, truncus communis for anonyma and carotis communis sinistra. D, vertebralis sinistra as aortic stem between carotis communis sinistra and subclavia sinistra. E, subclavia dextra as last branch of aortic arch. F, thyreoidea ima as aortic stem between anonyma and carotis communis sinistra. G, thyreoidea inferior as branch of descending aorta. H, anonyma dextra and sinistra. IJ, radix communis—truncus communis for all great stems of aorta, and vertebralis sinistra as last branch of aortic arch.

munis sinistra to arise close together from the arch, while the subclavia sinistra has a variable placement to the left (66/97 negroes or 68 per cent.). Among whites the carotis communis sinistra usually arises about midway between anonyma and subclavia sinistra (62/86 whites or 72 per cent.). In 22 cases (19 negroes, 3 whites) the three stems, though separate, emerge close together from the right extremity of the arch, thus continuing the ascending aorta and leaving the highest part of the arch without branches. In 6 of these cases (5 negroes, 1 white) and in 4 others (negroes) the aortic branches are grossly out of alignment. Here the anonyma is initially inclined somewhat to the left; the carotis communis sinistra may be in front as well as to the left of the anonyma and has a very oblique placement directed to the left; the subclavia sinistra lies variously behind and to the left of the carotis communis sinistra. Figs. 4 and 5 exemplify this right-sided clumping and malalignment as of pattern B.

In 20 cases (14 negroes, 6 whites) the two left stems, though distinctly separate, arise close together and usually more or less removed from the anonyma toward the left extremity of the arch. In 3 cases (1 white male, 1 negro male, 1 negro female), the anonyma is very short, the subclavia dextra and carotis communis dextra failing the status of separate aortic stems by 1–2 cm.* These various irregularities of spacing and alignment appear to offer no significant basis for classification, though it is obvious that they are much more frequent among negroes than among whites. Adachi (1914) has noted diverse spacing of aortic stems in the Japanese.

Incidence of pattern A: 86 *whites* (77·4 ± 3·97 per cent.) (males: 78 adults, 2 infants; females: 2 adults, 4 infants); 97 *negroes* (47·7 ± 3·50 per cent.) (males: 62 adults, 7 infants; females: 25 adults, 3 infants).

Incidence of pattern A from the literature, per centum: English—Quain (1844) 84, Thomson (1893) 82·4; Japanese—Adachi (1928) 83·3; Negro—Loth (1912) 78; American Negro—Report I (1923) (amended) 73·5; American White—Report I (1923) 84·6.

Among our mammalian material the normal human sequence, pattern A, is found in the following numbers of specimens: domestic cat (*Felis domestica*) 1, spider monkey (*Ateles ater*) 1, capuchin monkey (*Cebus malitiosus*) 1, Bengal macaque (*Pithecus rhesus*) 1, chimpanzee (*Pan* sp.?) 3, the tarsiers (*Tarsius philippinensis*) 1 and (*Tarsius saltator*) 1. In our two specimens of *Tarsius* the aortic arch is conspicuously lower and broader than any we have seen in Man, the two left stems emerging close together and diverging widely from

* The pattern of the four great stems arising separately and in sequence from the aorta has been found by Tiedemann (1822) in nine reports from the European literature. However, no record of such a pattern appears in the large series of Thomson (1893) and Adachi (1928). In a negro specimen of Report I (1923) there was the right-to-left sequence: subclavia dextra—truncus bicaroticus—subclavia sinistra. No other separate subclavia dextra has been found by us, except as arising anomalously from the left extremity of the arch (here pattern E). Of interest in this connection are the report by Vallois (1929) and the book by Weinert (1932).

the anonyma. Wood Jones (1929 and previously) regards the human sequence of aortic stems in *Tarsius* as an item supporting his view that this genus is more nearly related to Man than are the other Primates. Two facts would seem to relieve this argument of some significance, namely: (1) the human sequence of aortic stems occurs at times in Primates other than *Tarsius*, and in various other Mammals (see Parsons, 1902); (2) the prevailing mammalian pattern of truncus communis for anonyma and carotis communis sinistra occurs as one of the frequent variants in Man.

Pattern B

Next in order of frequency is pattern B, characterised by a common root of origin for anonyma and carotis communis sinistra (figs. 1 B, 2 and 4). This common root is easily recognised from the exterior, yet if the aortic arch be incised along its concavity and turned inside out, the exit of the common root is most strikingly demonstrated (see figs. 3 and 5).

Frequent and obvious as this pattern is, it has not been accounted separately in the literature. Thomson (1893) evidently includes it in the pattern of the common trunk for anonyma and carotis communis sinistra, since he remarks that this common trunk may vary in length from 1¼ in. to zero. Now a common trunk of zero length is manifestly not a common trunk at all; it is merely a common root, or, exemplified as a geometric model, it is the common intersection of two cylinders, the anonyma and carotis communis sinistra, with a third, the aorta. This distinctive configuration of pattern B we propose to call *radix communis*. Developmentally and in point of frequence the radix communis stands intermediate between the disparate arrangement of pattern A and the *truncus communis* of pattern C.

Not infrequently the radix communis and the origin of the subclavia sinistra, though separate, are crowded together at the right extremity of the arch, and occasionally one of the left stems is much out of alignment. Figs. 4 and 5 are of a specimen showing this right-sided crowding with forward displacement of the carotis communis sinistra.

Incidence of pattern B: 9 *whites* (8·1 ± 2·59 per cent.) (males: 4 adults, 1 infant; females: 1 adult, 3 infants); 51 *negroes* (25·1 ± 3·03 per cent.) (males: 30 adults, 3 infants; females: 17 adults, 1 infant). Report I (1923) amended: 4 whites (7·7 ± 3·69 per cent.); 10 negroes (11·5 ± 3·42 per cent.).

Among our mammalian material the radix communis is found in the following: *Felis domestica* 2, *Pithecus rhesus* 1, squirrel monkey (*Saimiri sciureus*) 1. Dr W. L. Straus, Jr., has called our attention to the radix communis in a specimen of the common marmoset (*Callithrix jacchus*).

Pattern C

The prevailing mammalian arrangement of aortic stems is that of pattern C, characterised by the truncus communis for anonyma and carotis communis

sinistra (figs. 1 C and 6). The truncus communis of our human specimens has an average length of less than 1 cm., and an exceptional length of 2·5 cm.

