MEMOIRS OF THE COLLEGE OF SCIENCE, KYOTO IMPERIAL UNIVERSITY, SERIES B,
VOL. XIV, No. 2, ART. 7, 1938.

Studies on Some Specimens of Double Monsters of Snakes and Tortoises*

By

Kenji NAKAMURA

(Institute of Zoology, Kyoto Imperial University)

With Plates III, IV and 16 Text-figures

(Received November 15, 1937)

Contents

Introduction

Previous works dealing with the duplicity in reptiles are by no means scarce. Especially in snakes, such cases are rather many. In other groups, however, they are comparatively rare. In lizards, we have only a few reports, namely, GEOFFROY ST. HILAIRE 1838 (cited by BATESON 1894), HENNING 1869, WILLIS 1931-32, excluding the cases of double or triple tail formation by regeneration after injury.

* This being a part of "Studies on Twins and Double Monsters found in Vertebrates" carried out in the Institute of Zoology, Kyoto Imperial University by T. KOMAI, K. NAKAMURA and M. TOKUDA, the authors are grateful to the Department of Education of the Government for financial help given to their works.

The types of duplicity found in reptiles may be classified as follows:

Snakes

I. Teratopagus: Complete but conjoint twins with the axial skeletons fused partially
   1. Craniopagus: Fusion by cranium
   2. Cephaloderopagus: Fusion by cranium and cervical vertebrae
   3. Anakatamesodidymus: Separated at the anterior and posterior ends and also in the middle of the trunk

II. Teratodymus: An individual with a part of body doubled
   Duplicitas anterior: Axial skeleton bifurcated anteriorly
   1. Rhinodymus: Double-nosed
   2. Opodymus: Cranium bifurcated, mostly three-eyed
   3. Derodymus: Vertebral column bifurcated in the cervical region, double-headed

Lizards

I. Teratopagus, with axial skeletons fused partially
   Craniopagus

II. Teratodymus
   Duplicitas anterior
   Derodymus

Tortoises

I. Teratopagus, with independent axial skeletons
   Pygopagus: Pelvis fused

II. Teratodymus
   1. Derodymus
   2. Thoracodymus: Vertebral column bifurcated in the thoracic region
   3. Psodymus: Vertebral column bifurcated near the sacrum.

Nearly one hundred cases of these kinds of monstrosities have been reported hitherto. Of these only nine were dissected: double-headed snakes, by REDI (1684), VSEVOLOJSKY (1812), DUTROCHET (1829), DORNER (1873), BORGERT (1896), CANTONI (1912), STROHL (1925) and HEASMAN (1933), and a double tortoise by KUWANO (1902).

The present paper deals with the dissection of six snake and two tortoise duplicated monstrosities. Of these one snake specimen is of a very rare type, namely, a craniopagus, and this is the first record of the dissection of a teratopagus found in this group.

I wish to express my cordial thanks to Professor Taku KOMAI for his kind suggestion and criticism throughout the work. My thanks are also due to the gentlemen who have submitted the valuable materials to our disposal.

Materials

The materials employed in the present work belong to the following species:

Snakes
- Crotalidae
  - *Agkistrodon halys blomhoffii* (BOIE)
- Elaphidae
  - *Hemibungarus japonicus* (GUENTHER)
- Colubridae
  - *Elaphe climacophora* (BOIE)
  - *E. conspicillata* (BOIE)
  - *Natrix tigrina* (BOIE)
  - *N. vivakari* (BOIE)

Tortoises
- Testudinidae
  - *Geoclemys reevesii* (GRAY) . . . . . A derodymous specimen
  - ,, ,, ,, ... A psodymous specimen

In some of these materials precise observation was difficult, as they had been kept in poor preservation for years. But some specimens reached us shortly after their death, and was in better condition.

The Specimens of Double Monsters of Snakes

In his review of the records of duplicity in snakes, STROHL (1925) mentioned 84 cases. To this HEASMAN (1933) added 12 cases more recently. To his list, the following cases are to be added, apart from the seven cases belonging to four genera and six species to be described in the present paper.

