"The origin & developement of the larger arteries" with 39 figures

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The subject of which this paper proposes to Treat, is one which from its importance & the complexity of its details has attracted the attention of numerous observers, but it is chiefly to the works of Baer ~~Rathke~~ and Rathke that we owe our present views of the origin & development of the great vessels. Before proceeding to follow in detail the explanations which Rathke has offered and which are the views still held on the present day, I think it will be to notice briefly the opinions held by Baer since they possess far as much more than a historical interest.

From observations made by him and by earlier observers upon the embryos of Birds & Mammals Baer[1] pointed out that the pulmonary arteries & the aorta with its primary branches, the large arteries springing from the heart, were developed by a series of modifications from a system of vessels very similar

to the branchial arteries & veins of fishes and Amphibians. The truncus arteriosus arising from the embryonic heart passes upwards upon the ventral side of the throat and gives off five pairs of arches. The ~~posterior~~ dorsal end of the first arch passes into a vessel which descends upon the dorsal aspect of the throat receiving as it passes backwards the successive terminations of the other arches. Finally the dorsal vessel of each side unites with its fellow of the opposite to form the aorta which is continued backwards towards the tail end of the embryo. Baer's views as to the special changes which this system undergoes in its transformation from its simple or type form to the fully developed state in each class may be shortly noticed. In the Mammalia according to him (compare fig I) the fifth arch of the right side disappears while the fourth arch of that side in conjunction with the fifth arch of the left forms the pulmonary artery.

The fourth arch of the left side along with the third arches of both sides gives rise to the aortic system of vessels. The whole of the fourth left arch becomes the aorta while the carotids of each side are developed from the ~~dorsal~~ ventral trunks connecting the fourth with the third arches, the third arches themselves & the portion of the dorsal trunks connecting the terminations of the third arches with the termination of the higher arches. The subclavian arteries arise from the carotids as branches from the terminal extremities of the third arches. The ventral trunks connecting the first & second arches & these arches themselves are obliterated & lost.

In Birds according to Baer, the carotids & subclavians have an ~~similar~~ origin similar to that ascribed to these vessels in the Mammalia. The aorta ~~is~~ represents the fourth right arch & the pulmonary arteries arise from the fourth left & fifth right arches.

Such may be taken as a general account of the views held by Baer & the earlier observers since his time while many of his opinions have been substantiated by later workers much has been discredited, so that it will be necessary to go with much more detail into the work of Rathke[2] whose ~~op~~ explanations are now universally accepted. The following description of the changes by which the complicated vascular system of the higher animals has been developed from the comparatively simple arrangement found in the lower vertebrates has been taken partly from the works of Rathke & partly from the accounts given in the standard works upon Comparative Anatomy of the present day, those of Huxley[3] Macalister,[4] Balfour,[5] Kölliker,[6] Gegenbaur[7] and Gadow.[8]

In the embryos of all vertebrata a large vessel the truncus arteriosus is given off from the common ventricle of the heart & is continued forwards for some distance on the

Ventral aspect of the neck terminating underneath the head by dividing into two symetrical branches which pass upwards backwards round the anterior extremity of the alimentary on each side, to a position underneath the notochord. From this they are continued backwards approaching one another as they go, until they finally fuse into a single median vessel, the aorta. The aorta is continued still further backwards towards the tail. Between the truncus arteriosus and the vessels passing backwards upon each side, dorsal to the alimentary canal, a series of anastomoses is formed, the arterial arches thus formed appearing in succession from before backwards. The No of arches having their origin in this manner is very variable, in the higher vertebrate no more than five appear and even these are not all present at one time; while in the lower forms there may be as many as nine but this extreme is not usual.

In the lower forms of vertebrate life the first and second arches are known respectively as the mandibular & hyoid. they are usually evanescent but occasionally one or other of them is preserved as a small artery to be afterwards specially noted. The succeeding arches are named 'branchial' from the functions which they afterwards assume.

In fishes the branchial arteries pass into the branchiae or gills where they lose themselves in a capillary networks in which network the blood is submitted to oxidation. From each gill the capillaries resolve themselves into a vein which carries the oxidised blood into the dorsal trunk or root of the aorta. The original arterial arches then become the vessels connected with the gills & they are subdivided into two portions, an arterial portion arising from the truncus arteriosus & a venous portion entering the aortic root. The No of arches is generally reduced to four. The hyoid arch remains patent in some fishes as the branch supplying

the rudimentary gill of the spiracle (Ganoids) in others (Elasmobranchs) it is the mandibular vessels which remains to do this duty; in others (most Dipnoi) both disappear. (Balfour) Among the other changes which take place in the power of conversion of the simple aortic arches in embryo fishes into the arterial system of the adult form may be noticed—(1) the passage forward of the carotid artery to supply the head from the anterior extremity of the dorsal vessel or aortic root, (2) the origin of the subclavian arteries from the aorta or from the aortic roots, (3) the origin of an artery to the swimming bladder from the aorta or from the last branchial vein before joining the aortic roots, and (4) the development of visceral arteries from the dorsal aorta. Figure 2 from Wiedersheim is a diagrammatic representation of the circulation in Fishes.

In the Amphibia the mandibular is never developed and the hyoid arch disappears

with the exception of its ventral portion which remains as the lingual artery. The carotid artery extends to the head from the anterior end of the dorsal connecting trunk or root of the aorta. The subclavian arteries arise from the aorta or from its roots. In the ~~pre~~ perennibranchiate forms there are four ~~arches~~ arches (besides the hyoid) but only the three anterior of these supply gills; the fourth upon each side gives off a pulmonary artery and is connected with the aortic root. In the caducibranchiata where the gills atrophy the first branchial arch is continued into the root of the carotid & is connected by a ductus Botalli with the dorsal portion of the second. The second & third arches form simple aortic arches carrying the blood from the truncus arteriosus directly into the dorsal aorta without the intervention of gills. The fourth arch on each side gives off a branch to the lungs & is connected by a narrow

"ductus Botalli" with the aortic root.

In the Anura a still further change takes place. The fourth or last branchial arch disappears & the pulmonary artery arises from the third. The second branchial arch on each side forms the aorta while the first forms the basal portion of the internal carotid artery. (compare fig. 8 the great arteries of the frog) Thus in the highest group of the Amphibians three arches are said to remain patent, ~~The fourth forms the~~ the first, second, & third branchial arches of the lower types. The third forms the pulmonary artery, the second the aorta, the connecting portion of the ventral vessel or truncus arteriosus, between the second & first arches forms the common carotid, the further prolongation of this forward the external carotid or lingual artery, the first branchial arch & the forward prolongation of the dorsal vessel beyond

& the internal carotid artery.

After we pass Amphibians the No. of embryonic arches is reduced constantly to five. These may be taken as representatives of the mandibular & hyoid & the first three branchial arches as in the Anura. Gills are never developed so that the arches never break up into capillaries but remain simple

In the Reptilia we have numerous modifications In the lizards (compare fig 10) the last or fifth arch on each side becomes pulmonary artery. The fourth arch upon each side becomes the aorta. The trunks uniting the fourth arch with the third & the third arch with form what may be called the carotid arch upon each side. The continuation forward of the ventral vessel or truncus arteriosus forms the lingual or external carotid artery & the continuation forwards of the dorsal vessel or aortic root of fishes, forms the internal carotid artery. The subclavian arteries arise together from the right aorta before it

~~Lent~~

joins with its neighbour of the left side to form the single median trunk.

In the Ophidian Reptiles (1899), the main difference is this — the carotid arch is not connected dorsally with the aorta. Its component parts are made up as follows — The common carotid arises from the truncus arteriosus between the fourth & third arches & the external carotid is the prolongation forwards of this vessel beyond the third arch. The internal carotid artery is formed out of the third arch itself — the continuation forwards towards the head of the dorsal trunk uniting the arches; it is not connected posteriorly with the arch of the aorta.

In all the Reptiles & in all the higher forms the first & second arches disappear entirely.

While it is easy to understand the explanation which Balfour has put forward of the origin of the great arteries in the Sauropsidan & Ophidian Reptiles as above set forth, the application of

his principle to the Chelonian & Crocodilian system of bloodvessels is by no means a simple matter. I have not been able to find in those works of Rathke which I have had at my disposal, any attempt to give a diagrammatic representation of the arterial origins in those two groups of Reptile as has been done in all the other cases (see figs. 9, 10, 11 & 12) Further, with one exception, I have not been able to find any such attempt in the works of any of the numerous Authors who have written upon the subject since Rathke's time. The one exception to which I have referred is contained in a work by Sabatier[a] whose opinions I will specially notice at a later period of this paper. The diagram which, I think, falsely, Sabatier ascribes to Rathke is given in fig. N° 13. From the figure it will be noticed that while in most of its details the Arterial System of Crocodiles is made to

resemble that of other Reptiles it differs in ~~figuring~~ thus-that the subclavian arteries are made to spring from the dorsal extremities of the third veins, that is to say from the internal carotids, an origin similar to that which Baer ascribes to the same arteries in Birds. This however I believe to be a wrong interpretation of the account given by Rathke upon this point. According to the text of his later works it would seem that Rathke ascribes to the subclavian arteries a very different origin, before describing which however it will be necessary to note briefly the anatomy of the great vessels. The truncus arteriosus is divided into ~~2 part~~ two canals through one of which venous blood passes, through the other arterial. From the front of these canals (the ventricles) spring the two pulmonary arteries & the aortic arch of the left side. Out of the second (anterior) pair the aortic arch of the right side (see fig 15). Two large arteries spring from the right aorta. The first of these divides into the left carotid

and left subclavian arteries & also a small trunk the arteria collateralis colli. From the second & third two branches of which arise from the right aorta spring the right subclavian & right collateral artery. There is thus in the crocodile but one carotid which runs ~~up~~ forwards immediately underneath the bodies of the cervical vertebrae & divides near the head into right & left common carotids.

Applying to these details the principles which Balfour indicates they would be explained in the following manner. In the first ~~instance~~ place the fifth pair of arches form the pulmonary arteries. The fourth pair form the right & left aortae. The ventral connections between the fourth & third pairs of arches form the common carotids. The third arches & the continuations forward of the dorsal vessels form the internal carotids. The subclavians arise near one another from the descending portion of the right aortic arch; they cannot arise

symmetrically because the left aorta carries venous blood. All this is similar to what is found in the Lacertilia (see fig 10) except that the carotid arches & the aortic arches are not connected dorsally. Secondary changes now take place. The common carotids fuse together so as to form a single trunk (carotis primaria) The right arch of the aorta shortens so as bring the subclavian arteries up into connection with the carotid. The left subclavian artery fuses with the base of the carotid so as to form the left innominate artery while the right subclavian arises from the arch of the aorta in close proximity.

Such is Rathke's explanation of the development of the arterial system in the Crocodilia; it remains however to be proved at a later part of this paper that neither this nor any other explanation in the line which Rathke has

set down can ~~fully~~ account for the origin of the vessels which spring from the right aortic arch in this group of Reptiles.

In the Chelonian Reptiles the ~~state~~ anatomy of the large arteries is similar in many respects to that already described in the Crocodilini but there ~~are~~ to a difference in some points of detail. The truncus arteriosus is similarly divided into two channels the one carrying venous blood & the other carrying arterial. From the venous channel spring the right & left pulmonary arteries & also the left aortic arch (vid pg. 16) From the arterial channel springs the right aortic arch. Out of the right aorta arise two innominate arteries each dividing into common carotid & subclavian of its own side.

Applying Rathkes principles, for I know of no explanation which he has offered of this form, it is only possible to explain the position of the left subclavian artery by supposing that it originally sprang

from the left or venous aorta & that by ~~the~~ some ~~unaccountable way~~ process of shortening not very easily explicable its portion was transferred to the left innominate branch of the right aorta; a supposition which however Rathke himself does not apply in the case of the Ruminantia

In Birds we have no difficulty in following Rathke's views since fig h° II representing the development of the arteries in this class of vertebrates is taken from one of his papers.