Incidence of pattern C: 6 *whites* (5·4 ± 2·15 per cent.) (males: 4 adults; females: 1 adult, 1 infant); 21 *negroes* (10·3 ± 2·12 per cent.) (males: 11 adults, 2 infants; females: 6 adults, 2 infants). Report I (1923) 2 negroes (2·3 per cent.).

Among the very large number of Mammals in which this pattern occurs, the truncus communis is as a rule relatively much longer than in Man, and there is wide diversity as to the placement of its branches. In some Mammals the subclavia dextra is the first branch given off, the truncus continuing as a further common stem for the carotides. Among our material this latter arrangement is found in the following: *Felis domestica* 10, dog (*Canis familiaris*) 1, Siberian tiger (*Felis tigris*) 1, green guenon (*Lasiopyga callitrichus*) 1, bonnet macaque (*Pithecus sinicus*) 1. In most of our specimens the truncus communis approaches that found in man by giving off the carotis communis sinistra as the first branch. This arrangement is found in the following: *Felis domestica* 24, *Canis familiaris* 2, orang-utan (*Pongo pygmaeus*) 1, gibbon (*Hylobates leucogenys*) 1, *Pithecus rhesus* 9, *P. sinicus* 6, Javan macaque (*P. mordax*) 2, common macaque (*P. irus*) 2, *Ateles ater* 3, *Lasiopyga callitrichus* 6, sooty mangabey (*Cercocebus aethiops*) 1. From Dr Straus we have records of this type of truncus communis in the following: slow loris (*Nycticebus borneanus*) 1, *Ateles geoffroyi* 1, *Pithecus rhesus* 1. In certain cases (*Felis domestica* 5, *Canis familiaris* 2) there is precise trichotomy of the truncus communis.

Combined incidence of patterns B and C

Since, as already mentioned, pattern B is not accounted separately in the literature, it is necessary to combine the frequencies of patterns B and C in order to make an approximate comparison with the findings of other authors. Therefore it must be borne in mind that the figures here cited per centum from the literature are those given by the respective authors for frequency of the so-called common trunk. These figures are as follows: English—Quain (1844) 11·8, Thomson (1893) 10·2; Japanese—Adachi (1928) 10·9; American White—Report I (1923, amended) (patterns B and C) 7·7, present report 13·5; American Negro—Report I (1923) 13·5, present report 35·4. The frequencies here given from the present report do not include certain other variants with which pattern B or pattern C is associated.

Pattern D

The distinctive feature of pattern D is the origin of the vertebralis sinistra from the aortic arch between carotis communis sinistra and subclavia sinistra (figs. 1 D and 12). Among the 8 specimens in which this anomaly occurs, the vertebralis sinistra begins its vertebral course at the foramen transversarium of the following cervical vertebrae: fifth in 3 cases, sixth in 4 cases, seventh

in 1 case. In two negroes (male, female) pattern D is associated with the truncus communis (pattern C). In the male specimen with truncus communis, the vertebralis sinistra arises ventral to the subclavia sinistra, this latter being closely crowded against the truncus communis. In other cases of pattern D the vertebralis sinistra emerges from the arch in a plane somewhat dorsal to one or both left stems (see fig. 12).

Incidence of pattern D: 2 *whites* (male adults) (1·8 ± 1·26 per cent.); 6 *negroes* (5 male adults, 1 female infant) (2·9 ± 1·17 per cent.).

Incidence of pattern D from the literature, per centum: English—Thomson (1893) 5·8; Italian—Pellegrini (1906) 5·7; Japanese—Adachi (1928) 4·8; Indian—Iyer (1928, Madras, 828 subjects) 0·8; American Negro—Bean (1905) 5·2, Report I (1923) 1·1; American White—Report I (1923) 1·9.

Pattern D^1

Intermediate between the aortic vertebralis sinistra (pattern D) and the normal is the arrangement (pattern D^1, not figured) in which the vertebralis sinistra arises from the subclavia sinistra very near the aortic arch. In both of our specimens having this arrangement the origin of the vertebralis sinistra is less than 1 cm. from the aorta; also in both the artery in question begins its vertebral course at the foramen transversarium of the fifth cervical vertebra.

Incidence of pattern D^1: 1 *white* (male adult) (0·9 ± 0·90 per cent.); 1 *negro* (male adult) (0·49 ± 0·49 per cent.).

Pattern E

This pattern of the anomalous subclavia (figs. 1 E and 7)* includes three slightly different arrangements of aortic stems, all arrangements, however, being characterised by the subclavia dextra arising dorsally as the last branch from the left extremity of the aortic arch. In two cases (negro males) there are four separate stems from the arch, the right-to-left sequence being: carotis dextra—carotis sinistra—subclavia sinistra—subclavia dextra. In two cases (negro females) this sequence is varied by a common trunk for carotides. In one case (negro male) the carotides and subclavia sinistra are closely crowded and arise by a common root.

Four of these cases have been completely dissected by two of us (I. B. and E. R.), and the following relations are demonstrated: in each case the anomalous subclavia dextra passes between the oesophagus and vertebral column; the vertebralis dextra is retained as a subclavian branch; the ansa

* Fig. 1 E serves to indicate relations to the trachea and oesophagus, but is necessarily diagrammatic. In none of the specimens reported here can the origin of the anomalous subclavia be seen from in front, since it arises dorsally from the left extremity of the arch, not from the descending aorta, as represented in fig. 1. The specimen photographed from behind (fig. 7) shows the typical arrangement.

subclavia of the truncus sympatheticus is robust; the ductus thoracicus empties into the angulus venosus of the left side; there is no nervus recurrens on the right side. In one specimen the nervus laryngeus inferior on the right side, though not recurrent in relation to neighbouring structures, is distinctly curved downward in its course to the larynx; in another specimen this nerve is recurrent under the thyreoidea inferior; in two specimens the nerve passes directly to the larynx.

A recent specimen of pattern E, not dissected under our supervision, was removed with heart and lungs, so that no information is available as to the thoracic relations of the anomalous subclavia, save that it passed behind the oesophagus. The complete aortic pattern was kindly added to our collection, and the following branches of the anomalous subclavia have been identified: vertebralis, mammaria interna, truncus thyreocervicalis.