Agkistrodon halys blomhoffii, 3 specimens (YOSHINAGA, 1901, INUKAI, 1929);

Elaphe dufodorsata, 1 specimen (KURODA, 1928);

Heterodon almadensis, 1 specimen (CUNNINGHAM, 1927);

Opheodrys aestiva, 1 specimen (GATES, 1929);

Liophis almadensis, 1 specimen (VELLARD et PENTEADO 1931).

Though the cases of such monstrosities are distributed in various groups, we find that they tend to occur more frequently in some particular genera or species than others. For instance, in Japanese publications there are ten authentic cases of duplicity

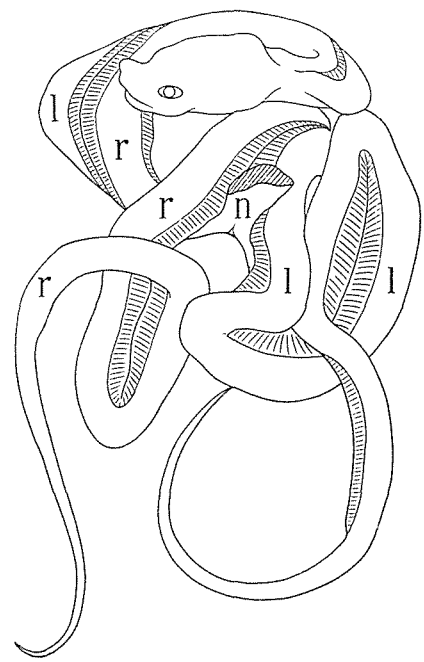


Fig. 1. The craniopagous specimen of *Hemibungarus japonicus*. l—left body, n—navel, r—right body.

including the present work, and four of these cases are of *Agkistrodon halys blomhoffii*, though this snake is comparatively uncommon.

Most of the duplicities found in snakes are the cases of duplicitas anterior. Only four teratopagi belong to some other types.

I. Teratopagus

Craniopagus of Hemibungarus japonicus
(Plate III, figs. 1 and 2)

The specimen was collected from Amami-Osima of the Riukiu Group, by Dr. MAKI, formally of our institute. This snake is ovoviviparous.

The specimen which is a full-grown embryo just before hatching, about 30 cm in length, has a single head and double bodies. The latter are fused ventrally from the neck to the navel, and separated in the region behind the navel which is situated nearly in the middle of the whole length (Fig. 1). Of the two bodies, one situated on the left side is larger than the other. The bodies are twisted in a complex manner partly because of their difference in size. In the posterior halves, three sharp windings occur, one in the right and two in the left body, and the descending and ascending parts of the windings are fused ventrally for some distance as shown in Fig. 1.

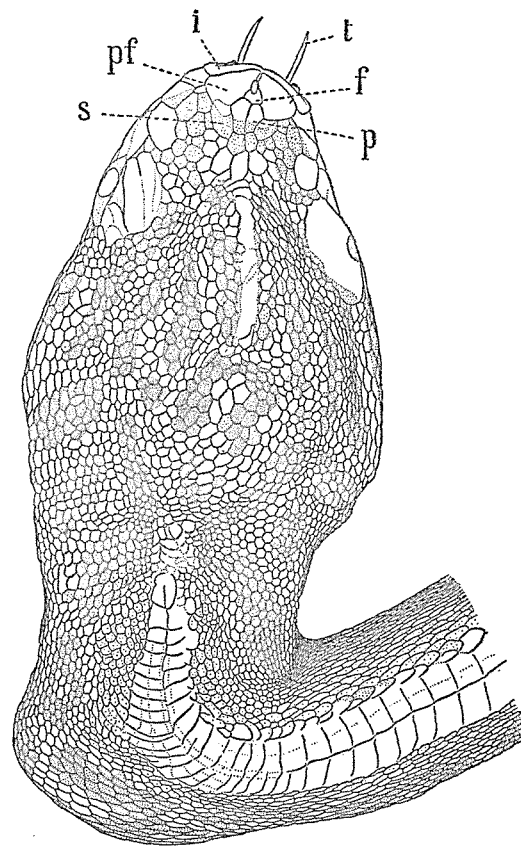


Fig. 2, A. Head of the craniopagous specimen of *Hemibungarus japonicus*; dorsal view showing the arrangement of shields. Highly magnified. f—frontal, i—internasal, p—parietal, pf—prefrontal, s—supraocular, t—tongue.

