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The pattern of aortic arch branching in the Rhinocerotidae

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(With 6 figures in the text)

The little-known pattern of aortic arch branching in the Rhinocerotidae has been determined in 10 individual rhinoceroses representing four of the five extant rhinoceros species. Present observations augment recorded information concerning this pattern of branching in the Asian rhinoceros forms and permit its first-time description in the African forms. They tentatively indicate the canonical pattern of aortic arch branching in certain rhinoceros species, and demonstrate the taxonomic insignificance of such branching.

Contents

Introduction

The mammalian head, neck and forelimbs are vascularized, directly or indirectly, from the aortic arch by a series of arteries whose pattern of mutual relationship tends to be specific for different mammalian groups and is thus often regarded as of taxonomic importance. Determination of the pattern of aortic arch branching has therefore been customary in the exploration of mammalian morphology with the object of establishing the canonical pattern of branching in any particular species.

Such determination must take cognizance of the known variability of the arterial system and so be based upon the examination of a quantitatively sufficient specimen sample. This desideratum, however, is unattainable in connexion with the larger exotic mammalian forms, the investigation of which is perforce restricted to the examination of such individual specimens as become periodically available. This consideration applies particularly to the Rhinocerotidae, of which family, to date, only some half-dozen individuals have been systematically anatomized: the pattern of rhinoceros aortic arch branching is thus insufficiently known and its norm for any rhinoceros species remains undetermined.

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Recorded information on the subject, unillustrated and sometimes insufficiently precise, may now be supplemented by that derived from the more recent examination of 10 additional rhinoceros specimens (representing four of the five extant species). The additional information, presented below, affords a clearer appreciation of the aortic branching pattern in the Asian rhinoceroses and permits a first-time description of this pattern in the African rhinoceroses. It also permits a tentative, but not unreasonable, estimation of the canonical pattern of aortic branching in the Indian, the black and white rhinoceroses.

Material and methods

The pattern of aortic arch branching was determined by dissection in the following rhinoceros specimens.

Indian rhinoceros (*Rhinoceros unicornis*)	
R.41 Male, adult ('Felix'), 20 years	Zool. Soc. Lond. 1941
R.45 Male, adult ('Hush'), 15 years	Zool. Soc. Lond. 1945
R.21 Male, adult ('Mohan'), 18 years	Zool. Soc. Lond. 1961
R.75 Male, adult ('Manik'), 15 years	Zool. Soc. Lond. 1975
Sumatran rhinoceros (*Didermocerus sumatrensis*)	
R.62 Female, adult ('Bettinga'), 11–12 years	Basel Zool. Gardens 1961
African black rhinoceros (*Diceros bicornis*)	
R.19 Female, *c.* 2 years	Zool. Soc. Lond. 1960
R.24 Male, 4 years	Zool. Soc. Lond. 1962
R.27 Female, adult ('Lorna')	Zool. Soc. Lond. 1963
African white rhinoceros (*Ceratotherium simum*)	
R.20 Male, 3 years	Zool. Soc. Lond. 1964
R.162 Female, adult ('Bebe'), 11 years	Zool. Soc. Lond. 1964

Observations

Indian rhinoceros (***Rhinoceros unicornis***)

The first and only published account of the pattern of aortic arch branching in this rhinoceros species was given by Owen (1852), whose authoritative monograph on *R. unicornis* anatomy apparently inhibited subsequent investigation of the subject. Ironically, however, Owen's animal proved to be anomalous in respect of the disposition of the aortic arch branches, in that the innominate artery gave origin to the internal thoracic (mammary) arteries—an excessively rare variation, and one not encountered in any rhinoceros specimen anatomized later. Owen did not illustrate the aorta of his animal but commented on the marked subdivision of its arch into a larger ascending and a smaller descending portion. 'The vessels derived from the ascending portion [innominate artery, truncus cephalobrachialis communis] were the two internal thoracics, the brachials [subclavians] and the common trunk of the two carotids [truncus bicaroticus].' The sequence of branch origin was not particularized but presumably the left subclavian arose from the innominate proximal to the right subclavian, as indicated in Fig. 1a.