Incidence of pattern E: 5 negroes (2·46 ± 1·08 per cent.) (3 male adults, 2 female adults).

In reference to the anomalous subclavia dextra from Report I it may be recalled that the vertebralis on the right side arose, not from the subclavia, but from the carotis communis dextra, thus involving a somewhat different interpretation than that applying to the cases here. Interpretations of the anomalous subclavia dextra have received much attention in the literature. Cairney (1925) has ably discussed this subject, especially in the light of recent work on the development of the aortic arches by Congdon (1922). The interpretation of the anomalous subclavia from Report I has been discussed in connection with an anomalous pattern of arm arteries on the right side (De Garis, 1932). One of the cases reported by Adachi (1928) was likewise associated with anomalies of the arm arteries. Among the five cases reported here, four are known to have no gross anomalies of the arteries in the upper arm. One of these four had in each forearm a large mediana which passed deep to the transverse carpal ligament and terminated in the arcus volaris superficialis. Regarding the arm arteries of the fifth case we have no information.

The high incidence of the anomalous subclavia dextra (pattern E) in negroes as compared to other races is shown in the following enumeration per centum from the literature: European—Quain (1844) 0·4, Tiedemann (1846) 0·8, Turner (1862) 0·4, Thomson (1863) 0·6, Thomson (1893) 1·0, Leboucq (1894) 0·5, Stieda (1894) 0·8, Götz (1896) 0·8, Holzapfel (1899) 0·6; Japanese—Adachi (1928) 0·2? or 0·38; Negro—Loth (1912) 9·7*; American Negro—Bean (1905) 3·5, Report I (1923) 1·15, present report 2·46.

The anomalous subclavia dextra has very seldom been encountered in other Mammals. Cuvier (1810) refers to it as having been found in the hedge-

* Loth's very high incidence of the anomalous subclavia in negroes serves to illustrate, as does the high incidence of the aortic thyreoidea ima in Report I, the statistical distortion resulting from a large distribution of one type within a small group. Within a group of 31 negro specimens he found the anomalous subclavia 3 times.

hog; Ogilvie and Cathcart (1874) found it in the lamb; Smith (1891) found it in the rabbit.

Pattern F

In this pattern the thyreoidea ima arises from the arch of the aorta between anonyma and carotis communis sinistra. In one of our specimens (negro male) the artery is extremely slender and passes in a tortuous manner to the left lobe of the thyroid gland, the thyreoidea inferior on the left side being normal in origin and course and only slightly smaller than its fellow of the opposite side. In our other specimen (negro female) the thyreoidea ima (fig. 1 F) is distributed symmetrically by medial branches to the infrahyoid muscles and trachea and by lateral branches to the thyroid gland. On each side the thyreoidea inferior is normal in origin and course, but is much reduced in size. In neither of our specimens does the thyroid gland appear enlarged.

Incidence of pattern F: 2 negroes, male and female adults (0·98 ± 0·69 per cent.).

Incidence of pattern F from the literature, per centum: Russian—Gruber (1872) 0·5; English—Thomson (1893) 0·4; Italian—Livini (1900) 1·0; Japanese—Adachi (1928) 0·36; American White—Report I (1923) 3·8; American Negro—Report I (1923) 4·6. The high incidence of pattern F in Report I is surely not a typical distribution for either race (see p. 606, n.).

Pattern F^1

In this pattern the thyreoidea ima is given off by the anonyma, at times from its distal third (here 2 cases), at times from its proximal third (here 3 cases), usually from its intermediate third. In one of our cases (negro male) the thyreoidea ima supplies only the left lobe of the gland and the thyreoidea inferior on the left side is lacking. In one case (white female) the thyreoidea ima is very slender and supplies only the right lobe, the thyreoidea inferior on that side not being appreciably reduced. The only case of the thyreoidea ima associated with marked enlargement of the gland is in a male white; in this case the artery is very robust, the thyreoidea inferior on the left side is absent and the other arteries to the gland are enlarged. In two cases (male and female negroes) the thyreoidea ima is associated with, but does not exclusively supply, a pyramidal lobe of the gland.

In one case (negro female) the thyreoidea ima is associated with the truncus communis (pattern C) and arises from the anonyma very near its proximal end; in two cases (white male, negro male) it is associated with the radix communis (pattern B) and arises from the middle third of the anonyma. In one case (negro female, fig. 9) patterns F^1 and H are combined, there being a short anonyma sinistra and a long anonyma dextra, the latter near its bifurcation giving off the thyreoidea ima. This case is included in the statement of incidence for each pattern, but is entered separately in Table I as F^{1}H.

Incidence of pattern F^1*: 4 whites* (3·6 ± 1·77 per cent.) (males: 3 adults; females: 1 adult); 7 *negroes* (3·4 ± 1·27 per cent.) (males: 3 adults, 1 infant; females: 2 adults, 1 infant).

Incidence of pattern F^1 from the literature, per centum: English—Quain (1844) 3·2; Russian—Gruber (1872) 10·5; Swiss—Streckeisen (1886) 10·0; Italian—Livini (1900) 4·0; Japanese—Adachi (1928) 7·8; American Negro—Bean (1905) 4·3; Report I (1923) 4·6; American White: Report I (1923) 1·9.

The current text-book statement that the thyreoidea ima occurs in about 10 per cent. of cases is perhaps traceable to the figure of Gruber cited above. Considering collectively the various types of the thyreoidea ima for all nationalities and races in which it has been observed, a figure between 5 and 6 per cent. would appear to be nearer the true average frequency.

Occasionally the thyreoidea ima is recorded as arising from the carotis communis dextra. We have found this arrangement at a high cervical level in the dog (1 specimen), but have not encountered it in our human material; Gruber and Livini likewise did not find it; Streckeisen and Adachi each found it twice.

In our mammalian material no example of the thyreoidea ima has thus far been found, except in the dog, mentioned above, and in the chimpanzee. Among four specimens of aorta from chimpanzee, the thyreoidea ima arises from the root of the carotis communis sinistra within 1–2 mm. of the arch in two cases, from a short left truncus communis (anonyma sinistra) in one case, and is lacking in one case. Concerning the thyreoidea ima in primates Keith (1895, p. 455) remarks that this artery arises from the aortic arch in 1 chimpanzee (of 11 examined), and from the carotis communis sinistra in 1 gorilla, 4 gibbons, 3 semnopitheques, and 2 macaques; in the last two genera it is a branch of the carotis in the neck region.