The truncus arteriosus is completely divided into 2 channels ~~an aortic~~ venous & an arterial ~~Lung~~ The venous channel springing from the right ventricle of the heart is continued into the right & left pulmonary arteries. The arterial channel from the left ventricle forms the right aortic arch. There is no left aorta. From the (right) aorta spring two innominate arteries each dividing into a ~~right~~ carotid & subclavian artery

The explanation offered is as follows.
The first arches form the pulmonary arteries
The fourth right arch forms the arch of
the aorta. The fourth left arch gives rise
to the left subclavian artery. The ventral trunks
between the fourth & third arches form the
common carotids. The continuations of these
trunks further forwards form the external
carotids. The internal carotids ~~from~~ arise ~~from~~
from the third arches & the continuations
forwards from the dorsal extremities of these
of the anterior portions of the dorsal vessels.

In Mammals while there are many varieties
in the mode of origin of the large arteries from
the arch of the aorta all may be reduced
to a single type & the anatomy of man
offers a very fair example. Two large
arteries spring from the heart - the pulmonary
artery & the aorta. The pulmonary artery
divides into two branches one for each
lung. The aorta bends upwards ~~outwards~~

& descends upon the left side. From the aorta spring first – the innominate artery which divides into right carotid & subclavian, second – the left carotid third – the left subclavian.

The explanation offered is very similar to what is offered in the case of Birds. (See ps 12) The fifth left arch forms the pulmonary arteries, while the fifth right fails. The fourth left arch is developed into the aorta, the fourth right into the right subclavian. The ventral trunks between the fourth & third arches form the common carotids & their continuations forwards the external carotids. The internal carotids arise from the third arches & the continuations towards ~~of the~~ from their dorsal ends of the dorsal trunks.

From the foregoing facts it will be seen that in explaining the various transformations which the aortic system of vessels has undergone in the development from the lower forms to the higher, Balfour attempts to show that each vessel has but one constant place of origin & that when

this place of origin does not accurately correspond with what we find in the anatomy of the adult form the difference is to be explained by secondary changes.

Starting with the five arches found in the embryos of Reptiles representing the mandibular hyoid & three branchial arches the same series of changes is supposed to take place in all the higher forms.

The Pulmonary arteries always arise as branches of one or both of the fifth pair; in the Ophidians & Mammals from one only & in all the others from both.

The arch of the Aorta be it single or double always arises from the fourth pair of arches; in Reptiles both fourth arches are so transformed in Birds the right fourth arch alone, & in Mammals the left fourth arch alone.

The common carotids always arise from the portions of the original trunceus

arteriosus connecting the ventral ends of the fourth arches with the ventral ends of the thirds. The external carotids always arise from the forward prolongations of these ventral trunks towards the head. The internal carotids arise from the third arches & from the prolongations forwards from their dorsal extremities of the vessel connecting the third arches dorsally. The subclavian arteries spring from the aortic roots close to the spot where these join to form the single aorta; by secondary shortening of the aortic arches they are supposed to be drawn upwards towards the carotids whence innominate arteries are explained.

Such is the system put forward in most part by Rathke himself though partly by later writers who have accepted

Rathke principles as the guide to the explanation of details.

In the succeeding pages of this paper I intend to apply these principles more closely than has as yet been done to the anatomy of the vascular system in the different groups of animals to show that in many cases they are inadequate ~~for the purpose intended~~. I am of opinion also that in assigning the origin he does, more especially to the carotid & subclavian arteries, Rathke has fallen into error. & I hope to be able to point out the true place of this vessel in the developmental plan.

It will be necessary for these purposes to consider with some detail the vascular anatomy of the different groups of vertebrate animals; each of the large classes is therefore taken in series. In the cases of Reptiles, Birds, & Mammals a new explanation of the changes will be offered.

In Amphioxus, the details of the circulation which have been very carefully described by Langerhans, there is no definite organ corresponding to a heart, but the want of this is made up for by the capability of contraction which all the vessels possess. The blood vessels are divided into veins & arteries. The first consist of a set of vessels lying underneath the alimentary canal (vid fig 17) & having an intimate connection with the liver. The venous blood passes forwards from the liver & the hinder end of the body into a vessel which lies underneath the branchial apparatus. From each side of this longitudinal vessel a series of transverse trunks are given off which pass backwards into the gills & may be called the branchial arteries. The branchial arteries in the gills lose themselves in a capillary anastomoses from which the blood emerges by a dorsal branchial vessel or veins. The branchial veins terminate in two longitudinal vessels or aortic roots lying above the alimentary canal

on the right & left sides of the body respectively.
The aortic roots pass backwards towards the tail approaching one another as they go until the & finally fuse into a single median vessel or aorta.
The sub intestinal vein after giving off the gill arteries is continued forwards towards the head & immediately in front of the anterior gill arch dilates into a sinus or cavity which Langerhans has compared to a heart. From this dilated heart springs an aortic arch which arches backwards & to the right forms the commencement of the right aortic root. A pouch on the left side of the "heart" appears to indicate a similar arch upon the left side but it ends blindly & the left aortic root begins simply as a small vessel among the muscles near the anal aperture.
The circulation in Amphioxus is interesting from its similarity in many points to that of fishes more especially in this - that the arteries which supply the head are continuations forwards of the dorsal vessels joining the ends of the arches, while the trunk which supplies the hinder portions of the body is a continuation backwards towards the tail of the same vessels.

In the Fishes The heart lying close under the head consists of a single auricle & ventricle. In the lower forms the auricle is situated posteriorly & the ventricle anteriorly as is the case in embryos of the higher ~~forms~~ vertebrates, but in the ~~late~~ higher forms the auricle is bent forwards above the ventricle so as to lie anteriorly. As we pass up the vertebrate series the position of the heart ~~changes~~ the organ gradually passing backwards so as to be finally lodged in the thoracic cavity. From the heart an elongated vessel the truncus arteriosus passes forwards ventral to the alimentary canal giving off the branchial arteries the No of these being usually four. ~~In~~ In addition an artery is sometimes given to the rudimentary anterior gill but this vessel is often wanting as already pointed out.

The carotid arteries for the supply of the head internally & externally pass forwards as continuations of the dorsal vessels or aortic roots; they are frequently united to one another by a transverse anastomosis the circulus cephalicus (see fig 2)

The roots joining from the aorta give off subclavian arteries. The aorta as it passes backwards

supplies numerous visceral arteries among which may be mentioned a branch to the swimming bladder Figs. Nos 18a 19a represent the heart & great vessels of Polypterus one of the ganoidei; they are taken from a paper by F. Boas. Figure No 3 represents the heart & arterial arches of ~~Crocodilus~~ Crocodilus Here the swimming bladder functions as a true lung & is supplied by an artery which springs from the ~~ventral~~ dorsal portion of the last arch

It is to be noted then in connection with the circulation in fishes that the carotid artery giving branches both to the ~~outside~~ inside of the skull is a continuation forwards of the dorsal vessel or aortic root & that nothing arises from the ~~anterior~~ ventral portion ~~aspect~~ of any of the arches because these carry only venous blood. ~~What~~ The opercular artery is occasional only. When present it often gives a few branches to the ~~front~~ parts beneath the tongue in front of the neck. It is this opercular artery which is said to give rise to

the lingual artery in Amphibians & the external carotid in the higher forms, so that its position & branches in the other groups will have to be enquired into very carefully.

The next division which we now come to, that of the Amphibians, possesses a very peculiar interest in this connection, inasmuch as while the larval forms breathe by means of gills, as do the fishes, most of the fully developed forms respire by means of lungs only. Like the fish type since the blood is not ~~aer~~ oxygenated until after its passage through the gill the arteries for the supply of the body can only come from the dorsal portions of the branchial vessels but in the higher ~~types~~ forms where arterial blood is circulating in the thoracic arteriosus & its primary branches the vessels carrying the blood to the body may spring from any portion of the arches. The method of change

from the one type to the other, as exemplified in the Amphibians, is very interesting

Most of the following details have been taken from the works of Van Bras[11] an author who has devoted a very great amount of attention to this class.

Figure No. 4 represents the truncus arteriosus & large vessels of a Salamander-larva. Four arteries spring from the truncus on each side. The first three represent the three branchial arches of higher forms; the last, ~~the~~ one of the branchial arteries of fishes; here does not supply a gill but is principally connected with the pulmonary artery. This arch is lost in the higher forms, even in many of the higher Amphibia, & the pulmonary artery becomes connected with the third arch. In addition to these arches there existed in the embryo Salamander two placed more anteriorly, - the mandibular & the hyoid, but we find no appearance of the organ of

either of these arches from the truncus arteriosus of the larval salamander.
The first three arteries supply gills & here they lose themselves in a capillary network. From each of the three gills a branchial vein emerges & the veins join to form an aortic root which unites with its fellow of the opposite side to form the aorta. The fourth artery does not supply a gill but joins the pulmonary artery which is arising from the third branchial vein.

The first branchial vein gives off two branches before it joins with the second. The first of these branches represents the lingual or as it is sometimes called external carotid trunk, the second is the internal carotid artery so called, an artery which passes forwards towards the head supplies branches both externally & internally. Between the second & third arteries & the corresponding veins internal to the gills anastomotic branches stretch putting the vessels into communication with one another

The lingual or external carotid artery lies in series with the anastomotic branches just mentioned & as it passes above the first gill artery it is joined thereto by a No. of anastomosing branches. The base of the lingual artery is therefore homologous with the anastomotic ~~of the~~ branches between the succeeding arteries & veins & its continuation forward beyond the place of anastomoses may be looked upon as the ventral portion of the ~~continuation~~ the hyoid arch. The anastomosis which is formed between the ~~ear~~ lingual artery & the first branchial artery has been proved by Van Wijhe to be the beginning of the carotid gland a structure which is seen in a fully developed form not only in the adult Salamander but also in many other Amphibians.

It is in this peculiar way that the ventral portion of the hyoid arch remains patent. When the gill with which the arch is normally connected disappears; by an anastomotic branch ~~the~~ arterial blood is brought up & to have a passage through it is distributed to the front of the neck extending as far as the

tongue. In the adult form, fig 5, when the lungs have begun to act & arterial blood circulates through the truncus & branches this anastomotic branch disappears as such being no longer needed. By the long the gill it takes the place of the branchial arch, as do the other anastomotic branches, & in this way forms the basal portion of the internal carotid. Such, I take it, is the explanation of the anatomical peculiarities of the Amphibian larva.

The system of vessels of the adult Salamander fig. shows the effect of these changes above noted. The four arches are still represented but the first branchial or carotid arch has lost its ventral connection that is with the aortic arch & is entirely continued into its anterior connection or carotid (int. carotid)

The second & third arches are aortic & the fourth is pulmonary. The subsequent changes as we pass through the groups of Amphibians are mainly connected with the disappearance of the 4th arch & the connection of the pulmonary artery with the third arch. This alteration is mainly brought about by the complete coalescence of the third

& fourth arches for the route many tendencies towards obliteration of the arches in the different groups of the Amphibians.

Figure No 6 of the arterial arches of Proteus a perennibranchiate form shows very much the same state of matters as found in the larval Salamander. There are however only two large trunks given off from the truncus arteriosus: the first of which represents the first branchial artery, the second represents a united second & third branches & soon divides into its component elements. The fourth arch has disappeared & the pulmonary artery comes from the third gill area before it entry into the root of the Aorta.

Figure 18 represents the anatomy of the vascular Menopoma a caducibranchiate form shows a very close resemblance to the adult Salamander. The four arches are present but the fourth is exceedingly reduced in size. The main difference between this form & that of the Salamander is shown in the relative want of development of the

carotid gland. When this structure is well developed it seems to cause a shortening of the arch & thus a swallowing up of the basal portion of the internal carotid artery & the rupture of the connection between the arch & the root of aorta arch.