The head measures 1.6 cm in length and 1.2 cm in width; the top is strongly convex at the centre. The dorsal surface of the head is covered with minute scales which apparently have taken the place of the shields which ordinarily cover the top. The shields are localized to the anterior part of the head. Some of them are deformed and diminished, so

that it is with some difficulty that even larger shields have been identified as parietals, frontal, supraoculars, prefrontals, internasals and rostral (Fig. 2). Of these shields, the rostral and internasals are nearly of normal sizes, while the supraoculars are displaced to the side of the parietals. Contrary to the shields on the dorsal side, those on the ventral side are normal (Fig. 2 B). The eyes and nostrils are in the ordinary situation.

The vertebral column is doubled all through the length. The cranium is doubled for the most part in spite of the apparent singleness. The two halves are somewhat twisted, the right half counterclockwise and the left half clockwise in the frontal view. The bones constituting the cranium are arranged symmetrically on both sides of the median line. In the dorsal view (Fig. 3) the parietals (pa) and frontals (f) are arranged pairwise on each side of the median line. The prootic (pro) lies posterior to the parietal and the postorbital (po) in front of the outer frontal bordering the posterior-dorsal corner of the orbit. In front of the frontals there are four pairs of small bones arranged in a transverse row. The outermost pair bordering the antero-dorsal corner of the orbit, are the prefrontals (pf) without doubt; the next two pairs are the nasals (n), and the remaining pair are probably the prefrontals (pf). The inner prefrontals enclose a deep hollow at the anterior end of the snout. This hollow is possibly a vestigial orbit; but it contains no rudiment of eye-ball, nor does it open on the surface of the head.

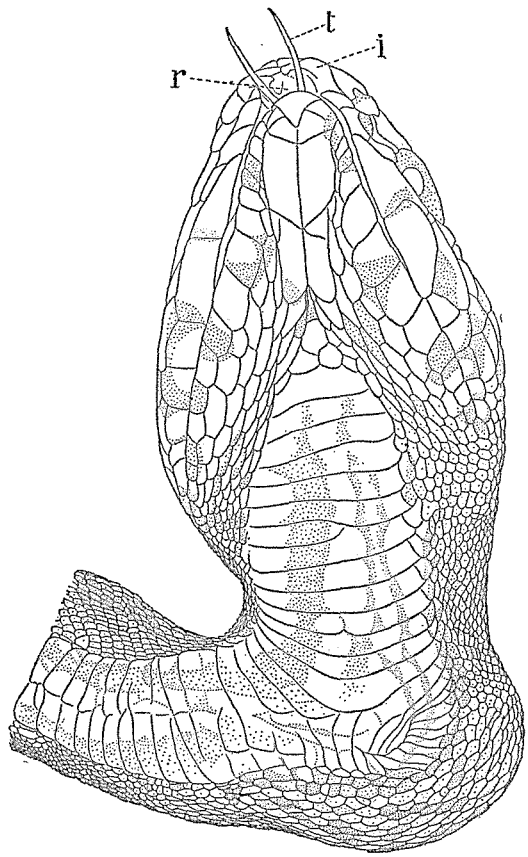


Fig. 2 B. The same, ventral view showing the arrangement of shields. r—rostral.

To the prootic is attached, on the outer side, a slender squamosal (s) which is connected to the lower jaw by the intermediation of the quadrate. At the posterior end of the median line where the prootics of the inner side are approximated to each other, lies a small rod-like squamosal, and to this