Pattern G

In this singular pattern (fig. 1 G) an artery, having the terminal distribution of the thyreoidea ima or inferior, emerges as a sizable trunk from the upper part of the descending aorta and passes upward in the interval between trachea and oesophagus, distributing twigs to these two structures. Just above the convexity of the aortic arch it turns sharply to the ventral aspect of the trachea, supplies twigs to the infrahyoid muscles and trachea, and terminates on the deep surface of the thyroid gland, sending branches to each lobe. The other thyroid arteries are normal in origin and course, though both inferior arteries are reduced. Our one example of this pattern also includes the radix communis (pattern B).

There appears to be no precedent for the anomalous thyreoid artery of pattern G. It may be significant that in this specimen there are only two bronchial arteries, the first right aortic intercostal artery supplying the right bronchial, the left bronchial arising from the aorta just above the anomalous

thyroid artery. If this anomalous artery be regarded as an aberrant bronchial stem, then it is one with tracheal, oesophageal and thyroid connections, but no bronchial distribution whatsoever.

Szawlowski (1888) has reported a case of anomalous vertebralis dextra which had an origin from the aorta practically identical with that of our anomalous thyreoidea. Such a case is explained by Kemmetmüller (1911, fig. 16) as persistence of the junctional part of the right dorsal aorta plus a postcostal longitudinal anastomosis. If the anomalous thyreoidea of pattern G be regarded as the junctional portion of the right dorsal aorta, the interruption must have occurred in the plane of the oesophagus and trachea, leaving the original stem with only tracheal, oesophageal and thyreoid anastomoses. This is the explanation which we favour, though we are bound to admit that the adult condition does not warrant any fast conclusion.

Incidence of pattern G: 1 *negro* male adult (0·49 ± 0·49 per cent.).

Pattern H

In this pattern (fig. 1 H) there is a bi-anonymous sequence, the anonyma of each side giving rise to carotis communis and subclavia. Also in one specimen (previously noted, fig. 9) the anonyma dextra gives off the thyreoidea ima. In the specimen of fig. 9 the anonyma sinistra is scarcely 1 cm. long; in the specimen of fig. 1 H the anonyma sinistra measures roughly 2 cm., the anonyma dextra 3 cm.

Pattern H has been figured by early commentators from occasional human records. Tiedemann (1822) regards the bi-anonymous arrangement as most frequent in Mammals with short necks. He found it in the bat, and cites Daubenton as finding it in *Pteropus rufus*, also Cuvier as finding it in the porpoise. Parsons (1902) likewise found this arrangement in the Cheiroptera (3 species), and in two species of mole, in the hedgehog, and in certain Cetacea. In our mammalian material the sequence of pattern H occurs but once, this being from a recent specimen of chimpanzee. Here the anonyma sinistra, though less than 0·5 cm. long, is a distinct truncus communis for carotis communis sinistra and subclavia sinistra; about 2 mm. from the aorta it gives off the thyreoidea ima.

Incidence of pattern H: 2 *negroes* (0·98 ± 0·69 per cent.) (adult male and female). There is a duplication here of one specimen also included under the incidence of pattern F^1. This specimen is accounted separately in Table I as F^1H.

Pattern H^1

This pattern (fig. 8) is characterised by a radix communis for the carotis communis sinistra and subclavia sinistra. Such an arrangement is the expected intermediate between the bi-anonymous pattern H and the type of normal pattern wherein the two left stems, though distinctly separate, arise close together and usually at an interval from the anonyma. When the left stems

are thus closely crowded, their fascial coverings often render it difficult to ascertain whether they are completely separate in origin or not. However, if the aortic arch be laid open and the exits viewed from the smooth interior, the question as to separate or common origin may be answered unequivocally.

Incidence of pattern H[1]*:* 2 *whites,* male adults (1·8 ± 1·26 per cent.); 8 *negroes* (3·94 ± 1·36 per cent.) (males: 5 adults; females: 2 adults, 1 infant).

Pattern I

This pattern (fig. 11) is peculiar in having the truncus communis for anonyma and carotis communis sinistra and the radix communis for the truncus and the subclavia sinistra. This completely clumped arrangement is the logical extreme of the tendency toward crowding and fusion of the great stems, and for that reason might be expected to occur with some degree of frequency. Yet in our human material we have found it elsewhere only in the combined pattern IJ. In both patterns I and IJ the aortic arch is of very high pitch.

Among our mammalian material the completely clumped pattern I is found in the following: domestic cat 2, dog 1, *Ateles ater* 1, *Perodicticus potto* 1. In these the subclavia sinistra arises at the root of a long truncus communis for subclavia dextra, carotis communis dextra and carotis communis sinistra.

The completely clumped arrangement of the great aortic stems in Man is a clear intimation of the candelabrum, or single aortic stem, which according to Tiedemann (1822) is found especially in Mammals with long necks. Parsons (1902) figures exceptional cases of the Carnivora and Rodentia and a considerable number of the Ungulata as having one or another variety of the single stem, yet curiously enough, in the light of Tiedemann's generalisation, the giraffe and llama are found to have the subclavia sinistra widely separate from the truncus communis of the other stems. Recently we have acquired a specimen of aortic arch from the musk ox (*Ovibos m. wardi*) where the single aortic stem is a conspicuous feature.

Incidence of pattern I: 1 *negro,* male adult (0·49 ± 0·49 per cent.). The true incidence of the common origin for all great aortic stems requires the inclusion of pattern IJ, thus giving a total of 2 negroes (0·98 ± 0·69 per cent.). This entry is not duplicated in Table I.

Pattern J

This pattern (fig. 10; see also fig. 1 IJ) is peculiar in that the vertebralis sinistra arises as the last branch of the aortic arch, i.e. to the left of the subclavia sinistra. In the specimen of fig. 10 the vertebralis sinistra is in series with the intercostales, and enters the foramen transversarium of the seventh cervical vertebra.