Owen's account established the canonical pattern of aortic arch branching in the Indian rhinoceros—the origin from the arch of a single (innominate) branch—whilst the origin in his animal of the internal thoracic arteries was clearly recognized as anomalous by Garrod (1873,

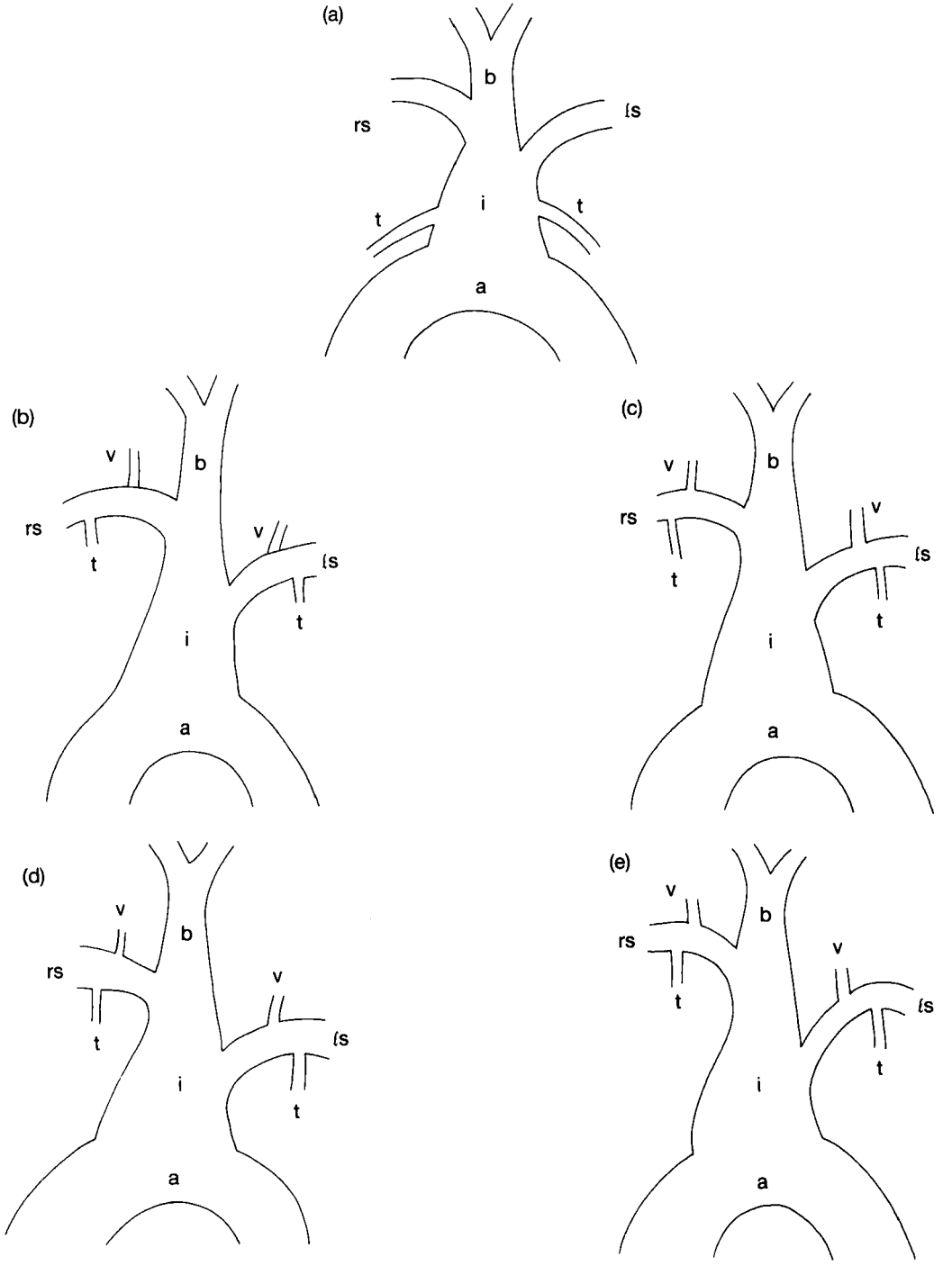

FIG. 1. *Rhinoceros unicornis*. Aortic arch branching pattern in: (a) Owen's (1852) anomalous specimen and (b, c, d, e) in present specimens R.41, R.45, R.21, R.75. a = aortic arch; b = bicarotid trunk; i = innominate artery; ls = left subclavian artery; rs = right subclavian artery; t = internal thoracic artery; v = vertebral artery.