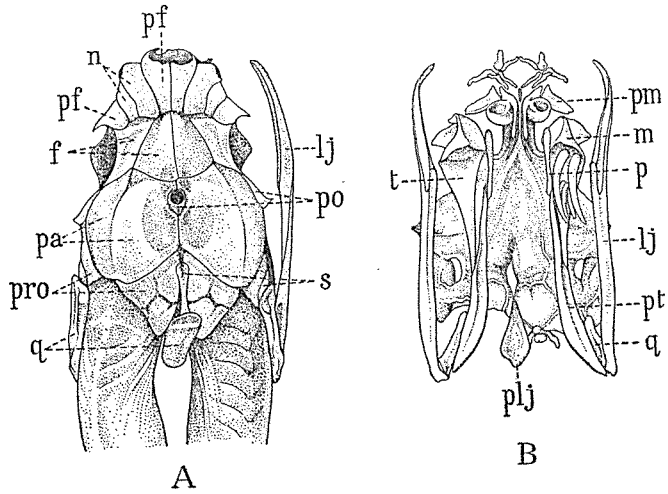


Fig. 3. Cranium of the craniopagous specimen of *Hemibungarus japonicus*; A. Dorsal view, B. Ventral view; f—frontal, lj—lower jaw, m—maxillary, n—nasal, p—palatine, pa—parietal, pf—prefrontal, pm—premaxillary, po—postorbital, pro—prootic, pt—pterygoid, q—quadrate, s—squamosal.

is articulated the quadrate at the hind end. The quadrate (q) is placed vertically to the squamosal, and its ventral end comes in contact with a small but comparatively broad bone. These squamosal and quadrate situated on the median line, apparently represent the two squamosals and two quadrates to be found on the inner side of both parts, while the small bone just mentioned is possibly the rudiment of fused lower jaws. Between the inner parietals is found a black spot covered with a pair of minute bones. It looks like a rudimentary eye. Microscopic examination, however, has revealed that this is not the case. The two minute bones may be the postorbitals (po). The bones of the palate are not doubled and located in the ordinary position, although many small bones of problematical nature occur in the anterior part of the upper jaw (Fig. 3 B). The bones of the lower jaw are normal.

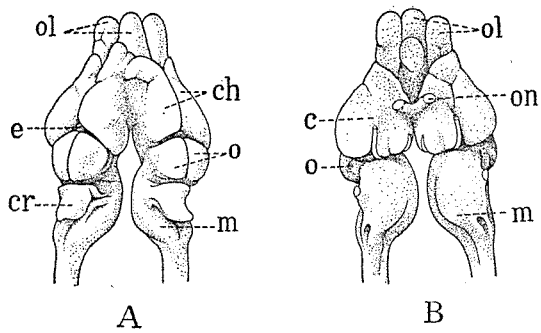


Fig. 4. Brain of the craniopagous specimen of *Hemibungarus japonicus*; A. Dorsal view, B. Vetral view; c—cerebrum, ch—cerebral hemisphere, cr—cerebellum, e—epiphysis, m—medulla oblongata, o—optic lobe, ol—olfactory lobe, on—optic nerve.

Internally, the brains are united in the anterior half (Fig. 4). The cerebral

hemispheres of the inner side are fused partially, and the olfactory lobes of the same side are completely unified. In the ventral view, only a pair of optic nerves (on) are issued from the ventral surface of the fused part of the hemispheres, and there is a remarkable swelling at the middle of the unified olfactory lobes (ol).

The body cavity is single, even in the fused part of the body. There are two sets of respiratory systems; the tracheae and lungs lie side by side (Fig. 5 A). The alimentary canal is doubled; the canals are united for a short distance near the posterior end of the duodenum, and are separated again behind the navel (Fig. 5 B). There are two livers (l), each of which

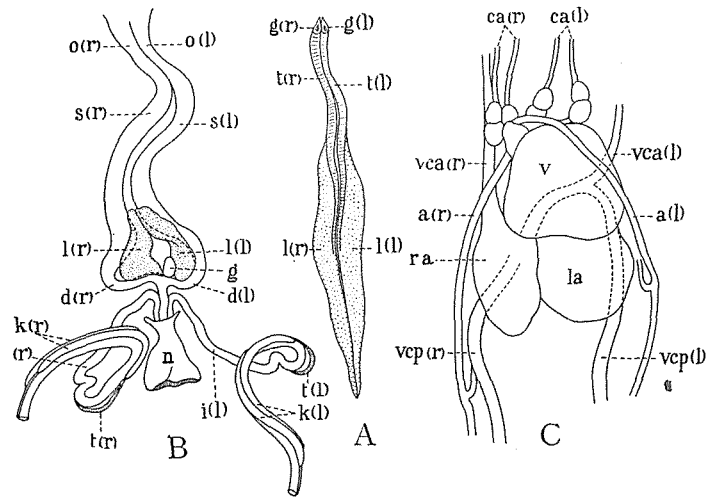


Fig. 5 A. Respiratory system of the craniopagous specimen of *Hemibungarus japonicus*; ventral view. g—glottis, t—trachea, l—lung, r and l in brackets show organs belonging to the right and the left body respectively.