This anomaly is apparently rare among whites and negroes; in truth for negroes we find no previous record of it whatsoever. Among whites it was

seen twice by Tiedemann (1822, Table III, figs. 1 and 10), who also cites cases from Walter, Winslow, and Meckel. However, neither Quain nor Thomson found a single instance of this anomaly in their extensive material (a total of 800 specimens). Adachi (1928) reports 3 cases among 516 specimens of Japanese (0·6 per cent.).

Incidence of pattern J: 1 *negro*, female adult (0·49 ± 0·49 per cent.). The true incidence of this anomalous vertebralis sinistra requires the inclusion of pattern IJ, thus giving a total of 2 negroes (0·98 ± 0·69 per cent.). This entry is not duplicated in Table I.

Pattern IJ

This combination of anomalies (fig. 1 IJ) has, as in pattern I, the truncus communis—radix communis for all great stems of the aorta, and, as in pattern J, the vertebralis sinistra arising as the last branch of the aortic arch. The vertebralis sinistris in this case, as in pattern J, is in series with the intercostales and enters the foramen transversarium of the seventh cervical vertebra.

This combination of anomalies has not, as far as we know, been previously reported.

Incidence of pattern IJ: 1 *negro*, male adult (0·49 ± 0·49 per cent.).

Pattern K

This pattern (not figured) is one of the right aorta, the arch and stems being a mirror-image of the normal, i.e. the sequence from *left* to *right* is: (1) anonyma, giving rise to subclavia sinistra and carotis communis sinistra; (2) carotis communis dextra; (3) subclavia dextra. This case has been fully described and figured by Sprong and Cutler (1930). Their report should be consulted for details of the case and for a most comprehensive treatment of the literature.

Incidence of pattern K: 1 *white*, male adult (0·9 ± 0·9 per cent.).

THE EXTENT AND CHARACTER OF AORTIC VARIATIONS IN AMERICAN WHITE AND NEGRO STOCKS

In Table I is given a summary of aortic patterns as they occur in the white and negro specimens of our series. The most striking feature of this table is the greater number of diverse patterns represented in the negro group. Pattern A being normal (most frequent) in both groups, the number of cases in each group having patterns outside the normal would express the extent of variability. Thus there are in whites 25 cases outside the normal (22·6 ± 3·97 per cent.), in negroes 106 (52·3 ± 3·50 per cent.). While the difference in number of variants is here so large as to appear at once significant, it is possible to express this significance numerically, the tested variants in this

instance being the total variants in whites and negroes respectively*. In this comparison the value of the constant χ^2 is found to be 26, from which the interpolated value of P is 0·0000004. In other words we would expect to get an equal or greater value of χ^2 on random sampling 4 times in 10,000,000 trials. We may therefore regard the above findings in whites and negroes as being in a very high degree significant.

As for variability according to sex within the two races, the female whites numbering 13 (5 adults, 8 infants) are, like the infants of both races (11 whites, 22 negroes), too few to be accounted as separate statistical groups. There is,

Table I. *Summarising the incidence of aortic patterns in white and negro stocks*

	Whites 111 specimens		Negroes 203 specimens	
Patterns	Samples	%	Samples	%
A	86	77·4 ±3·97	97	47·70 ±3·50
B	9	8·1 ±2·59	51	25·10 ±3·03
C	6	5·4 ±2·15	21	10·30 ±2·12
D	2	1·8 ±1·26	6	2·90 ±1·17
D^1	1	0·9 ±0·90	1	0·49 ±0·49
E	—	—	5	2·46 ±1·08
F	—	—	2	0·98 ±0·69
F^1	4	3·6 ±1·77	6	2·90 ±1·17
F^1H	—	—	1	0·49 ±0·49
G	—	—	1	0·49 ±0·49
H	—	—	1	0·49 ±0·49
H^1	2	1·8 ±1·26	8	3·94 ±1·36
I	—	—	1	0·49 ±0·49
J	—	—	1	0·49 ±0·49
IJ	—	—	1	0·49 ±0·49
K	1	0·9 ±0·90	—	—

it may be noted, a comparatively large distribution of variants among these small groups, involving mainly the patterns B and C. The female negroes numbering 65 (56 adults, 9 infants) show slightly more distribution of variants than do the negro males numbering 138 (125 adults, 13 infants): thus variants in female negroes 37/65 or 56·9 ± 6·17 per cent.; variants in male negroes 69/138 or 50·0 ± 4·27 per cent. It would be a matter of interest to work with equally representative numbers of males and females among the two races in order to find out how variations are distributed according to sex. This enterprise, however, is not feasible, since the supply of laboratory material is usually much limited as to female subjects.

* The test of significance (goodness of fit) depends on the value of χ^2 according to the following equation, adapted from its more general form for present purposes:

$$\chi^2 = \frac{(n_1.d_2 - n_2.d_1)^2.(N_1 + N_2)}{N_1.N_2.(n_1 + n_2).(d_1 + d_2)},$$

where N_1 is the total number of negroes; N_2 the total number of whites; n_1 the number of the observed variant in negroes; n_2 the number of the observed variant in whites; d_1 all other negroes examined, i.e. $N_1 - n_1$; d_2 all other whites examined, i.e. $N_2 - n_2$. The expression for probability (P) is found by turning up the value of χ^2 from interpolation in Table XV (C), p. 30, *Tables for Statisticians and Biometricians*, edited by Karl Pearson, Cambridge, 1914.

In Report I (1923), where the two groups are less than half as large as those dealt with here, the greater variability of the aortic branches in negroes is also striking: thus, including the amendments already noted, variants in whites 8/52 or 15·3 ± 4·97 per cent., variants in negroes 23/87 or 26·4 ± 4·72 per cent. The same tendency toward greater variability of arterial patterns in negroes is a conspicuous result of work on the arm arteries. The records thus far reported are on the subclavian artery (De Garis, 1924) and the axillary artery (De Garis and Swartley, 1928).

On the basis of the present report it may be inquired whether or not any variant patterns of the aortic stems occur with sufficient frequency to warrant the assumption that such patterns constitute, for one group or the other, a racial tendency. Without for the moment attempting to define the "sufficient frequency" involved in this question, it is at least possible to discuss certain preponderancies which seem significant. Among the whites there is obviously no variant pattern requiring attention here. Among the negroes there are two groups of patterns which should be considered, namely (1) the partial or complete mammalian patterns B and C of the radix communis and truncus communis, and (2) pattern E of the anomalous subclavia dextra.