Figure 19 represents the Arches of Amphiuma One has disappeared but owing to the relatively weak development of the Carotid gland the first & second arches are still connected The pulmonary arch is now entirely separated from the aorta arch as in the Reptiles & higher forms.

Figures Nº 20 & 21 represent the arches in the Gymnophiona.

Figures Nº 7 & 8 represent the arches in the young frog Nº 7 is considerably younger than that represented in Nº 8. These figures show in a very marked way the changes which take place also in the Reptiles; they are introduced here chiefly for the sake of comparison at a later period.

Among the Reptiles the Saurii may be noticed first time in this group the arrangement of the large arteries more closely resembles that found in the higher Amphibia than is the case in any of the other groups. Fig. Nos 22, 24, & 23 represent the carotid & aortic arches in Anguis, Chamaeleo & hyniocephalus respectively. In the Saurians as in all reptiles the truncus arteriosus is divided into three channels, two of them being connected with the right ventricle of the heart & circulating venous blood only, while the third arises from the left ventricle & carries arterial blood. The venous channels are the Pulmonary Artery & the left aortic arch & the arterial channel is the right aortic arch. The pulmonary artery divides into a right & left branch which represent the two arches of the fifth pair.

The left aorta arches forwards outwards & backwards forming round the trachea & oesophagus & it ends beneath the vertebral column by joining with the right arch & form the median aorta. As a rule no branches arise from this vessel.

The right dorsal aorta passes forwards outwards backwards embracing the trachea oesophagus upon the right side & ends beneath the vertebral column by uniting with the left dorsal arch to form the single median aorta. These two vessels represent the fourth arches of the left & right sides.

From the right dorsal arch a series of branches arise. The first of these arches forwards outwards & in many cases backwards upon the left side may be called the left carotid arch marked C.A. in the diagrams alluded to Nos. 22, 23, 24. The second branch forms a similar arch upon the right side & is called the right carotid arch.

In the different groups of Saurians there are slight though for our purpose important modifications to be noted in respect to the carotid arches. In the Lacertilia as represented in figure No. 22 by Anguis the carotid arches bend backwards on the right & left sides & join the right & left dorsal arches respectively a fact which will be found very interesting if this figure

be compared with figs Nº 4 & 8 of the arches of Rana

In other cases while the carotid arch bends backwards towards the aortic arch the communication between these two vessels is very much reduced in size as in figs Nº 23 & 24 of hyrocephalus & Chiromaeleo. In some of the Chiromaeleons the communication between these two arches is reduced almost to a thread in other cases it is entirely wanting. A comparison of figure Nº 24 Chiromaeleo with figure Nº 25 representing the same parts in the Crocodile is also exceedingly interesting.

From the carotid arches arise in the Saurians two or three branches the course & distribution of which are of great interest in the present investigation. The first branch arising from the anterior portion of the carotid arch passes forwards for a very short distance on the ventral aspect of the neck as a trunk of medium size & divides into a large No of branches.

These branches mainly supply the ~~musculature~~ muscles of the front lateral parts of the neck & the thymus gland some of them extend forwards as far as the tongue; branches also supply the muscles of the shoulder where they come into relation with branches of the subclavian arteries to be afterwards described, which supply the same muscles. On glancing at the two figures coupled with the facts of its distribution will show at once that this artery is homologous with the so called 'external carotid' or lingual of Rana & other Amphibians.

The next branch which leaves the carotid arch comes from the highest portion & in a line with the dorsal portion connecting the aortic recurved arches when that is present. This artery runs forwards towards the head for the supply of which it is destined. On its course which it continues for a long distance without branching, it passes sooner or later in the different varieties of the dorsal

aspect of the alimentary canal approaching
the fellow of the opposite side. At last
underneath the skull it terminates by dividing
into two branches one destined for the supply
of the interior of the skull, the other, subdividing
into facial & temporal arteries, for the supply of
the outer portions of the skull. This artery
is the homologue of the internal carotid of
Amphibians (compare the figures).

The third or occasional branch of the carotid arch
is a small twig sinking into the surrounding
muscles.

The carotid arch is to be considered then as the
representative of the third embryonic arch,
the first described branch of it as forwards of
the continuation forwards of the dorsal
arterious & the second branch of it as
the continuation forwards of the dorsal
trunk connecting the branchial roots.

The subclavian arteries among the Saurians
arise either close together or by a common
stem from the right aortic arch close

placed
to its junction with the left arch. They pass
forwards upon each side out of the chest into
the neck among the muscles of which they
distribute branches, & finally they are directed
outwards, supplying the muscles the
shoulder & enter the arm. Among the
most constant branches which they give in
the lower part of the neck may be mentioned
the internal mammary the vertebral but
it is to be noticed that in Varanus & some other
forms the internal mammary artery arises
as a branch of the first branch of the
carotid arch. The branches of the subclavian
come into close relations with the branches from
the ascending portion of the carotid arch
among the muscles of the neck & shoulder.

I wish to lay special stress upon this
close relationship between the subclavian artery
& those branches which spring from the ventral
portion of the carotid arch as I am of opinion
that with this is connected the altered position
of the subclavian in the higher groups

The Ophidian group of Reptiles would ~~[illegible]~~ from the mode in which the great vessels arise / face to be considered next but as I have only had as yet an opportunity of dissecting two specimens (Boa Snake & Python) in both of which I was unable to trace the arteries to the head owing to previous evisceration & as it seems to me that the arterial system of this group requires further elucidation I mean to leave it out of from the subject of a future investigation. Figure N° 9 sets forth Rathke's ideas as to the origins of the great arteries in this group.

The main difference between the Cheloneans & the two previous groups of Reptiles is shewn in the place of origin of the Subclavian arteries These arteries which in all the cases we have as yet considered springing from the roots of the Aorta or from the right root only are now found springing from a right & left innominate artery. In the Cheloneans we find ~~a~~ pulmonary artery dividing into a right & left branche & ~~a~~ Aortic arches the left of which springing from

The right ventricle carries venous blood & gives off only, shortly before its junction with the right, a few veneral arteries.

The right aortic arch before bending ~~dorsal~~ downwards gives off two innominate arteries a right & a left from which spring in their turn carotid & subclavian arteries. The subclavian arteries give off branches to the ~~front~~ ventral lateral aspects of the neck & thorax & the pectoral arteries & are continued outwards to the fore limbs. The carotid arteries run forwards in the neck for a long distance & finally divide into internal & external branches. On their course upwards the carotids give off a few slender branches to the sides of the trachea & oesophagus.

I reserve comment upon the homologues of these vessels until after the description of the arterial system of the Dicondylia.

In the Crocodilus the truncus arteriosus is divided into three channels two of which receive venous blood & the third arterial. Of the former channels one communicates with the pulmonary arteries & the other with the fourth left arch both springing from the right ventricle. The pulmonary arteries pass on either side to the lungs & surround the fifth arches.

The fourth left arch, or left aortic arch, passes forwards upwards & backwards & joins under the vertebral column with its fellow of the right side & form the aorta; one branch a coeliac artery usualy arises from it.

The right aortic arch holds a similar course but to the right side. The aortic & pulmonary arches on both sides are crossed by the pneumogastric nerve which sends its recurrent branch forwards to the trachea & larynx over the anterior arches on each side. The large descending venae cavae cross their arches also in the same way. The importance of these last facts will shortly be noted.

From the arch of the Aorta Sprung two
innominate arteries which require separate notice.
The left innominate artery divides into three trunks
a carotid Trunk, a subclavian & an arteria
Collateralis colli. Figure No 15 from Rathke
indicates these parts but it is incorrect in as
much as it represents the subclavian & collateralis
colli arteries springing from the outer side of the
carotid trunk instead of from the inner
margin. Figure No 25 from a drawing
of my own represents these arteries in their
correct position as regards one another. I insist
upon this point on account of its importance
in the relative comparison of the arteries.
The left innominate artery then is continued
mainly into the carotid but gives off from its
inner side the left subclavian & collateralis colli
artery together.
The carotid artery (left) bends outwards &
forwards across the neck lying immediately
anterior to the left aortic arch. From the
dorsal extremity of this arch which
the base of the carotid artery makes as it
crosses the neck a well marked ligamentous

band passes backwards to join the dorsal portion of the left aortic arch. The band ~~so far as I know~~ has not been figured or described by Rathke; so it is probable that he did not know of its presence. It is shown in fig. 25 representing the arches of ~~Emydes~~ Crocodilus Niloticus. The base of this carotid artery along with this ligamentous band may be considered as completing the third arch in the Crocodilini. Compare with this figure the figures Nos. 24, 22, 7, 28 of the arches in Chamaeleo, Anura & Rana.

From the point where this band is given off the carotid artery passes forwards & to gain a position beneath the vertebral bodies & dorsal to the alimentary canal from whence it is continued upwards to the head. Its subsequent course will be traced when we have considered the corresponding artery of the right side. Rathke called this vessel the Superior Carotid but there is no reason why we should not call it the common carotid.

The carotid arch which I have just described is crossed by the pneumogastric nerve & the descending vein from the neck in the same way as the aortic & pulmonary arches behind it.

~~The~~ Leaving out of account for the time the other branches arising from the left innominate artery we will first consider the artery upon the right side corresponding to the carotid just described.

The right innominate artery passes forwards from the right aortic arch in the same way as the left & divides into its branches. According to Rathke's plate fig. XI. 15 the subclavian & collateralis colli arteries alone spring from this trunk but Rathke states from the text of his later works that he was aware that in many cases a right carotid artery arises also. This artery as directed by me in Proc. Roy. Soc. I will now describe.

The right carotid artery is a very slender trunk which forms the continuation of the right innominate artery after the subclavian & collateralis colli artery have been given off from its

inner side. It arches upwards on the neck embracing the trachea & oesophagus after the manner of the corresponding artery upon the left side & is connected dorsally with the right aortic arch in the same way as is the left carotid artery with the left aortic arch. The carotid arch thus formed on the right side of the neck is similar to that of the left side & is crossed in the same way by the pneumogastric nerve & descending vein.

From the point where this connection takes place with the right aortic arch, the right carotid is continued forwards reaching the dorsal surface of the alimentary canal underneath the bodies of the vertebrae. It then joins with the artery of the left side & the two are continued forwards & the head as a single median vessel.

The right carotid artery is frequently wanting & is always very slender. In most birds both carotid arteries are usually present & they embrace the alimentary canal in a similar way & pass forwards beneath

the vertebral bodies side by side without uniting; yet there are many cases in which they do unite as in bodies, & again there are cases among the birds in which the artery of the right side is much reduced in size & in some Birds it is absent altogether.

After the junction of the right & left brunks the carotid artery passes forwards on the neck underneath the bodies of the cervical vertebrae as far as the first or second. Here the artery divides again into its two component brunks the right & left carotids. A general description of one of these brunks will suffice as they are similar in all respects. The ~~right~~ artery ~~passes~~ is continued into an internal carotid artery but gives off before this a no. of brunks for the supply of the outside of the head, which the chief of which Wolff has named internal maxillary, infra maxillary, & temporal, the names indicating their courses.

~~The left artery, is similar, in similar in all respects.~~

The next branch to be considered is the

Arteria collateralis colli.

The arteries pass forwards upon both sides of the neck & divide into a large no. of branches as will be seen from figure No 15. They are intimately connected with the sub clavian arteries at their origin. The branches into which they divide pass into the muscles ~~of the anterior~~ & lateral parts of the neck both on the lateral & ventral aspect they extend as far upwards as the tongue where they anastomose with the supramaxillary branches of the carotid stem. Branches also pass to the trachea & oesophagus & to the glands of the neck.