B. Alimentary canal and urogenital system of the same; ventral view. d—duodenum, g—gall-bladder, i—intestine, k—kidney, l—liver, n—navel, o—œsophagus, s—stomach, t—testis.

C. Heart of the same; ventral view. a—aortic arch, ca—carotid artery, la—left auricle, ra—right auricle, v—ventricle, vca—vena cava anterior, vcp—vena cava posterior.

is situated close to the respective alimentary canal between the pyloric portion of the stomach and the end of the duodenum. Only one gall-bladder (g) is found at the point of fusion of the duodena.

The circulatory system is entirely mutilated by poor preservation, and only the heart and the proximal parts of large blood vessels are observable. The heart consists of three portions, and it looks as though placed upside-down, the ventricle being situated anterior to the auricles (Fig. 5 C). There is a swelling near the right anterior corner of the ventricle; and one can

recognize two aortic arches, a pair of carotid arteries (car) of the right body, the right carotid artery of the left body and the common pulmonary artery, all arising from the swelling. At a short distance from its origin, the aortic arch of the left body branches off the left carotid artery (cal). The arch divides near the posterior end of the heart into an anterior and a posterior aorta which run beneath the vertebral column of the left body. The aortic arch of the right body also divides in the same manner shortly behind the heart. The common pulmonary artery is divided into two branches going into the lung of the respective body. Only one anterior vena cava occurs in each body; that of the right body (vcar) goes directly to the right ventricle and that of the left body (vcal) joins with the posterior vena cava of the same side on the dorsal side of the ventricle; this common vena cava seems to form a sinus venosus together with the posterior vena cava of the right body.

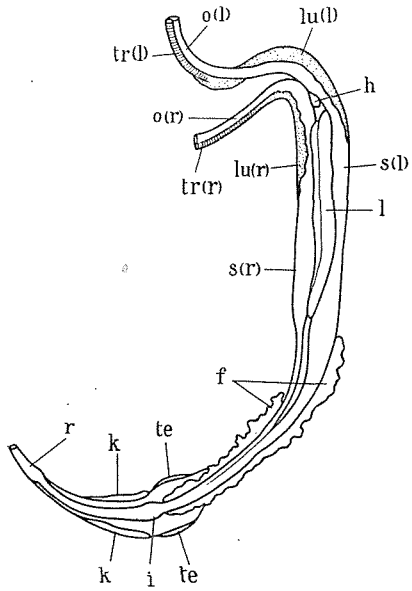


Fig. 6. Viscera of the derodymous specimen of *Agkistrodon halys blomhoffii*, ventral view. f—fat body, h—heart, i—intestine, k—kidney, l—liver, lu—lung, o—œsophagus, r—rectum, s—stomach, te—testis, tr—trachea.

The urogenital system is well developed. The right kidney and gonad lie slightly anterior to the left ones in each body.

In appearance this snake looks like a case of duplicitas posterior, and because of its single head it might be taken for a deradelphus. Precise examination, however, shows that most of the organs, not only the viscera and vertebral column, but also the cranial bones and brain, are doubled, so that it is most probably a craniopagus, a type of the teratopagi—complete duplicities.

II. Teratodymus

All the specimens are derodymi, in which the vertebral column is bifurcated in the neck region.

A. *Derodymus of Agkistrodon halys blomhoffii*

(Pl. III, fig. 3; Pl. IV, fig. 2)

This is a very young specimen, probably two or three months old, measuring 16.5 cm in total length.

At a point about 13 cm from the tip of the tail, the body is bent to the right about 50 degrees, and is bifurcated at a short distance in front of the bending. The two branches are of unequal length, the right branch measuring 2.3 cm and the left 2.8 cm. The angle between the branches is about

45 degrees, and the left head is slightly twisted clockwise in the frontal view.