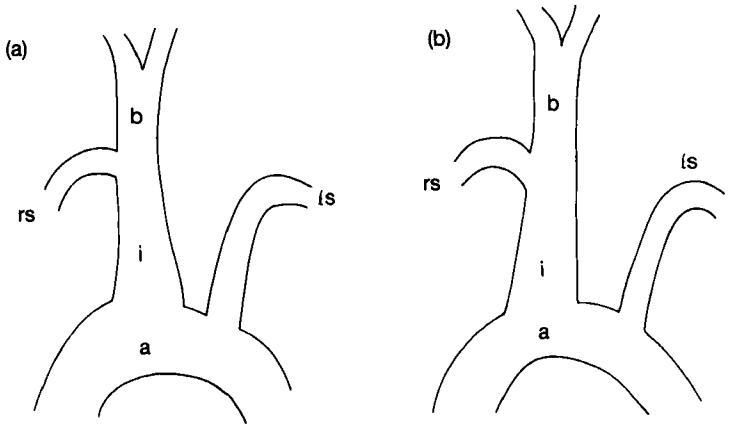

FIG. 2. *Rhinoceros sondaicus*. Aortic arch branching pattern in: (a) Garrod's (1877) specimen and (b) Beddard & Treves' (1887) specimen. Lettering as in Fig. 1.

1877) and by Beddard & Treves (1887, 1889) who were at pains to particularize the origin of these vessels in their specimens of the Javan and Sumatran rhinoceroses.

In present specimen R.41, the aortic arch gives off a single branch, the innominate or truncus cephalobrachialis communis. This soon gives off a left subclavian artery and then proceeds cranialwards to terminate in an equally capacious right subclavian artery and a narrower-calibred truncus bicaroticus. Bilaterally, the internal thoracic and the vertebral arteries arise from the subclavian artery (Fig. 1b).

In present specimen R.45, the aortic arch is partially subdivided into ascending and descending (more accurately transverse) portions, the former being continuous with the initial portion of the aorta. This ascending portion of the arch is its sole branch—the innominate artery (truncus cephalobrachialis communis), a conical vessel which after a short course gives off a left subclavian artery and a narrower truncus bicaroticus. The internal thoracic and vertebral arteries arise from the subclavians (Fig. 1c).

In present specimen R.21, the aorta has an initial external diameter of 95 mm and its arch gives off a single branch, an innominate artery (truncus cephalobrachialis communis) some 25 mm long and 55 mm wide. This short, large vessel lies in direct alignment with the ascending portion of the arch, the descending (transverse) portion of which is but 4 mm wide and is attached to the truncus pulmonis by a 35-mm broad ligamentum arteriosum. A distinct kink distinguishes the arch moieties. The short innominate artery gives off a 25-mm wide left subclavian artery and then continues cranialwards as a 27-mm wide truncus cephalobrachialis minor to terminate in a 25-mm wide right subclavian artery and a narrow truncus bicaroticus. Each internal thoracic artery arises from the caudal aspect of the ipsilateral subclavian. The right vertebral arises from the dorsum of the right subclavian artery at its origin: the left vertebral arises more distally from the dorsum of the left subclavian artery (Fig. 1d).