The subclavian arteries arising from the inner sides of the innominate trunks pass forwards in the neck for some little distance internal to the carotids. They then pass outwards upon the ventral aspect of the carotid trunk passing to the arm. In arching over the neck they lie superficial or ventral to the pneumogastric nerve & jugular veins.

The most important branches which the Subclavian artery gives off in the neck are the internal mammary & vertebral There are not of sufficient importance to warrant a special description. Muscular branches are given to the breast & shoulder

In viewing the homologies of the great arteries of the Crocodilini a comparative glance at figs N° 7 & 8 representing the arches in the frog N° 24 ~~upon~~ the Chamaeleon & N° 25 the Crocodile is sufficient to show the marked similarities. In all, three arches are seen on both sides, the pulmonary the aortic & the carotid; The ~~difference~~ points of difference lie in the carotid arch In the very young frog the carotid arch passes backwards undiminished in size to join the aortic, in an older state the dorsal portion of this arch is much reduced, while in the adult the canal of this portion is obliterated

& the connection is by means of ligament only.

In the Lacertilian (Ameiva) the dorsal portion of the arch passes backwards as a large vessel & the aorta, in Hyrocephalus we have seen it much reduced in size, while in Chamaeleo it is almost obliterated. In the Crocodile the arch is still there but the dorsal portion of it is obliterated as a vessel & remains only as a ligamentous band.

What of the branches of the carotid arch?
In Rana it will be noticed that from the ventral portion of the arch a vessel arises, named external carotid in the diagram & from the dorsal portion of the arch a vessel named 'internal carotid'.
The first of these the so called 'external carotid' supplies the front of the neck & the tongue; it is the continuation of the ventral vessel or truncus arteriosus forwards. The 'internal carotid' supplies the head internally & externally; it is the continuation of the dorsal vessel ~~& aorta~~ which joins the roots of the branchial veins.

In Amiva hyrocephalus ~~Barnum~~ Chamaeleo we have still the same two vessels still supplying the same parts so that the homology is perfect.
In Crocodilus, putting aside the subclavian artery, which will be considered immediately, we have still the same two vessels still supplying the same parts; if there be a difference it is that the dorsal one is relatively a little larger than before while the ventral one is relatively a little smaller than before. Otherwise all is similar.
In the Crocodiles therefore the Arteria collateralis colli is the representative of the lingual or external carotid of amphibian & the continuation forwards of the dorsal vessel or truncus arteriosus. The external carotid artery of crocodiles (& of higher forms as we shall see afterwards) is a branch simply of the dorsal vessel or internal carotid artery & is ~~the same as~~ similar to that branches of the internal carotid artery ~~of Rana~~ in Rana Amiva & c

which supply the outside of the skull.

This is very different from the explanation which Rathke & his followers have given of the external carotid artery. They look upon the arteria collateralis colli simply as a branch of the subclavian & look upon the external carotid artery of the crocodiles & the higher forms as the continuation forwards beyond the third arch of the ventral vessel or truncus arteriosus. The error into which they have fallen is due to their attempting to explain the lower forms by the higher & not the higher from the lower. The arteria collateralis colli is branched off from the subclavian in mammals & birds, hence their looking upon it in the lower forms. The relation of the subclavian artery to the arteria collateralis colli in the higher forms must now be explained.

In all the groups lower in the scale than the Chelonians & Crocodilians the subclavian arteries arise from the roots of the aorta

on one or both sides or from the aorta itself
The followers of Rathke explain the change in the position in Chelonians Crocodiles & higher forms by supposing a shortening of the arch of the aorta to take place by which the root of the subclavian artery is drawn forwards upon the arch so as to reach & fuse with the carotid artery, an innominate artery ~~is~~ being thus produced.

That this is a mechanical impossibility is seen in the Crocodilia (& it will also be shown in Birds) where the subclavian artery lies ventral & superficial to the pneumogastric nerve & jugular vein (See fig 2) while all the arches lie dorsal to the nerve & the vein. Again in Crocodiles the subclavian artery arises from the inner side of the carotid stem & not from the other side as it would do were it the shortening of the arch of the aorta the cause of its displacement. ~~Other arguments might be urged but these are not needed~~.

The alteration in the position of the subclavian must be accounted for in some other way.

In an earlier part of this paper while engaged in the description of the blood vessels of the Saurian, the last group in which the Subclavian artery arises from the aortic root, I pointed out the very close relationship which the branches of the subclavian artery in the lower part of the neck bear to the branches of the first branch of the carotid arch — (the arteria collateralis colli - the longitudinal external carotid & amphibians). The branches of these two arteries supply the same muscles. An anastomosis takes place between them as is always the case between arterial branches in similar circumstances.

The change that takes place then, in the passage from the Saurian to the Crocodilian form is that the original root of the subclavian artery from the aortic root arch becomes obliterated while the blood passes to the trunk of the artery through the anastomoses, from the arteria collateralis colli. That is to say - the subclavian artery in the Crocodilia is said here to show in the [illegible] Band as arising as a branch of the ventral vertebral arteries. In this way its position ventral to the pneumogastric

nerve jugular vein & all the other arteries of the neck is explained. Fig. 26 is a diagrammatic exposition of my views of the arterial modifications in the Crocodilini it applies also to the Chelonians.

Birds.

In the course of my investigations into the vascular system of Birds I have dissected more than twenty different varieties. As many of the individual forms must be allowed & I gave the best time & attention to each I have necessarily paid attention. They comprise — Auk, Guillemot Herring Gull larger black backed Gull, lesser black backed gull, Roseate Tern, Cormorant, Duck, Muscovy duck, Eider duck, Goose, Swan, Heron Adjutant, Redshank, Oyster catcher, Common fowl, Game fowl, Peafowl, Pheasant, Guinea, Pigeon, Crow, Raven, Hole, Kestrel, Buzzard Owl, & Sparrowhawk.

From the heart of Birds two large trunks arise — the pulmonary artery & the aorta. The first springing from the right ventricle the second from the left ventricular chamber.

After its origin the ~~pulmonary artery~~ right ventricle the Pulmonary artery passes in front of the aorta & arriving at its left border passes by its side downwards for a short distance & divides into the right & left branches. The arch of pulmonary artery may be be easily dissected apart from one another down to their origins from the ventricle although they lie in close proximity but in many birds there can be noticed

a short fibrous cord (Heron) or a broad ~~triangle~~ form band of fibres (Swan) stretching from the left side of the aorta to the right side of the pulmonary artery just opposite to its place of division into right & left branches. This form fibrous connection stretching across the loose tissue which binds the two vessels together - is not found equally developed on all birds; I have seen it to ~~most~~ the best advantage in the two birds mentioned above but I have found traces of it in a large no. of cases. It has not, so far as I know, been described before.

The left branch of the pulmonary artery arches forwards & outwards & on reaching the lung divides into a no of branches. A short distance before these breaking up it gives off from its upper border a fibrous cord - the remains of its original connection with the aorta root. This cord continues the arch of the pulmonary artery, passes dorsal to the lung, is directed backwards above its root & finally joins the descending aorta immediately in front of the first of the coeliac arteries are given to the liver & stomach.

The relative development of this band varies very much in some cases, as the Heron it is very large & distinct in other cases it is traced only

with difficulty. In some cases I have noticed it double (Mason + Farrowhaugh) & in others I have traced a slender connection forwards for some distance in the neck. It is accordingly interesting as the remains of the fifth embryonic arch & will be returned to again at a later period. The pneumogastric nerve crosses below it & sends its recurrent branch forwards above it. The jugular vein also crosses beneath it.

The right pulmonary artery crosses outwards & to the right side passing dorsal to the aorta at its origin from the ventricle. Before dividing into its branches for the lung & whilst lying underneath the arch of the aorta it gives off from its upper border a fibrous cord, the remains of its connection with the aortic root, which passes to join the descending aorta. This cord is always described as being exceedingly short, but in most cases I have found it of some considerable length reaching down upon the aorta to within ~~an eight~~ eighth of an inch of the spot of junction with the corresponding cord of the opposite side. Round this cord close to its origin the recurrent branch of the pneumogastric nerve passes on its way forwards to the trachea & larynx

The aorta first arches forwards outwards
& to right backwards sinuosorbs over the right
bronchus. It arises from the left ventricle
& at its origin is placed above the pulmonary
artery. Close to its origin from its ascending
portion it gives off two trunks the right &
left innominate arteries. The right pneumogastric
nerve & phrenic cross beneath & superficial
to the arch of the aorta

The left innominate artery the first branch
of the aorta passes forwards to the left without
giving off any branches until it ends by dividing
into the carotid & subclavian arteries on the left side.

The right innominate artery arises from the arch
of the aorta so close to the left that they almost
seem to spring off by one trunk. This artery
likewise divides into a carotid & subclavian
but gives off no other branches. Before leaving
the innominate trunks it must be mentioned
that Gegenbauer, Macalister & Henderson mention
that in connection with the left innominate
artery, a ligamentous band or cord is to be
noticed in some cases. The cord arising as
mentioned is said to pass backwards to the

Aorta. I have not seen such a cord in any of the birds which I have dissected nor have I been able to find anywhere any detailed description of its course & connections. I wrote to Prof Macalister some time ago asking if ~~there~~ a detailed description of this cord had ever been made & received ~~a letter~~ in reply ~~stating~~ a statement that he knew of none. but He mentioned that he himself had noticed the cord in the White Eagle & in one or two other specimens of the Larger Raptores. I have not been fortunate enough since the receipt of this reply to obtain a specimen for dissection of any of the birds ~~he~~ mentioned, ~~[illegible]~~.. (I have commonly found the left innominate artery a little longer than the right.) The common carotid arteries in birds, leaving the innominates thus arch upwards & forwards for some little distance embracing the trachea & oesophagus. Having gained the dorsal aspect of the alimentary canal the carotids ~~change their~~ continuing their arch pass forwards & inwards underneath the vertebrae of the neck approaching one another, until at last lying side by side they reach the middle line of the neck. They are then continued forwards.

in a bony canal formed by the hypapophyses (Owen) of the cervical vertebrae & do not separate from one another until they have reached a point distant about the breadth of three or four vertebrae from the head.

The calibre of the two arteries is usually the same but occasionally one or other is smaller In the Dabchick the left is the larger of the two (Owen) In the Apteryx (Owen) the right artery is obliterated altogether There is but one vessel passing forwards to the head dividing finally however into the branches of both.

This is a fact of matters recalling to mind the normal anatomy of the Crocodile. Very frequently the two carotids fuse into a single trunk when they have gained the bony canal in which they pass forwards, or they may remain distinct but be joined by a transverse anastomosis (Eichwald) just before entering the canal.

I have found in the Ringed Guillemot a very strong vessel passing from the right carotid backwards to the ~~arch of the aortic bulb~~ aorta joining that vessel just beyond the arch.

This vessel of which fig Nº 28 is a photograph

is undoubtedly the remains of a communication between the right carotid artery & the arch of the aorta & it seems probable to mind the dorsal portion of the carotid arch has been in frogs Nos 25, 24, 7 & 8 of the crocodile, the chamaeleon, & the frog. In this case (see the photograph) the carotid artery was bent backwards more than usual towards the aorta, the bending in this particular case doubtless being due to the fact that the cord has been sufficiently strong to withstand rupture. Since noticing this cord I have been able in many cases to notice a slender thread of connection passing between the two vessels & occupying a similar place The conclusion to which I have returned again that a cord of connection exists in birds between these two arteries but that it is usually ruptured owing to the rapid growth of the neck

Before it passes to the dorsal aspect of the oesophagus where the branch and ganglion of the common carotid gives origin to a N. depressor

One of these branches runs forwards on the lateral aspect of the neck supplying a set of branches to the cervical glands upon the side of the trachea & being continued forwards beyond that to be distributed to the trachea oesophagus & to the skin & subcutaneous ~~structures~~ parts of the neck. This branch I take to be homologous to the external collateralis colli of Meckel

Another & smaller branch passes backwards under the pneumogastric nerve towards the lungs.