The vertebral column is bifurcated just in front of the bending of the body (Pl. IV, fig. 2). The left branch comprises more than 30 vertebrae, and the right one less than 30. Some of the posterior vertebrae in the left branch are much shortened. The bending of the body is not an artifact, some of the vertebrae being wedge-shaped in the dorsal view.

The doubling of the alimentary canal extends much more posteriorly than that of the vertebral column, from the mouth to the middle of the intestine (Fig. 6). There are two livers fused firmly together (l).

The respiratory system is also duplicated, without any connection between them.

The heart lies between the two œsophagi just behind the bending of the body. It is apparently single, but because of the bad preservation, it is difficult to make out this with certainty.

The urogenital system is single. The gonads are probably testes.

B. *Derodymus of Elaphe conspicillata*

(Pl. III, fig. 4; Pl. IV, fig. 1)

The specimen measures 34 cm in length, and has an appearance to be bifurcated in the posterior part of the head. The right head is 3.1 cm and the left 2.7 cm long; they form an angle of about 30 degrees with each other. The heads are twisted about 20 degrees, the right head counterclockwise and the left one clockwise in the frontal view.

The skulls are independent. The vertebral column is bifurcated in the middle of the cervical region (Fig. 7). Each branch comprises 16 vertebrae, of which the 16ths of the two branches are fused with each other. The 17th vertebra is single but rather long; the vertebrae from the 18th to the 24th are very short, and the column is curved strongly in this region.

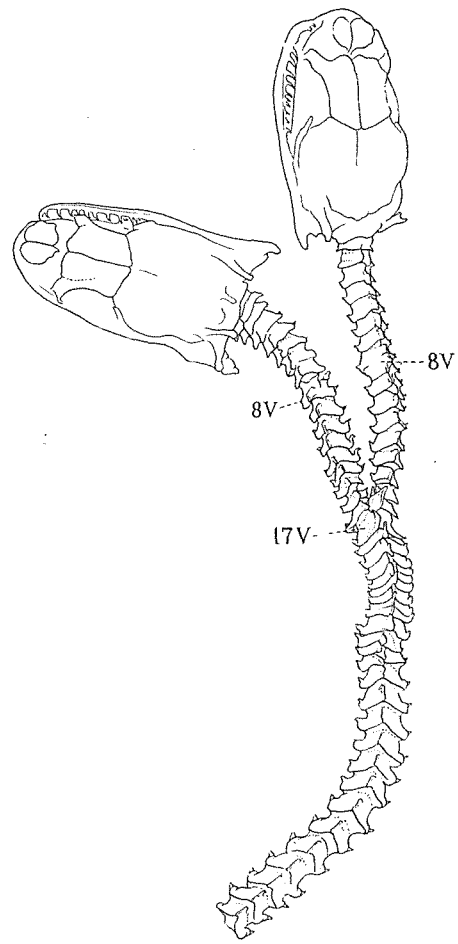


Fig. 7. Anterior part of the axial skeleton of the derodymous specimen of *Elaphe conspicillata*. 8V—the 8th vertebra, 17V—the 17th vertebra.

The body cavity is single even in the anterior part of the neck. The alimentary canal, however, is doubled from the œsophagus to the duodenum, although the two canals remain fused in the region from the anterior part of the œsophagus to the pyloric portion of the stomach (Fig. 8). The liver, gall-bladder and the pancreas are single. The liver extends from behind the heart to the posterior part of the stomach; the gall-bladder and pancreas are attached to the duodenum.