Present specimen R.75 presents a comparable pattern of aortic arch branching. From the ascending portion of the arch arises a single branch in the shape of a conical, capacious and relatively short innominate artery (truncus cephalobrachialis communis). This vessel gives off a left subclavian artery and thereafter proceeds cranialwards, narrowing the while, to divide into

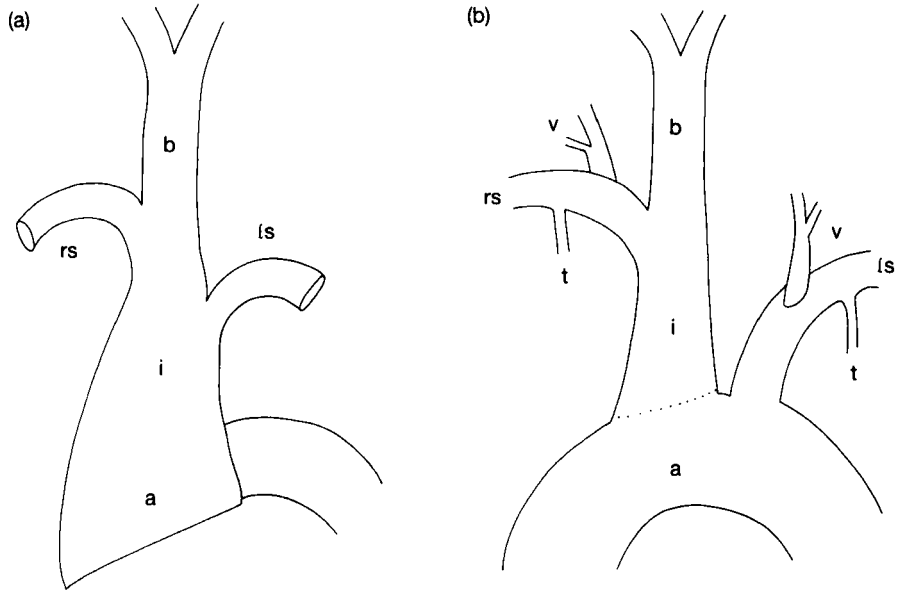

FIG. 3. *Didermocerus sumatrensis*. Aortic arch branching pattern in: (a) Garrod's (1873) specimen and (b) present (Basle) specimen R.62. Lettering as in Fig. 1.

two terminal branches—a right subclavian artery, equal in calibre to the left, and a narrow truncus bicaroticus. Each subclavian gives origin to the ipsilateral internal thoracic and vertebral arteries, from, respectively, its caudal and dorsal aspects (Fig. 1e).

It thus appears that *Rhinoceros unicornis* manifests a constant pattern of aortic arch branching. The arch gives off a single short (innominate) branch which gives early origin to a left subclavian artery and terminates by dividing into a right subclavian artery and a narrow truncus bicaroticus. Canonically, the internal thoracic and vertebral arteries derive from the subclavians.

*Javan (Sondaic) rhinoceros (**Rhinoceros sondaicus**)*

(Only two examples of this vanishing species have been anatomized to date and the likelihood of further examples becoming available for anatomical investigation is remote.)

Garrod (1877) made brief references to the pattern of aortic arch branching in a young female Javan rhinoceros. He described the arch as giving off two independent branches, viz. a large innominate artery and a smaller left subclavian. The innominate trunk proceeded distally, gradually diminishing in calibre, to divide into terminal right subclavian and bicarotid branches. Each subclavian artery gave off the ipsilateral internal thoracic artery (Fig. 2a).

Beddard & Treves (1887) described the heart of a young male Javan animal as showing 'nothing unusual' and made but brief reference to the great vessels arising from the aortic arch. These were two, viz. 'an innominate artery from which are derived the common carotid [truncus bicaroticus] and the right subclavian' and a left subclavian, wholly independent of the innominate. The internal thoracic arteries, 'large as in *Rh. indicus*', arose from the subclavians (Fig. 2b).

This limited evidence suggests the development of a constant pattern of aortic arch branching in *R. sondaicus* and emphasizes its unexpected contrast with that obtaining in *R. unicornis*.