The most important branch however which the carotid, close to its origin, gives off is the vertebral

The vertebral artery after its origin from the carotid takes a letter S curve, backwards outwards forwards inwards upwards & disappears among the muscles of the lateral part of the neck. It is found to enter the canal in the transverse processes of the cervical vertebrae & to proceed forwards towards the head giving off many branches as it goes Arrived at the

upper end of the back however it does not enter the cranium but terminates by anastomosing with a branch of the external carotid

The common carotid artery furnishes numerous smaller branches as they pass forwards in company towards the head. After separating each is directed towards its own side of the head & divides into numerous branches. On the naming of these arteries Owen has been followed

The first a branch going downwards &, entering the foramen in the transverse process of the second vertebra & so anastomosing with the vertebral is called "occipital."

The second entering the cranium for the supply of the brain & other parts is named 'encephalic'

The other branches given off in succession are the 'oesophageal', external mandibular, the 'posterior palatine' the 'lingual', & the external maxillary

It is to be noticed then that the arteries which supply the cranium proceed in two

middle one of the arch terminates by dividing into a bunch of vessels destined for the supply of the head external & internally

The subclavian arteries arise from the central aspect of the innominate trunks & pass forwards outwards with a bend & terminate by dividing into the pectoral & humeral arteries the first named of these being the larger of the two. In this course across the ribs the subclavian artery lies superficial to & internal to the pneumogastric nerve & jugular vein. This it will be remembered is the state of matters on the opposite side

The branches arising from the trunk of the artery are the coracoid & internal mammary arteries

The above may be taken as a general description of the arteries to be found in the neck of birds. The explanation which Rathke has given of these arteries has been already described

9 is represented in figure N° 11.

So far as I have been able to discover only one observer since the date of Rathke has disagreed his views or has replaced them by others

Sabatier Robin & Pf being struck with the similarity between the arrangement of the arteries in the Bird Fish & the Crocodile pointed out that the two systems were identical with one exception - that the left aortic arch of the Crocodile was absent in the Bird. I record on therefore believe that the left subclavian artery of Birds represented the fourth left arch but looked upon it rather as homologous with the left subclavian of Crocodiles.

In his Scheme which are represented in fig N° 13 for the crocodile & figure N° 14 for the bird he makes the subclavian arteries of both sides arise as branches from the dorsal end of the third or carotid arches, a supposition which I hope to be able shortly to be as unfortunate as that of Rathke. It will be noticed by comparing the last two last mentioned

figures with figure 9 of that this was the origin assigned by Barr to the subclavian arteries, a supposition to which Ballance and in his criticism of Barr's views by saying that arising in this situation they should be branches of the internal carotid artery. While agreeing with Ballance in condemning the views of Barr & in opposing the views of Sabatier it is not however for the same reasons as those which Ballance urges

Ballance opposes the right bronchial artery as a branch of the aorta or aortic cord; by the shortening of the fore-trunk. The vessel is supposed to be approximated to the carotids specially to give birth to have as often an innominate artery.

The left subclavian is supposed to be the fourth left aortic corresponding to the arch of the aorta.

Under this scheme the innominate arteries which from their origin direction & branches are similar to those of Dr Dobson are not like them symmetrical structures but are formed on different ways.

The left innominate artery, which represents the distance the fourth left arch is placed in front of the fourth right arch. The right innominate artery on the other hand simply represents the extent of fusion of two arteries supposed to arise at a considerable distance from one another. If this were so we should expect to find the carotid shorter than the right or to find branches of the left carotid appearing from the common innominate stem upon the left, or at least nearer to the place of division of the innominate artery into its branches upon the right side; but this is not the case.

Again if shortening of the arch of the aorta had taken place by which the subclavian & carotid trunks were approximated we should expect to find the fibrous cords which pass to the aorta — the remains of the embryonic vessels — passing to that artery at a higher place than usual. We have those such cords passing to the aorta & act as landmarks. The first passes to the aorta just below the arch coming from the carotid artery & is the cord described by me in the guillemot.

The second the next ductus arteriosus

down backwards for some distance along the side of the aorta before it joins it, which it does close to the spot of junction of the left ductus arteriosus. The left ductus art. joins the artery just in front of the first large visceral artery. These are the places where all these vessels enter in the embryo & also the place at which they join in the lower forms where they are retained. No evidence of a ~~contraction of~~ shortening of the aorta is to be obtained from them; rather indeed they point to an opposite conclusion.

Again it is perfectly impossible that an artery originally arising from the aorta at whose place of origin was altered by a shortening of the parent trunk could have such different relations to surrounding parts as it the case between the aorta & right Subclavian artery. In every bird which I have dissected the pneumogastric nerve crosses below, or superficial to, the arch of the aorta & its recurrent branch turns round that

vessel while on the other hand in every case the Subclavian artery lies below or superficial to the pneumogastric nerve & its recurrent branch Even although the Subclavian artery arise from a ~~point~~ portion the median aorta & passed outwards ~~towards~~ towards superficial to the nerve it could not possibly have an origin internal to the recurrent laryngeal nerve

The jugular vein has the same relations to both arteries as the nerve has & it is also a mechanical impossibility that this could be the case were the Subclavian artery to arise as Rathke has said.

The Subclavian artery of the left side has the same relations to the ~~great vessels~~ pneumogastric nerve & jugular vein as has the subclavian of the right side. That is to say, according to the system of Rathke, that the fourth arch left has different relations to the surrounding structures to that of the fourth arch right. It may safely be said that in no other case can it be shown that any

of the arches of one side lie in a plane either ventral or dorsal to those of the other side of the body.

I think supposition has been said to indicate that the origin ascribed by Burne to the subclavian artery on birds is not in accordance with facts. The only piece of evidence that Rose adduces in its favour is the cord which Macalister has said he has seen proceeding from the brachiocephalic trunk to the aorta. ("The fourth left arch forms the subclavian artery, sometimes Automorphic is continued by a ligament into the descending aorta" Macalister) I have been able to find no details of this cord. If it springs from the subclavian artery, which is very much doubt, it may be due to remains of an anastomosis between the true subclavian from the innominate & the original portion of the subclavian from the arch of the aorta. (See in connection my remarks upon the subclavian of

Crocodiles) If it springs from the innominate artery it may be the remains of the fourth arch but in that case it would form no proof of Rathke's theory that the Subclavian artery represents that arch.

Both reasons & the other theory of the subclavian artery that put forward first by Baer & afterwards adopted by Sabatier many of the same objections hold good.
The third arch as we have seen in Crocodiles & other forms is dorsal to the pneumatic nerve & jugular vein. The post origin position & course of the artery in Crocodiles also precludes this belief — & it is to be noted that it is upon the resemblance of Birds to Crocodiles that Sabatier founds his theory.

~~Turning now to the~~ As an additional proof of my assertion that neither the one nor the other theory expresses the facts I may mention a peculiar case of abnormal arteries which I noticed in a chick of twelve days

dissection. The left innominate artery was much smaller than is usual that time & than its neighbor of the opposite side. It ended entirely in the subclavian artery. On pursuing the dissection further I found that the left carotid artery was not wanting and at first had surmised but passed towards on the neck arising from the left pulmonary artery. There was a clear obstruction of the third arch & the blood had reached the carotid through the dorsal vessel instead of through the ~~aortic~~ ventral vessel. Instead of coming from the subclavian, as supposed towards arch the artery arose from the pulmonary as supposed fifth arch. Had the subclavian really represented an arch the dorsal vessel which remained patent as carotid artery should have come from it. By the theory of Sabatier the abnormality is utterly inexplicable. This interesting abnormality gives another point of reference will again be made to it when that point is under discussion.

In dissections made of chicks on the sixth day of incubation I have invariably found the subclavian arteries arising as branches from the top of the innominate stem. At this period the anterior limb is exceedingly small the subclavian arteries which supply it with blood are exceedingly fine vessels. During the third day of incubation I have not been able to find any trace of a subclavian artery but it may be noticed that the truncus arteriosus is prolonged ventrally for a very small distance as an exceedingly minute vessel from the ventral extremity of the third arch. At the same time the third arch & its dorsal continuation may easily be seen as a very large vessel passing up to the head.

Turning now to the relative positions of the common, external, & internal carotid arteries the state of matters in birds will be found to resemble very closely that noticed already in the Crocodilia.

According to the theory of Rathke the common carotid artery represents the truncus arteriosus & ventral vessel stretching

between the fourth & third arches, the external carotid artery is supposed to be the metamerism of that vessel still further forwards while the external carotid artery represents the third arch & its dorsal prolongation

I pointed out in my comparison of the Saurian & Crocodilian forms that the third arch which was most distinctly represented in the typical Saurian, — Amiura fig. 22) with less distinctness in Hyperoodon fig 23 & Chamaeleo fig 24 was also to be made out in the Crocodile fig. (25) In all these cases the common carotid artery formed the dorsal prolongation of the third arch & divided on reaching the head into branches for the supply both of internal & external parts.

The distribution of the common carotid in Birds is exactly similar to that of the same artery in Crocodilia & the similarity of the two forms is strengthened by my discovery of a cord of connection stretching between the ~~pulmonary~~ common carotid artery of the right side & the aorta. See fig h° 28

been if the case that the internal carotid artery represented the third aortic arch vessel and should have extended from that vessel to the aorta & not from the common carotid artery near its base. I have noticed ~~that this~~ Cord in many cases beside the gastrosmot but in none was it so strong or so distinct (Sparrow hawk) ardea Stenia &c.) On the left side I have noticed in many cases a very slender thread passing from the left pulmonary artery towards the left carotid but never with such distinction as in the case mentioned of that of the right side (Goose, Turkey Cormorant &c)

The inevitable conclusion to be drawn from all these facts seems to me to be that the common carotid arteries in their basal portion represent the third arches & in their more distal portion the dorsal vessel uniting the extremities of the arches. — That the so called common carotids of the Crocodile & many birds in fact represent an anterior aorta. On the same manner as the aorta terminates towards the hinder extremities by dividing into

ventral parietal branches as the carotid arteries terminate by division into ~~the~~ external & internal arteries.

The subclavian arteries in Birds as in reptiles & Rodentia I take to arise as branches from the ~~anterior~~ ventral truncus arteriosus. Their origin having been transferred from the aorta to this spot by means of anastomoses (see Rabl) between their branches & the branches of that bunch of arteries which in the earlier forms arises from the truncus arteriosus for the supply of the ventral & lateral aspects of the neck viz. the ext. carotid, occipital, & the prog. lingual hyoid & of hyoids & Arteria collaterales colli of Crocodiles.

The fourth left arch disappears but a thick trace may be found of its lower & connections. It seems to me that this arch at a very early period becomes incorporated with the fifth left arch just as in the amphibia we find all grades of fusion of contiguous arches (see figs. (6, 7, 8, 18, 19)

My reasons for this belief are as follows —

~~Yet~~ First, the left ductus arteriosus I have found to be in almost all cases

a thicker & stronger muscular than the right (swan & most other birds). I have commonly found a double (Heron Turkey Goose Cormorant Sparrowhawk &c) & I have noticed from the anterior & inner edge a slender process longitudinally upwards the common carotid (Cormorant Secondly in the swan Heron Cormorant, Buzzard & in other birds I have found a fibrous cord stretching between the base of the aorta & the base of the pulmonary artery The fibrous cord could in many cases be distinctly traced from the pericardium the aorta & the ventral aspect of the pulmonary artery running towards its left branch Thirdly in a chick of twelve days incubation I noticed the left common carotid artery arising from the left pulmonary artery. The only possible explanation of this is that the thoracic had become occluded about its middle & that the dorsal connection between the third & fourth arches had taken up the circulation.