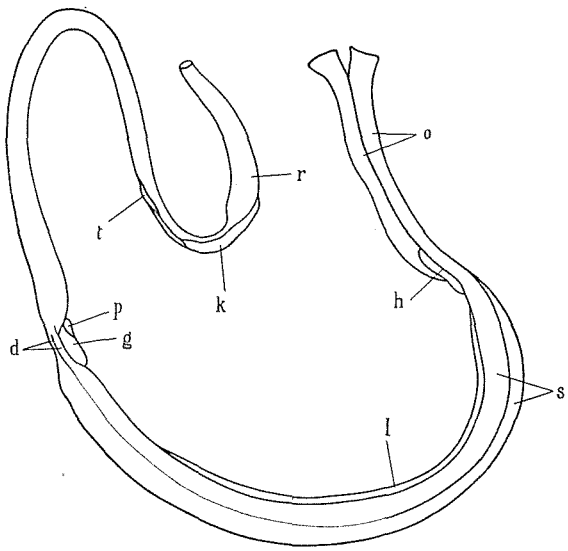


Fig. 8. Alimentary canal and the urogenital organs of the derodymous specimen of *Elaphe conspicillata*. d—duodenum, g—gall bladder, h—heart, k—kidney, l—liver, o—œsophagus, p—pancreas, r—rectum, s—stomach, t—testis.

The respiratory system is doubled; the lungs come in contact with each other, but apparently remain independent.

The heart is single and lies ventrally to the stomachs. The blood vessels were not made out clearly.

The urogenital system remains single, as it is also the case in the other specimens.

C. *Derodymus of Elaphe climacophora*

(Pl. III, fig. 5)

The specimen is double-headed but single-necked and is 33 cm long. The two heads are divergent about 50 degrees. The right head is slightly shorter than the left, and is twisted counterclockwise in the frontal view. The vertebral column is bifurcated in the neck region just as in the preceding specimen.

The doubling of the alimentary canal is limited to the anterior part; only the œsophagus is doubled, while the rest remains single (Fig. 9). The liver, gall-bladder and the pancreas are also single.

The respiratory system is doubled, and the two systems remain distinct. The right system is well developed, while in the left, the trachea (t) is very short and ends in a vestigial lung that lies along the right trachea.

The heart is single, and normal in structure and in position (Fig. 10). From the ventricle originate the aortic arches and pulmonary artery as in the ordinary case. Besides these, there is a supernumerary artery (sa) which arises from the anterior end of the ventricle, slightly to the left of the base of the pulmonary artery, and runs forward along the left œsophagus,

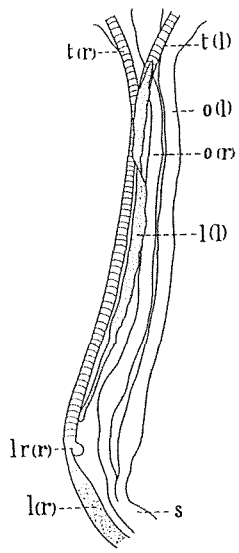


Fig. 9. Anterior part of the respiratory and alimentary systems of the derodymous specimen of *Elaphe climacophora*, ventral view. l—lung, o—œsophagus, s—stomach, t—trachea, lr—vestigial right lung.

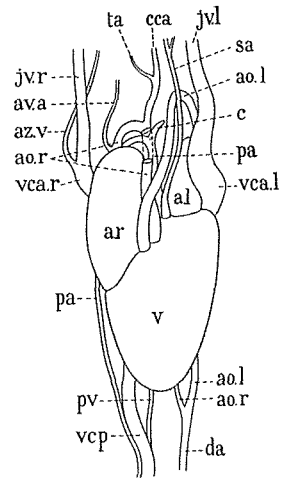


Fig. 10. Heart of the derodymous specimen of *Elaphe climacophora*, ventral view. a—auricle, ao—aorta, ava—anterior vena cava, azv—azygos vein, c—cæcum, cca—common carotid artery, da—dorsal aorta, jv—jugular vein, pa—pulmonary artery, pv—pulmonary vein, sa—supernumerary artery, ta—thyroid artery, v—ventricle, vca—vena cava anterior, vcp—vena cava posterior, r—right, l—left.

giving off a thyroid artery (ta), and also branchlets to the left œsophagus (Fig. 11). This artery corresponds to the common carotid artery of the left neck, which turns dorsad behind the right corner of the left mouth and penetrates into the left head. The ordinary common carotid artery, on the other hand, lies on the right side of this artery, and enters the right head, passing behind the left corner of the right mouth.