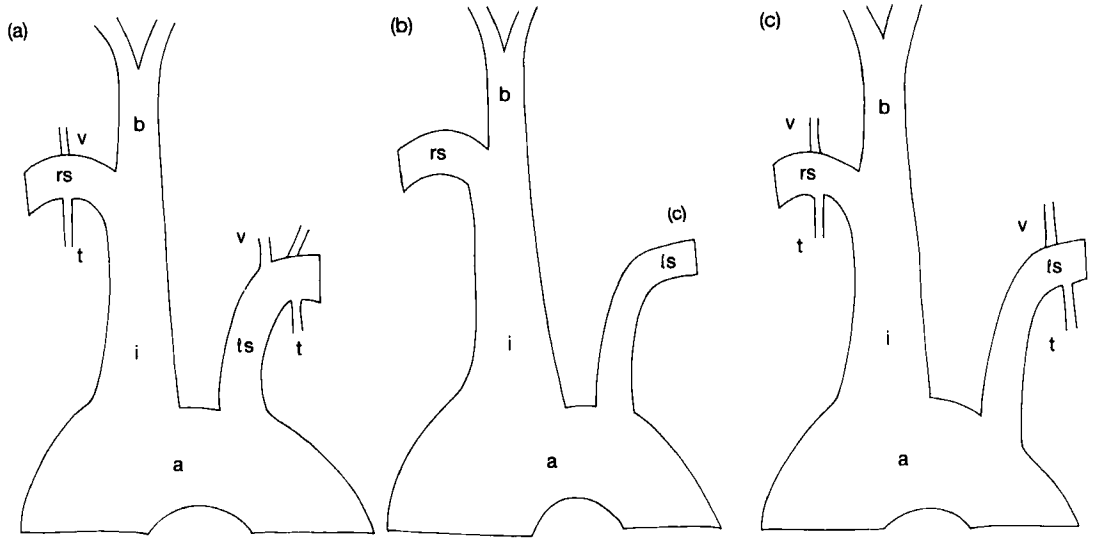

FIG. 4. *Diceros bicornis*. Aortic arch branching pattern in present specimens: (a) R.19, (b) R.24 and (c) R.27. Lettering as in Fig. 1.

Sumatran rhinoceros (***Didermocerus sumatrensis***)

Garrod (1873) gave the only published account of the Sumatran rhinoceros heart, this organ receiving no attention from Bell (1793) or from Beddard & Treves (1889). In his old female animal, the initial portion of the aorta, some 100 mm long by 87 mm wide, gave rise to an arch subdivided into moieties of almost equal calibre. The first arch moiety and sole branch was a 75-mm long innominate artery, the second constituted the descriptive descending or transverse portion of the arch. About half-way along its course cranialwards, the innominate gave off the left subclavian artery and thereafter continued to its terminal division into a right subclavian artery and a 62-mm long truncus bicaroticus. Garrod did not depict this vascular arrangement which is therefore reconstructed herein as Fig. 3a. He regarded the Sumatran rhinoceros pattern of aortic arch branching to be 'very much like that of the Llama as drawn by Prof. Owen', despite Owen's (1868) statement, supplemented by a confirmatory figure, that 'in *Auchenia* . . . the left brachial comes off close to, but distinct from, the innominate trunk, which, after dismissing the right brachial, sends onwards a long common bicarotid trunk'.

In present specimen R.62 (the formalin-fixed heart of a younger animal), a different pattern of aortic branching obtains, the aortic arch giving rise to two contiguous but independent branches, an innominate and a left subclavian artery. At the site of origin of these vessels, the arch is some 40 mm in external diameter: the 45-mm long innominate artery has an initial width of 26 mm, the left subclavian a corresponding width of 20 mm. The innominate terminates by dividing into a 20-mm wide right subclavian artery and a truncus bicaroticus 40 mm long and initially 20 mm wide. Each subclavian artery gives rise caudally to a substantial internal thoracic artery and dorsally to a vertebral and other arteries (Fig. 3b).

Since the different patterns of aortic arch branching manifested by these two Sumatran rhinoceros specimens may represent nothing more than individual variation, the canonical pattern