With reference to the other arches in the Bird I agree with Rathke's scheme

In the Man Mammalia, the vascular system which I need not describe since it is pretty well known, I believe that as in Birds the common carotid arteries meet the external carotids opposite the third arches. The continuation beyond the third arch of the ventral aorta becomes obliterated which in the former groups we have been examining has been becoming of less & less importance has at length disappeared. The subclavian arteries have consequently reverted to their original position upon the dorsal aorta. The comparatively small size of the ductus arteriosus of Mammals as compared with that of Birds seems to me to indicate that the area of the aorta has undergone considerable lessening by means of which the left subclavian artery has been brought to the summit of the arch. The right subclavian corresponds to the fourth right arch.

The only difference which I would introduce into the mammalian scheme is the

alterations of the adult portions of the
Common Internal & External Carotid arteries.

In conclusion I will say the last few lines
~~of this paper~~ to give a general account of
the system of vascular arches as interpreted in
the position which I have tried to prove.

In the embryos of all mammals higher than
Amphibians five vascular arches are found.
These arches arise from a trunk which
is prolonged forwards from the heart to
form the truncus arteriosus. The arches
pass round the respiratory & alimentary canals
into two dorsal vessels which pass forwards
& backwards having a tendency to fuse with
one another at either extremity into a single median
vessel from which the arteries of the body go off as branches.
The fifth arches in all cases are devoted to the
formation of the pulmonary arteries. In
most cases both arches persist for this purpose
but in some cases one only. In mammals the
right fifth arch disappears. In Ophidians
the left is lost.

The fourth arches are called the Aortae. The current of blood passing through these arches passes when it has reached the dorsal vessels backwards towards the tail. They commonly fuse with one another into single median vessel so produced is called the 'dorsal aorta'. In Reptiles both arches persist. In Birds the left arch disappears the right is lost.

The third arches are called the carotid arches. The blood which passes through these arches on reaching the dorsal vessels takes a forward direction towards the head. The two dorsal vessels prolonged forwards from the arch sometimes fuse with one another, (Crocodiles) at other times they lie side by side without fusing often being joined by a transverse anastomotic branch (many birds) ~~They~~ ~~At other t~~ In other cases they are separated from one another by a considerable interval. The relative length of the neck as compared with the body seems to have some influence upon the fusion of these vessels.

The dorsal vessels between the anterior & posterior systems remain patent in many of the lower

forms. As we pass up the scale however we find these connections becoming fewer & fewer. In Crocodiles they are represented by imperforate cords. In some Birds this is likewise the case but in most Birds & Mammals even these have disappeared.

The first second arches disappear playing no part in the circulation of the adult form.

The truncus arteriosus in front of the third arch gives rise to a set of vessels, large & of importance in the lower forms but becoming of less importance in the higher, finally disappearing in the Mammalia

The arteries arising from this spot supply the ventral & lateral aspects of the neck extending upwards to the tongue & outwards to the shoulder. In Birds & Crocodiles however the subclavian arteries arise here.

The internal carotid or lingual of the frog the lingual hyoid of the lizard the arteria collateralis colli of the Crocodile & the carotid arteries of Birds spring from from these vessels

The subclavian arteries in all the types below Crocodile arise from the aorta. Their most typical branches are the vertebral internal mammary arteries. It is to be noticed that in Saurians one of the Saurians while the subclavian artery arises from the arch of the aorta, the internal mammary an artery which is always associated with it in other cases, springs from the ventral end of the carotid arch from there it ends already mentioned arising from the portion of the truncus arteriosus. A fact which seems to foreshadow what is going to happen in the next group viz the origin of the whole subclavian artery from that point.

This change probably arises by means of an anastomosis between the branches of the subclavian supplying the muscles of the shoulder & those of the truncus arteriosus In Birds the vertebral artery is removed from the subclavian & the ventral portion of the carotid arch.

In Mammals the Subclavian artery assumes its original situation.

Figures 26, 27, 28 represent my views of the transformation of the Aortic arches in Crocodiles & Birds.

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Illustrations

Figures

Nos 1 & 24 inclusive representing the general subject are copies

Nos 25 & 28 inclusive are original & represent the writers views or are put forward as illustrations & proofs

Mammal.

(Baer.)

Fig. I

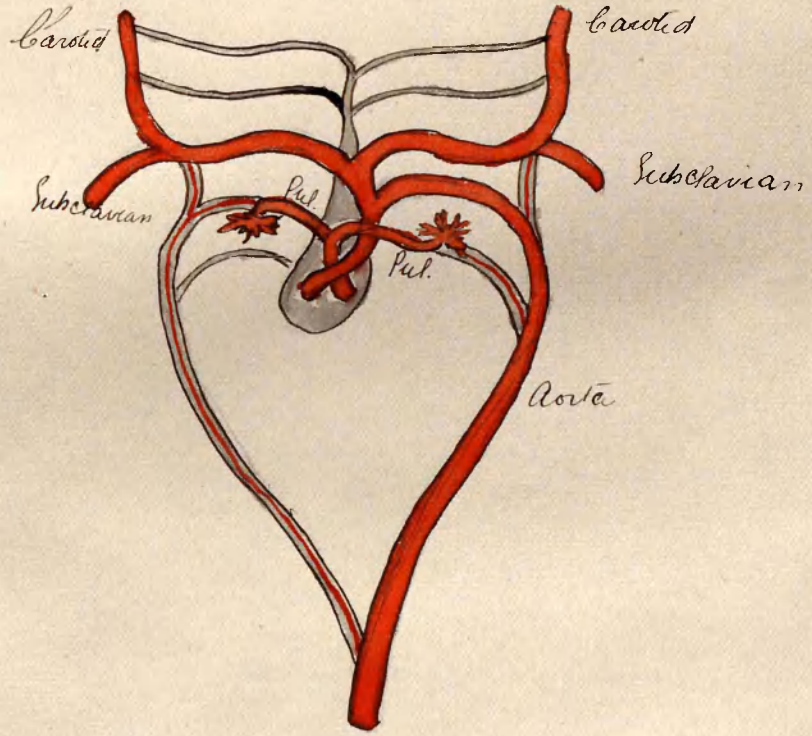
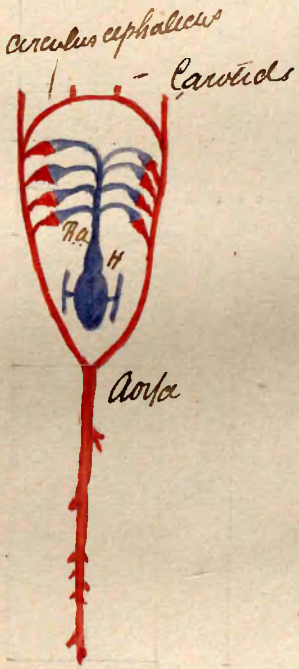


Fig. II

Fig. h

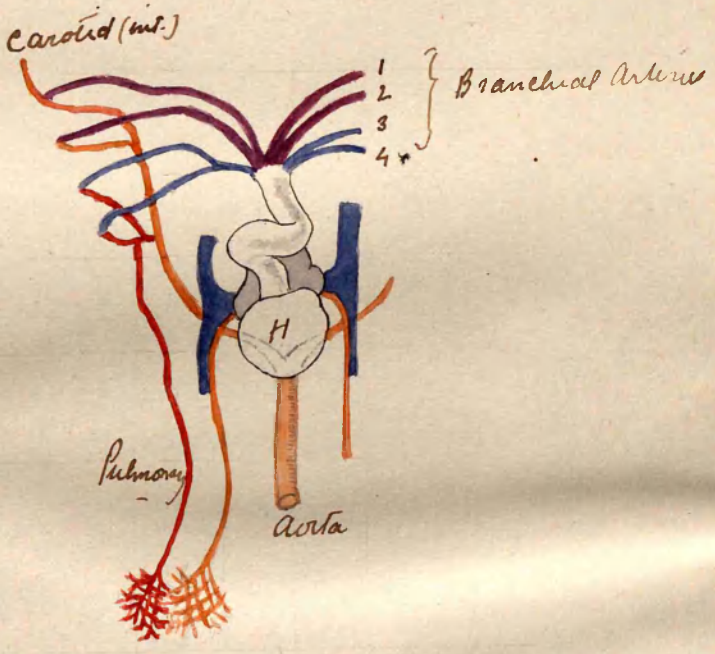
(Neudörfchen)



Ceratodus

(Wiedersheim)

Fig III



Salamandra
(Boas)

Fig. 5

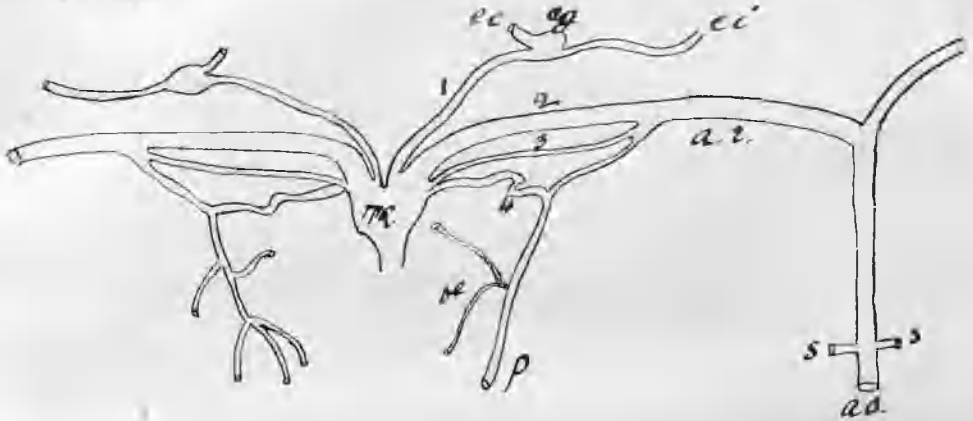
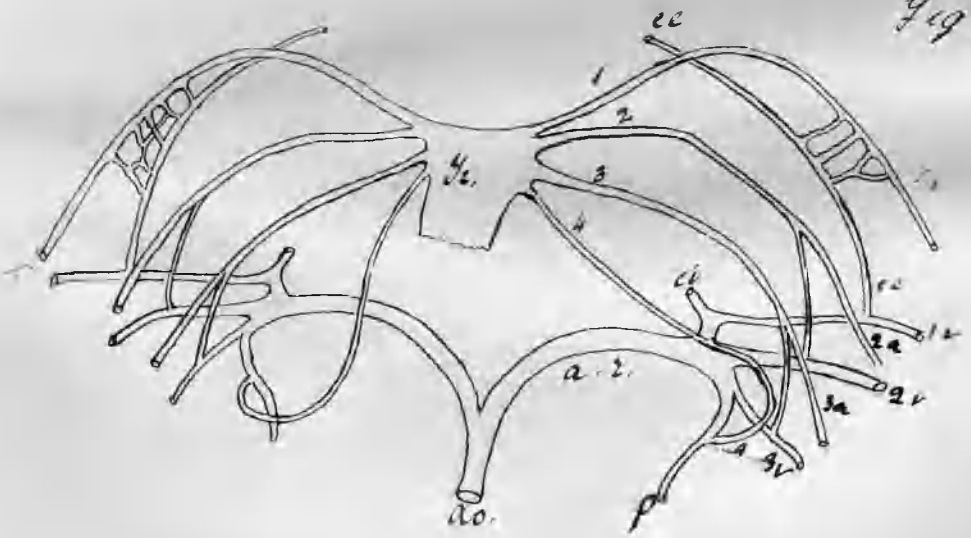