Concerning the frequency of the first group of patterns (B and C) in negroes, there is a statement by Keith (1895) to the effect that the common trunk for anonyma and carotis communis sinistra occurs three times as often in negroes as in whites. For our material the combined frequencies of patterns B and C in negroes and whites respectively are as follows: negroes 35·4 ± 3·35 per cent., whites 13·5 ± 3·23 per cent. While this falls somewhat short of the 3:1 ratio mentioned by Keith, it is interesting to apply the test of significance here. With patterns B and C occurring in negroes 72/203 and in whites 15/111, the value of the constant χ^2 (see p. 612, n.) is found to be 19·7, whence the interpolated value of P is 0·0000089; that is, we should expect to get an equal or greater value of χ^2 in random sampling 89 times in 10,000,000 trials. This, indeed, indicates a high degree of significance.

In connection with patterns B and C it is a matter of further interest to canvass all the other variant patterns for cases in which there is any degree of union between the origins of the anonyma and carotis communis sinistra. Among cases of pattern D there are two having the truncus communis (negroes); among cases of pattern F^1 there are two having the radix communis (1 white, 1 negro), and one having the truncus communis (negro). The exceptional pattern G of the thyreoidea includes also the radix communis (negro). A further negro case may be added from pattern I and another from pattern IJ, since one peculiarity of these patterns is the extreme clumping of all the great aortic stems. With the foregoing cases included, the combined frequencies of radix communis and truncus communis are as follows: negroes 79/203 or 38·9 ± 3·42 per cent.; whites 16/111 or 14·4 ± 3·33 per cent. From this over-all incidence it is found that patterns B and C occur among negroes and whites in the ratio 2·7:1. The combined frequencies of the same patterns

in Report I (amended) are: negroes 12/87 or 13·8 ± 3·69 per cent.; whites 4/52 or 7·9 ± 3·74 per cent. Here the ratio is 1·7:1.

From these comparisons it is seen that while our ratios are nowhere quite as large as that suggested by Keith, there is in both present and previous reports a large preponderance of negroes over whites having the partial or complete mammalian pattern of aortic stems. Not only does this preponderance contribute much to the net result of greater variability in negroes than in whites, but also on a statistical basis it must be taken to mean that the prevailing mammalian pattern is, in truth, a racial tendency among negroes[1].

Regarding the anomalous subclavia dextra (pattern E), the very high incidence of this in negroes as compared to whites has already been shown in the tabulation from the literature. To reach an over-all incidence of this anomaly in the two races the following reports are used: *whites*—Quain (1844) 1/212, Thomson (1893) 5/500, Report I (1923) 0/52, present report 0/111, total 6/875 or 0·68 ± 0·26 per cent.; *negroes*—Giacomini (1882) 2/8, Bean (1904) 2/57, Loth 3/31, Report I (1923) 1/87, present report 5/203, total 13/386 or 3·36 ± 0·76 per cent. Testing these totals for significance (see p. 612, n.) the value of the constant χ^2 is found to be 12·9, whence the interpolated value of P is 0·00031, i.e. we would expect an equal or greater value of χ^2 in random sampling 31 times in 100,000 trials. While the test here is not as decisive as it has been for other distributions among the two races, it is still a figure of high order as indicating significance. Pending further data, we are much inclined to regard this anomaly as a true racial tendency among negroes*.

Concerning racial variants of the aortic arch, Vallois (1929, p. 91) remarks: "La seule variation raciale incontestable que l'on puisse noter est la plus grande frequence du type III chez les Noir...," wherein type III (his fig. 6) can only be interpreted as the right-to-left sequence: subclavia dextra—carotis communis dextra—carotis communis sinistra—subclavia sinistra, each arising separately from the aortic arch (see here p. 602, n.). In support of his assertion, he says Loth (1912) reports type III in 9·7 per cent. of negroes, whereas Thomson (1893) reports the same type in but 1 per cent. of whites. Essentially the same statement is taken over by Weinert (1932). Now it is truly astonishing to find that neither Loth nor Thomson has ever reported such an arrangement as that of Vallois's type III. However, the per centum figures cited by him are exactly those of the respective frequencies found by Loth and Thomson for the anomalous subclavia dextra arising from the left extremity of the aortic arch (here pattern E). Thus it seems apparent that through some misapprehension Vallois, followed by Weinert, has figured a rare aortic anomaly as one of the incontestable racial variations in negroes, whereas, tracing his statement to its factual sources, we find that he has,

* Williams (1932) has found that the common origin of anonyma and carotis communis sinistra is much more frequent in negroes than in whites. Also he announces a high incidence of the anomalous subclavia dextra in negroes.

however inadvertently, said what we are saying in the present report, namely that the anomalous subclavia dextra is a true racial variation in negroes.

Concerning the material here spoken of as negro, it is well to recall that the American negro population is customarily regarded as mixed, to some extent with American Indian stock, to a much larger extent with white stock. The bearing of this race mixture on the question of greater variability among negroes has been discussed in a previous report (De Garis and Swartley, 1928). In the recent work of Loth (1931) there are valuable collections of data on the soft parts of various races, including negroes other than American. However, his chapter on the vascular system, in so far as it deals with the negro, cites data largely drawn from American sources. Nor is there any large series of other negro material available for comparison with our present findings.

In this connection the points we wish to emphasise are these: we do not really know what is the normal aortic pattern for other or so-called pure negro stocks (if such exist); nor do we know the range of variability in these stocks. From present findings we have assumed that the normal for negroes is the same as that for whites. But our further finding of greater variability in negroes is open to several interpretations: (1) since range of variability is an obverse measurement of the normal, there may actually be more than one pattern so frequent in negroes as to be considered normal; or (2) there may be a true racial tendency in negroes toward more unstable vascular patterns; or (3) this instability may be due to race-crossing. The first interpretation is so bound up with the second that, it seems to us, a true estimate of variability in negroes is best served by measurement from a single normal. As for the second and third interpretations, it is manifestly impossible to separate the factors of racial variability and hybrid variability in the American negro material with which we have to deal.