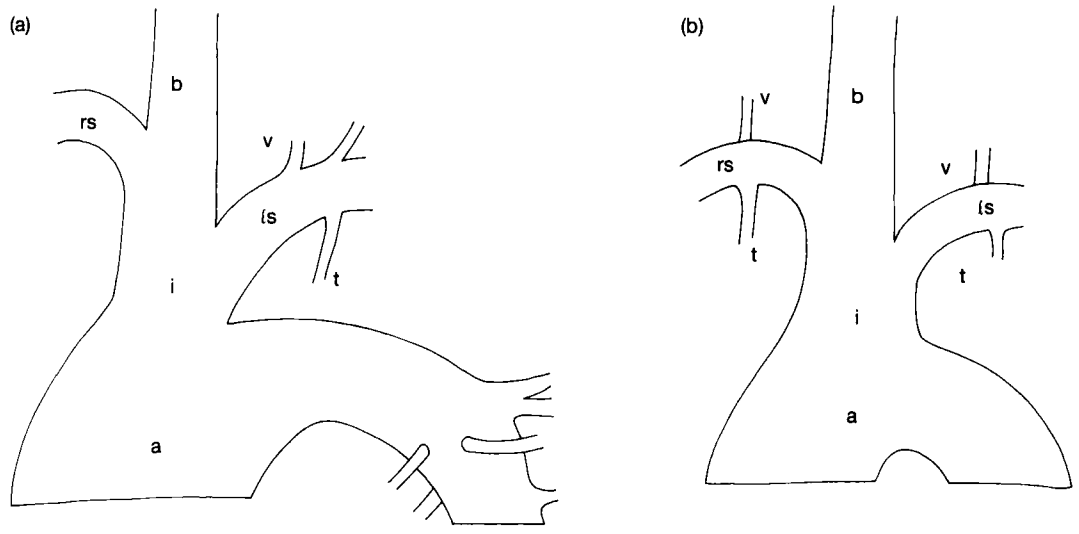

FIG. 5. *Ceratotherium simum*. Aortic arch branching pattern in present specimens: (a) R.20 and (b) R. 162. Lettering as before.

of such branching in *Didermocerus* must remain undetermined until additional specimens shall have been examined.

African black rhinoceros (***Diceros bicornis***)

In present specimen R.19, the 40-mm wide aortic arch gives off two branches separated by a 10-mm interval, namely, an innominate artery some 40 mm long and 30 mm wide, and a left subclavian artery initially 20 mm wide. The innominate artery is directly aligned with the first portion of the aortic arch and proceeds cranialwards to terminate by dividing into a right subclavian artery (some 25 mm wide) and a short truncus bicaroticus (16 mm wide by 15 mm long). The right subclavian gives rise dorsally to an internal thoracic branch, cranially to a vertebral branch: the truncus bicaroticus divides into two divaricating common carotid arteries, each initially 8 mm wide and some 200 mm or more in length. The left subclavian artery gives off a vertebral branch from its cranial aspect and a cluster of branches, including an internal thoracic artery, from its dorsal aspect (Fig. 4a).

In present specimen R.24, the aortic arch manifests a comparable branching pattern, save that the innominate and left subclavian arteries arise therefrom in juxtaposition. The arch diminishes in width from an initial 50 mm to one of 30 mm after the origin of the left subclavian artery: the ligamentum arteriosum is 20 mm broad. The innominate artery has a lumen diameter of 25 mm, the left subclavian one of 20 mm. The innominate terminates by dividing into right subclavian and bicarotid branches. Each subclavian artery gives origin to the ipsilateral internal thoracic and vertebral arteries (Fig. 4b).

In present specimen R.27, the aortic arch gives off two branches (innominate and left subclavian) separated by a 15-mm interval. The innominate artery is directly aligned with the first part of the aorta, is relatively long and terminates by dividing into a right subclavian artery and a