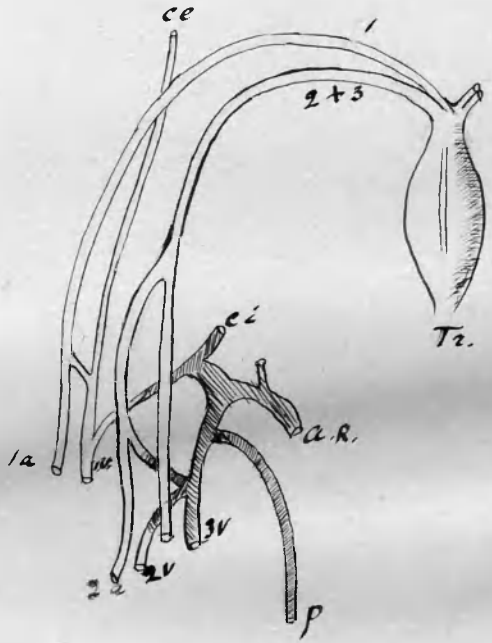
Fig 4



Proteus

(Boas)

Fig. 6



Rana

(Boas)

Fig. 7

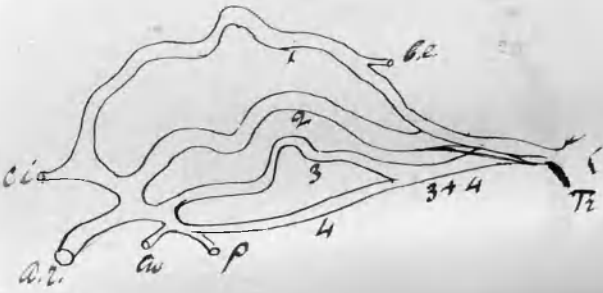


Fig 6

(Rathke)

Fig 9

Lizard
Snake

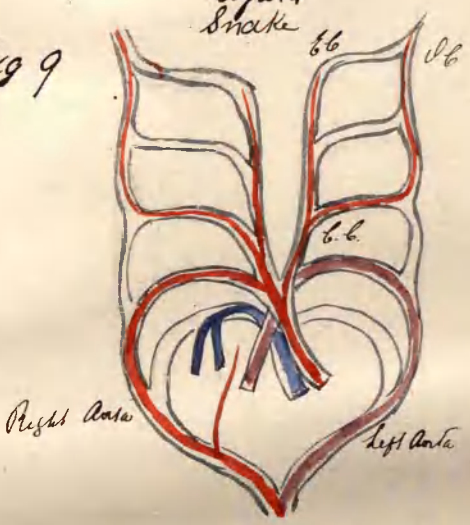


Fig 10

Lizard

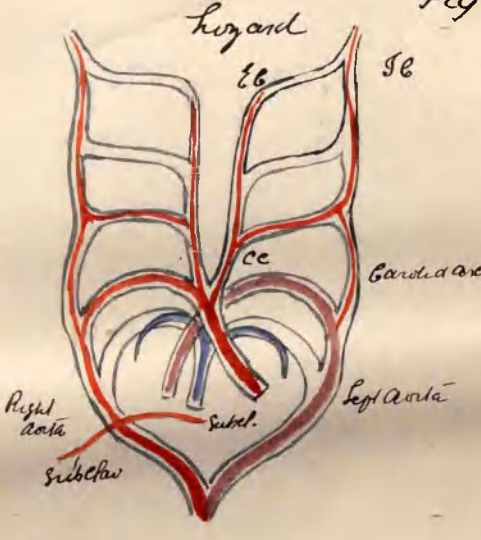
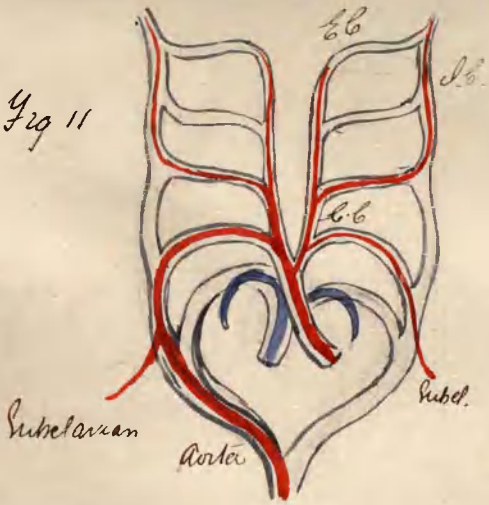
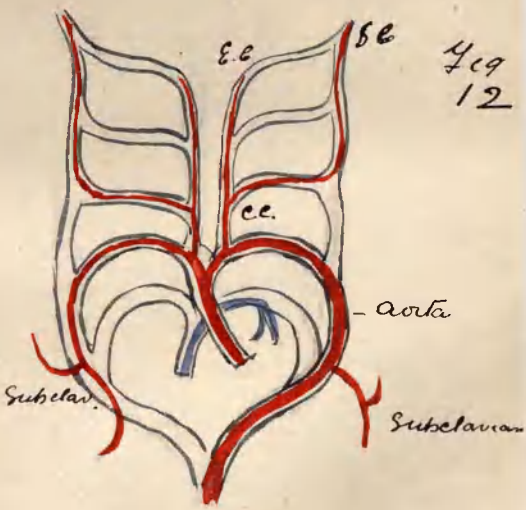


Fig 11



Bird

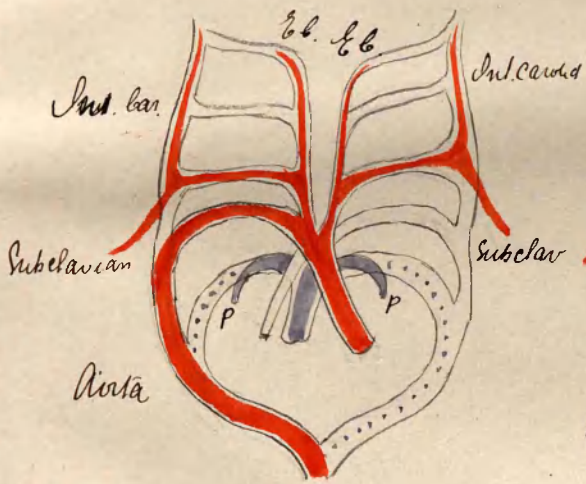
Fig 12



Mammal

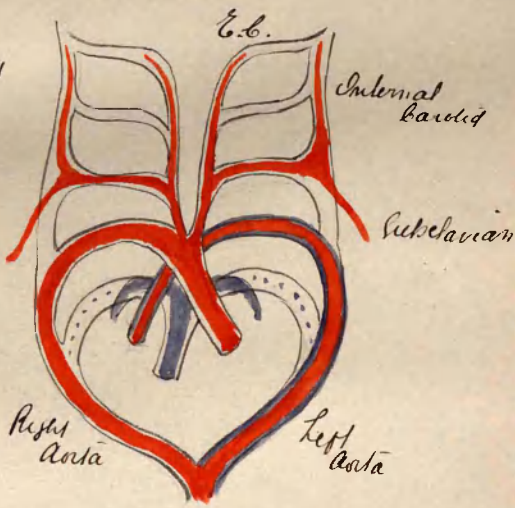
Sabatier

14



Bird

13

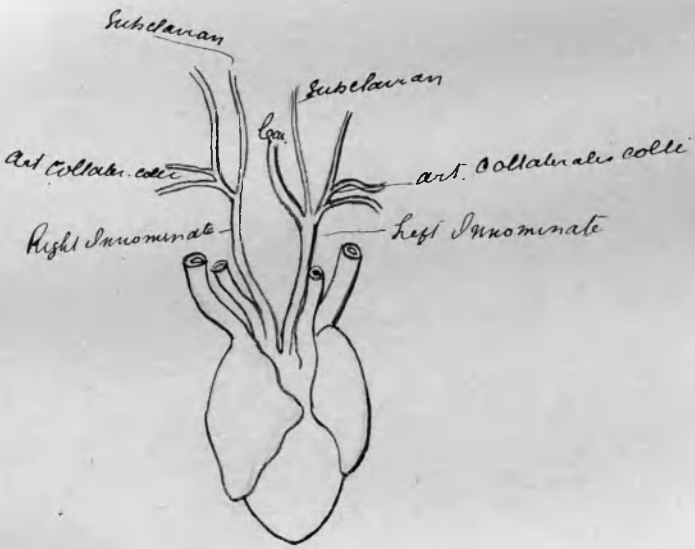


Crocodile

Heart of Crocodile

(Wiedersheim)

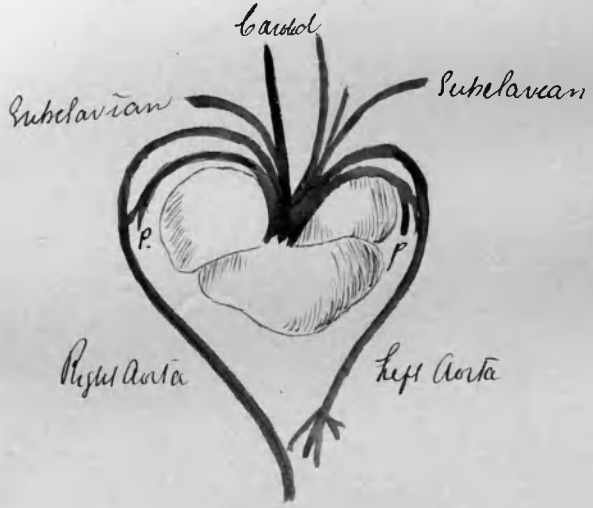
15



Heart of Chelonian

(Gegenbaur)

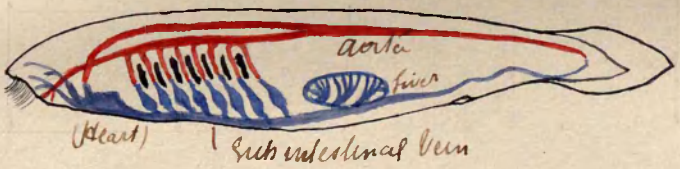
16



Amphioxus

(Lucidasheim)

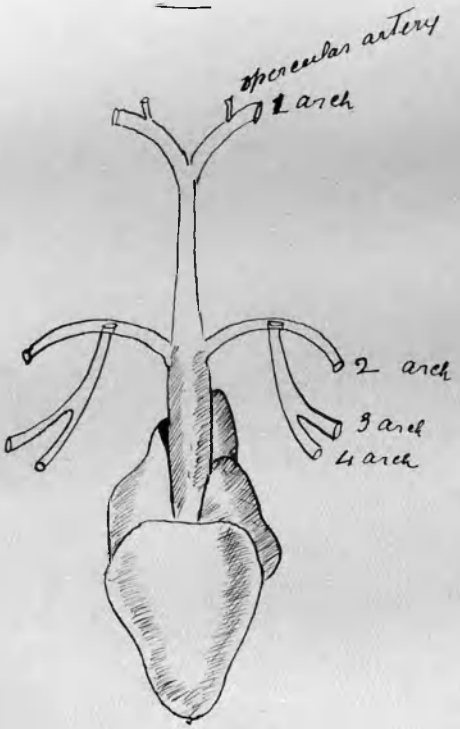
17



Polypterus

(Boas)