In the case of certain aortic patterns, namely (1) the partial or complete mammalian patterns (radix or truncus communis for anonyma and carotis communis sinistra), and (2) the anomalous subclavia dextra, we have already indicated that their preponderance in negroes is so distinct as to warrant the assumption that they represent true racial tendencies, or in terms of hybridisation, tendencies owing their increment to negro stock.

DISCUSSION

In considering what, if any, conclusions of a general nature may be drawn from the foregoing study of aortic patterns in whites and negroes, we would at once avoid the terms *high* and *low* as designating one or another race, since not only do these terms imply an invidious comparison but also a comparison far more simple than the facts permit.

Some of the facts are these: In our present and previous studies on the vascular system of whites and negroes we have found a much greater range of variation in negroes, except for arteries at the base of the brain, where the

range of variation is reversed (these latter data unpublished). As for the muscular system, there is a general impression that negroes are more variable than whites, an impression perhaps traceable to reports by Chudzinski. Here, selecting for illustration such statements as are readily available, we find that Howell and Straus (1931) report accessory humeral heads of the biceps brachii occurring more frequently in negroes than in whites. Their further observations confirm this report (personal communication). On the other hand, Thompson, Batts and Danforth (1921) have found that the palmaris longus is more frequently absent in whites than in negroes. Again, the ilium of the negroes of both sexes, according to Straus (1927), is on the average slightly less variable than that of the whites of corresponding sex, although the stock differences are so slight that the two races "may really be regarded as having like variability in the characters examined." Also in certain measurements on living models Herskovitz (1927, 1928) found that negroes are somewhat less variable than whites, though not so in all the measurements made by him.

These few illustrations suffice to show that in a comparison of the two races we have the usual concurrence of independent variables, biologically speaking. Therefore it is meaningless to say that negroes are more variable than whites, simply because we find that much of their arterial system is more variable. In at least one part of this system they are known to be less variable; likewise in other systems or parts they are known to be less or more variable. At present, then, all we can do with this comparison is to remain at once tentative and concise, i.e. concise and very explicit as to the parts compared, and altogether tentative as to general conclusions.

Speaking now only of the aortic arch in negroes and whites, what broad concepts are exemplified here? Schultz (1926, p. 323) has said, "Evolution will continue as long as variations occur." Since this statement seems as unassailable as the fact of evolution itself, and further, since the aortic arch in negroes is clearly more variable than that in whites, it is merely syllogistic to conclude that the aortic arch is evolving more in negroes than in whites. Then what is the direction of this evolution? We have found that the prevailing mammalian type (radix communis and truncus communis) is very much more frequent in negroes than in whites. Is the aortic arch in negroes evolving toward or away from this mammalian type? If toward it, then it would seem directed toward the alleged ancestral or atavistic pattern. If away from it, then it must approach the normal and more dispersed pattern prevailing in whites. Yet this latter, according to our present conception of developmental sequence, is the more primitive ontogenetic pattern. If we accept the view of Bolk (1926, 1929) that Man is a fetalised Mammal and has become stabilised as a result of retardation, then the negro in his aortic arch is less fetalised, less stabilised, more rapidly evolving and in the direction of the mammalian type.

This exercise in logic serves at least to point the horns of the dilemma and to confirm our present diffidence toward facile generalisations. Yet to be sure,

those of us who find adventure in this work cherish the hope that we are adding facets to a large mosaic wherein the races of men will ultimately appear in their true and significant contrasts.

SUMMARY

Among 314 subjects (111 whites, 203 negroes) are found 16 different patterns of branches associated with the aortic arch. Among whites 8 of the 16 patterns are represented, among negroes 15 of the 16. The text-book sequence (anonyma, carotis communis sinistra, subclavia sinistra, as separate stems) is most frequent or normal in both races. The gross incidence of variant patterns is: in whites 22·6 ± 3·97 per cent.; in negroes 52·3 ± 3·50 per cent. Among whites no variants occur often enough to suggest a racial tendency. Among negroes two groups of variants are conspicuous: (1) the prevailing mammalian patterns (radix communis and truncus communis for anonyma and carotis communis sinistra), taken together, occur 2·7 times as often in negroes as in whites; (2) the anomalous subclavia dextra occurs exclusively in negroes (5 cases, 2·46 ± 1·08 per cent.). By statistical test the higher incidence of these two groups of variants in negroes than in whites is found to be significant. Hence it is assumed that these particular variants represent true racial tendencies among negroes, or in terms of hybridisation, tendencies owing their increment to negro stock. The general finding of large diversity in aortic patterns among negroes, though by test significant, may be a hybrid variability, or a racial variability, or both. Comparisons are made with such aortic patterns as occur in our mammalian material.

For most of our Primate material and its identification we are deeply indebted to Dr A. H. Schultz and Dr W. L. Straus, Jr., who advise the nomenclature of D. G. Elliot (*A Review of the Primates*, 1913). Recent important contributions to our collection have been made by Prof. John F. Fulton, New Haven. Certain valued specimens from the U.S. National Museum were obtained for us by Mr Brazier Howell. Two specimens of *Pithecus irus* were kindly furnished by Dr G. W. Corner, Rochester. For aid in the statistical treatment of significance we wish to thank Dr Carroll Palmer.