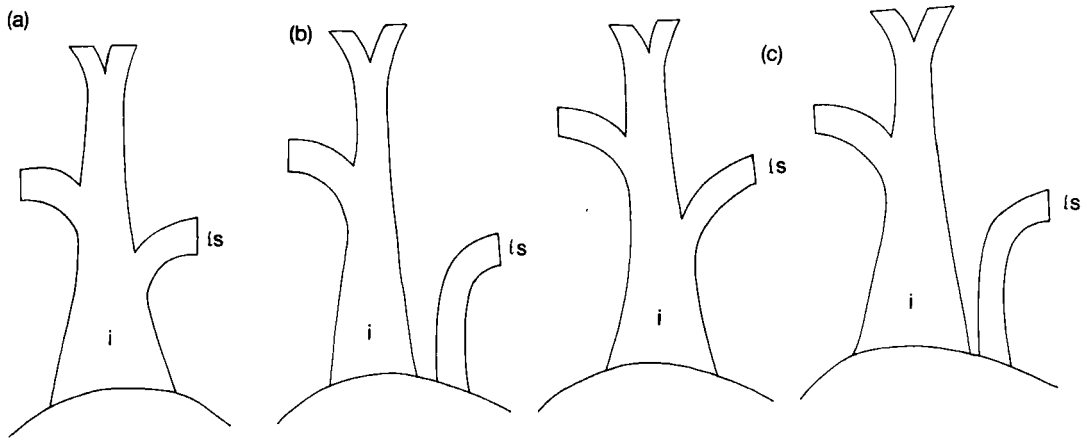

FIG. 6. Rhinoceros aortic arch branching pattern, showing its independence of taxonomic considerations. (a) Pattern in *Rhinoceros unicornis* and *Ceratotherium simum*, (b) pattern in *Rhinoceros sondaicus* and *Diceros bicornis* and (c) pattern in *Didermocerus sumatrensis*. Lettering as in Fig. 1.

notably short truncus bicaroticus. Each subclavian artery gives origin dorsally to internal thoracic and vertebral branches plus a leash of branches to the deep cervical and shoulder regions (Fig. 4c).

It would appear, therefore, that in *Diceros* the aortic arch provides two independent branches (innominate and left subclavian) and that the truncus bicaroticus is a notably short vessel.

African white rhinoceros (***Ceratotherium simum***)

In present specimen R.20, the aortic arch gives off a single branch—a short, wide innominate artery (truncus cephalobrachialis communis)—which stands in direct alignment with the first part of the aorta. This vessel almost immediately gives off a left subclavian artery and proceeds cranialwards to terminate by diving into right subclavian and bicarotid branches. Bilaterally, the internal thoracic artery arises from the caudal, and the vertebral artery from the cranial, aspect of the subclavian, whilst numerous branches to the deep cervical region spring from this vessel's dorsum (Fig. 5a).

In present specimen R.162, the aortic arch gives off a single branch—a short, wide, somewhat conical innominate artery—directly continuous with the first part of the aorta. This vessel fairly soon gives off a left subclavian artery and thereafter proceeds distally to terminate by dividing into right subclavian artery and truncus bicaroticus. Each subclavian gives rise to the ipsilateral internal thoracic and vertebral arteries, as well as to the costo-cervical, omo-cervical and other deep cervical arteries (Fig. 5b).

Such a pattern of aortic arch branching may prove to be canonical for *Ceratotherium*. It recalls that of *Rhinoceros unicornis* and differs markedly from that of *Diceros*.

Commentary

Despite its restricted range, the evidence submitted above suffices to demonstrate the absence of a uniform pattern of aortic arch branching in the Rhinocerotidae. Therein, two patterns of such

branching are manifestly dependent upon the origin of the left subclavian artery, namely, one in which the aortic arch gives off a single (innominate) branch and another in which it gives off an additional (left subclavian) branch. These patterns of branching—like those recorded for pinnipedes by King (1983)—remain uncorrelated with taxonomic affinities for they associate on the one hand the generically distinct Indian and white rhinoceroses and on the other the equally distinct Javan and black rhinoceroses (Fig. 6).

A canonical pattern of aortic arch branching is recognizable in the Indian rhinoceros and is discernible at least in the Javan, black and white rhinoceroses. The origin of the left subclavian artery either from the stem of the innominate artery, or from the aortic arch in close proximity thereto, may be indicative of the primitive occurrence of a single-branched type of aortic arch in the Rhinocerotidae.

In all rhinoceros forms, the innominate artery is a notably capacious, conical vessel directly continuous with the initial portion of the aorta and responsible for the descriptive subdivision of the aortic arch into ascending and descending moieties.

Gratitude is hereby tendered to the Council of the Zoological Society of London for access to rhinoceros material, to Dr L. Forcart, Basle Zoological Garden, for the extended loan of *Didermocerus* material and to Mr H. A. Bagshaw, F.R.C.S., Dr E. M. Walsh and Mrs Vari Harvard-Millar for prosectorial assistance in their undergraduate days.

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