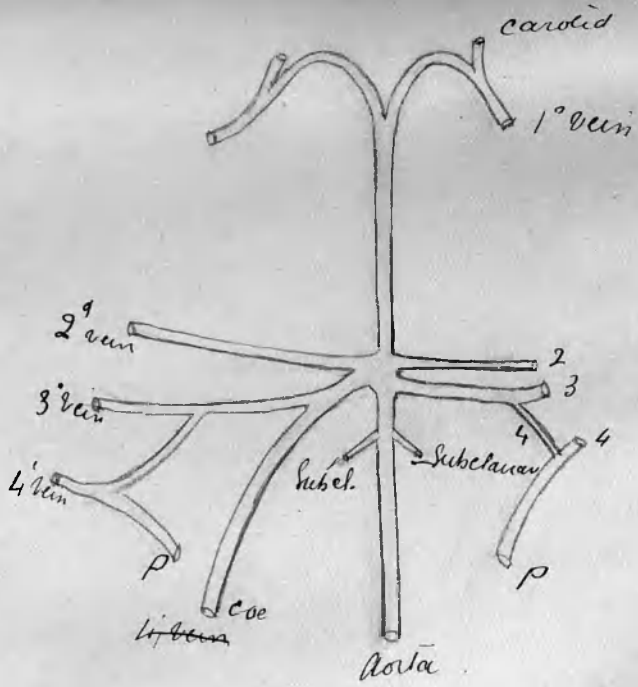
18a



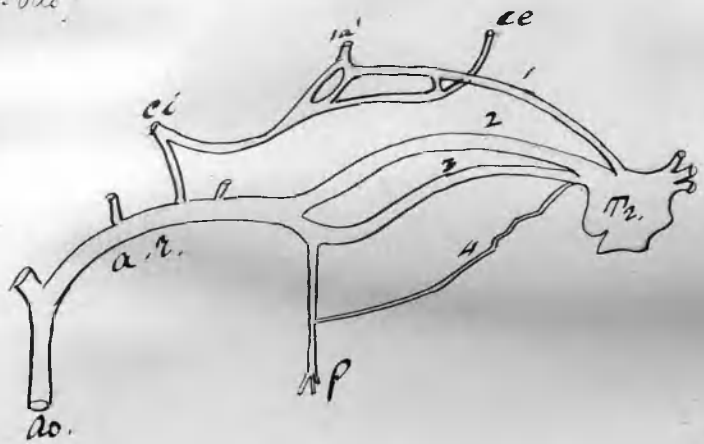
Polyptera

(Boas)

19 a



Menopoma
(Boas)



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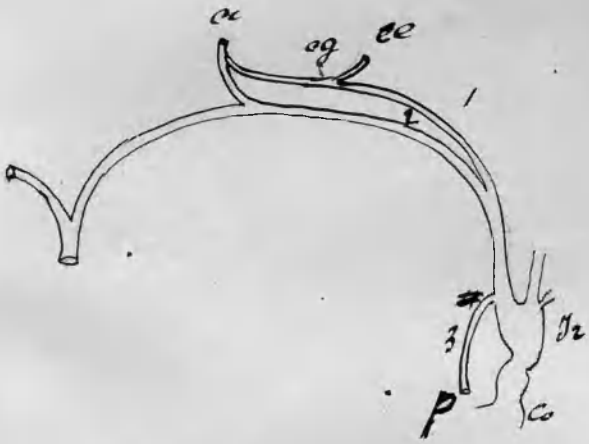
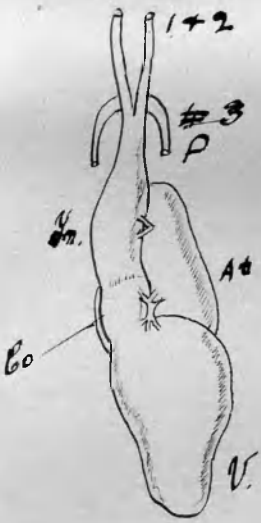


19

Amphiuma
(Boas)

Coccinia

(Boes)



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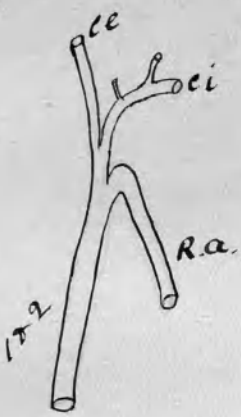

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Ameiva vulgaris

—

Baltikc

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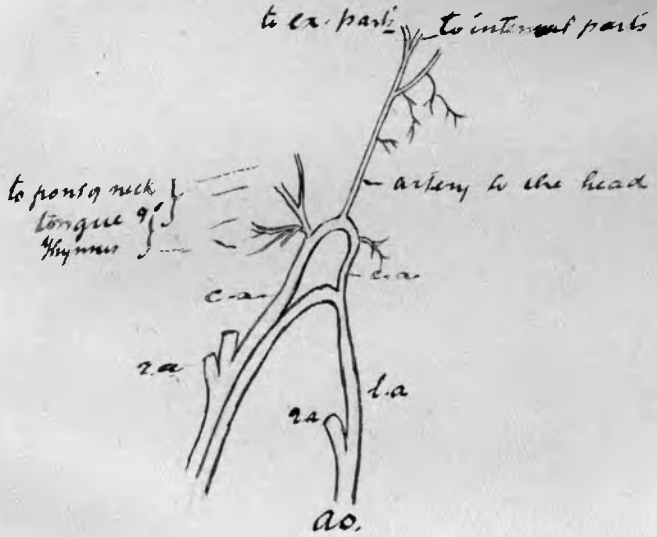
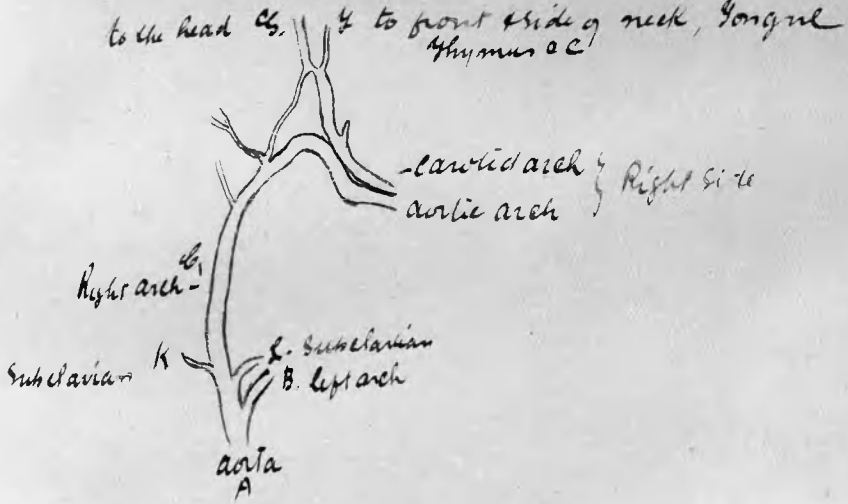
22



Hyriocephalus Margaritaceus

(Ralphke)

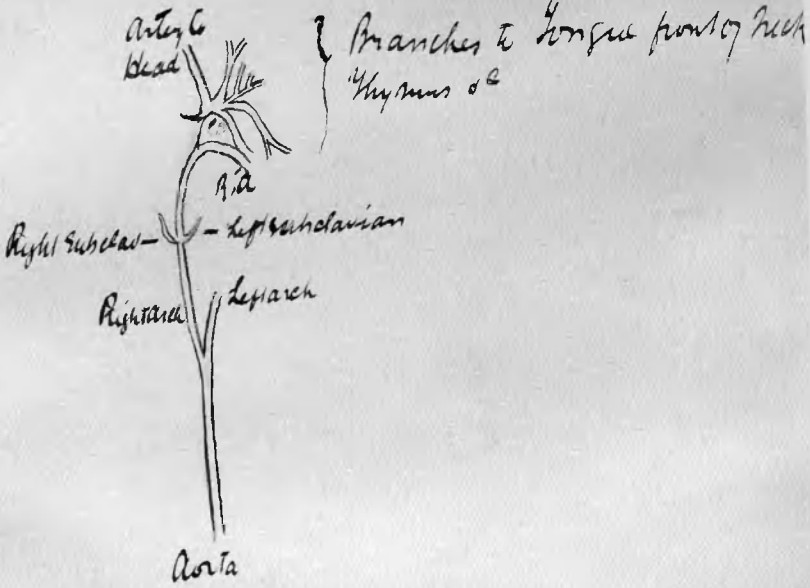
23



Chamaeleo planiceps

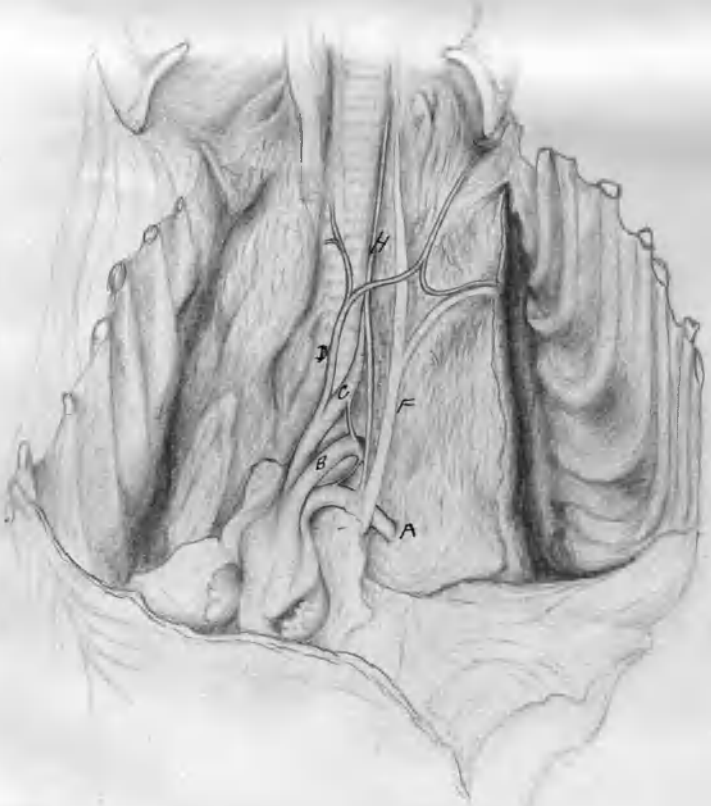
(Rathke)

24



25

Drawn for the Writer by R. B Young. MB.



Arterial Arches of the left Side of Crocodilus Biloricus

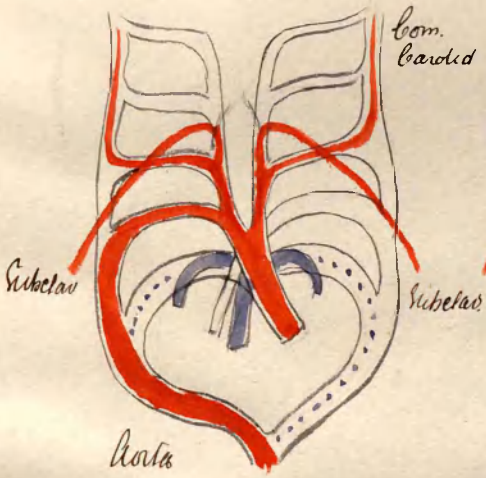
A. A pulmonary artery
B Aortic arch
C. carotid arch
D Subclavian arch

Cordo ~~Ligamentum~~ completing the pulmonary & carotid arches stretch between A & B & C & B

F. Jugular Vein
H Pneumogastric nerve

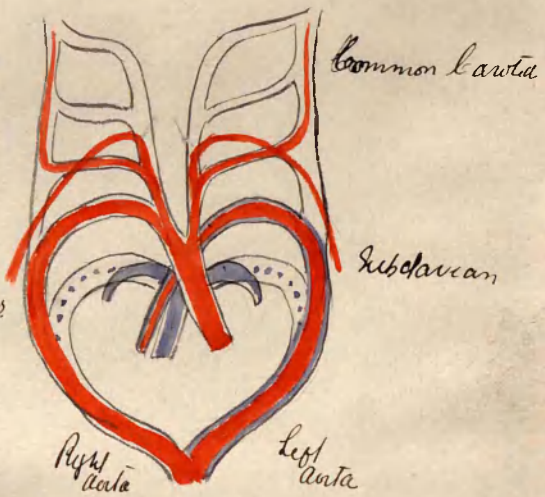
June 1883.

27



Bird

26



Crocodile

Fig. 28

Representing the viscera of a Ringed Guillemot seen from the dorsal aspect

The upper piece of paper is placed under the right carotid artery & shows a cord connecting it with the descending aorta. The lower piece of paper is under the left ductus arteriosus