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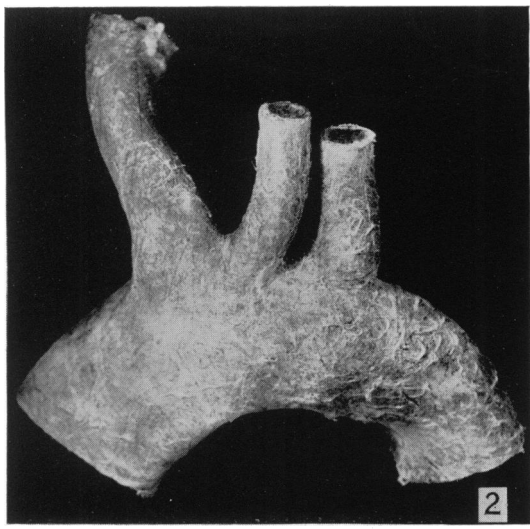
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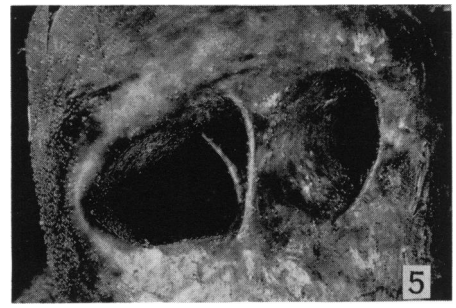
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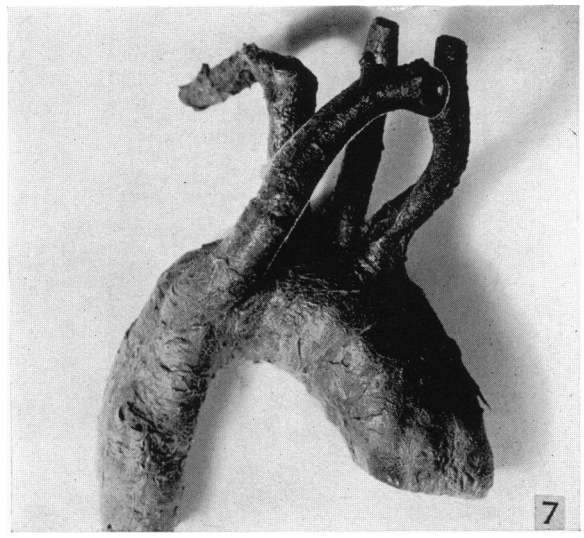
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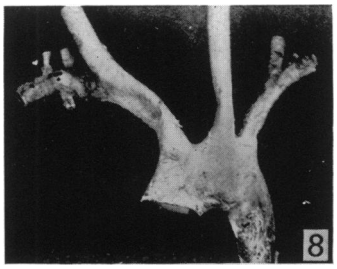
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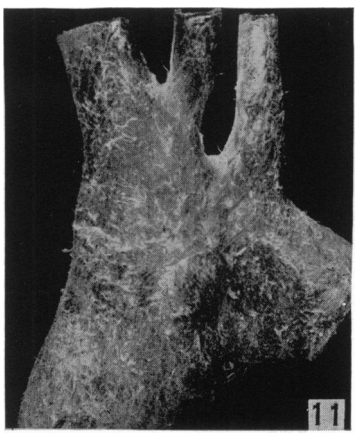
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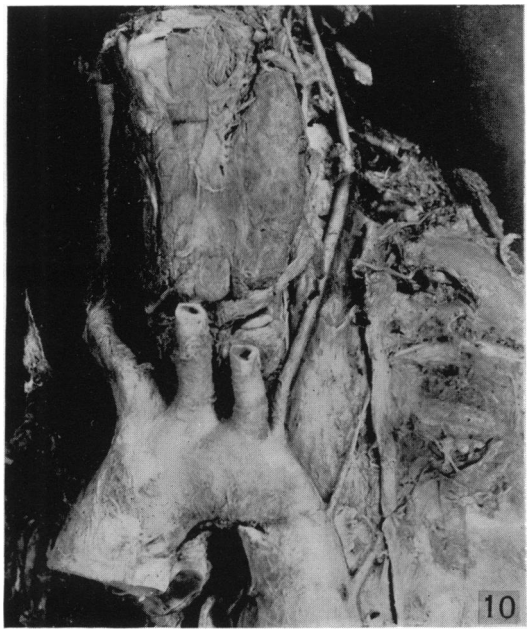
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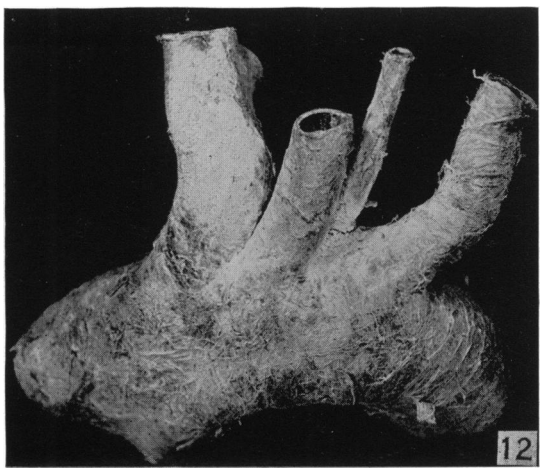
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EXPLANATION OF PLATES

PLATE I

Fig. 2. *Pattern B,* the radix communis for anonyma and carotis communis sinistra. (Adult negro male.)
Fig. 3. The specimen of fig. 2, opened along the concavity of the aortic arch and viewed from within, showing the common exit of the anonyma and carotis communis sinistra.
Fig. 4. Variety of *pattern B,* with marked crowding of the aortic stems to the right extremity of the arch, the root of the anonyma giving very oblique origin to carotis communis sinistra; behind the latter is the subclavia sinistra. The specimen is inclined somewhat to the right. (Adult negro male.)
Fig. 5. The specimen of fig. 4, viewed from within. The oblique exit of the carotis communis sinistra appears as a narrow slit.
Fig. 6. *Pattern C,* the truncus communis for anonyma and carotis communis sinistra. (Adult negro female.)
Fig. 7. *Pattern E,* viewed from behind. The subclavia dextra arises dorsally as the last branch of the aortic arch. (Adult negro male.)

PLATE II

Fig. 8. *Pattern* H^1, radix communis for carotis communis sinistra and subclavia sinistra. (Negro female, age 13.)
Fig. 9. Specimen combining features of *patterns* F^1 and *H,* the thyreoidea ima arising near the distal extremity of the anonyma, the carotis communis sinistra and subclavia sinistra arising by a short truncus communis (anonyma sinistra). (Negro female, age 15.)
Fig. 10. *Pattern J,* the vertebralis sinistra arising from the aortic arch to the left of the subclavia sinistra and entering the foramen transversarium of the seventh cervical vertebra. The artery is exposed by transection of the left sympathetic trunk and the costal elements of the cervical vertebrae and by removal of the vertebralis. (Adult negro female.)
Fig. 11. *Pattern I,* aortic arch of very high pitch, the anonyma and carotis communis sinistra arising by a truncus communis with which the subclavia sinistra forms a wide radix communis. (Adult negro male.)
Fig. 12. *Pattern D,* the vertebralis sinistra arising from the aortic arch between and behind the carotis communis sinistra and subclavia sinistra. The specimen is turned somewhat forward. (Adult negro male.)