In the venous system no supernumerary vessel occurs. The jugular veins arise in the heads and run along the œsophagus and become the anterior venae cavae. A pulmonary artery (pa) and a pulmonary vein (pv) occur, but they enter the right lung only. The pulmonary artery is bifurcate just in front of the heart; the left branch ends blindly as in the ordinary case, and does not develop into a pulmonary artery of the left lung. So, the pulmonary circulation is lacking in the left respiratory system. The aortic arches and their branches are normal. Singularly, however, the left aortic arch passes between the two œsophagi instead of passing along the outer side of the left œsophagus. In other words, the right œsophagus is encircled by the right and left aortic arches which fuse together on its

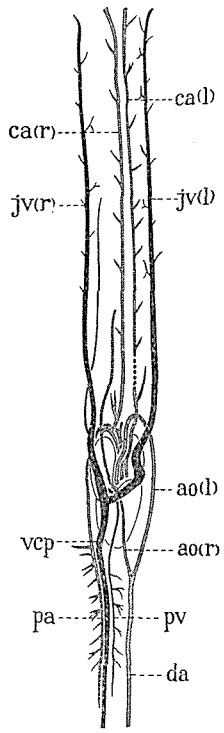


Fig. 11. Schema of the anterior part of the circulatory system of the derodymous specimen of *Elaphe climacophora*, ventral view. Abbreviations same as in Fig. 10.

dorsal side; the left œsophagus, on the contrary, is excluded from the circulation of these aortic arches. This fact seems to indicate that the right half of the bifurcation is prevailing as far as circulatory system is concerned.

D. *Derodymus of Natrix tigrina*

The specimen is a very young snake, measuring 18.2 cm in length, resembling much the foregoing specimen. The vertebral column is bifurcated in the anterior part of the neck, and there are two independent skulls. The alimentary canal is doubled from the mouth to the end of the stomach. The respiratory system is also doubled. There is one heart; but the details of the circulatory system could not be observed, owing to poor preservation. The urogenital system is not doubled; the specimen seems to be a female.

E. *Derodymus of Natrix vivakari*

The specimen has once been dried, so that observation on the viscera is hardly possible. It measures 16 cm in length, and resembles the foregoing specimens not only in appearance but in the condition of the vertebral column.

The Specimens of Double Monsters of Tortoises

The recorded cases of double monstrosities found in tortoises are fewer than those in snakes. Except a single teratopagus recorded by TOWNSEND (1928), they all belong to the duplicitas anterior, being two-headed (EDWARDS, 1751, cited by BATES, 1894; MITCHILL, 1826; BARBOUR, 1888, 1896; KUWANO, 1902; SEURAT, 1925, and CAULLERY, 1931; LIGHT, 1925, and DERICKSON, 1927; TOWNSEND, 1928; HILDEBRAND, 1930; CEDERSTROM, 1931; etc.). Of these, only one has been dissected (KUWANO, 1902).

In all these recorded cases of double tortoises the shell is incompletely divided, and only a pair of fore limbs and a pair of hind limbs occur. In only one specimen (SEURAT, 1925 and CAULLERY, 1931) the shell is rather widely divided by a longitudinal fissure, and two pairs of fore limbs occur.

The degree of duplicity in the vertebral column is difficult to determine by mere external examination. The point of bifurcation may lie in the cervical (KUWANO, 1902), or in the thoracic region (CEDERSTROM, 1931), or close to the sacrum (DERICKSON, 1927; CAULLERY, 1931). These cases are

to be sorted accordingly into the derodymus, thoracodymus and psodymus.

The specimens of double-headed tortoises available in the present study are a derodymus and a psodymus.

A. *Derodymus of Geoclemys reevesii*

(Pl. IV, figs. 5 and 6)

A very young specimen which died shortly after birth. It is two-headed, and shows no other doubling; the measurements are (in cm):

Length of carapace	2.4
Width of carapace	2.45
Length of plastron	2.4
Length of hind lobe	0.8
Width of hind lobe	1.65

The specimen possesses a pair of fore limbs, a pair of hind limbs and a single tail. The shields on the carapace are normal, but for an extra shield which occurs between the gular shields of the plastron (Fig. 12). In the centre of the plastron there is a navel which measures 0.9 cm in length

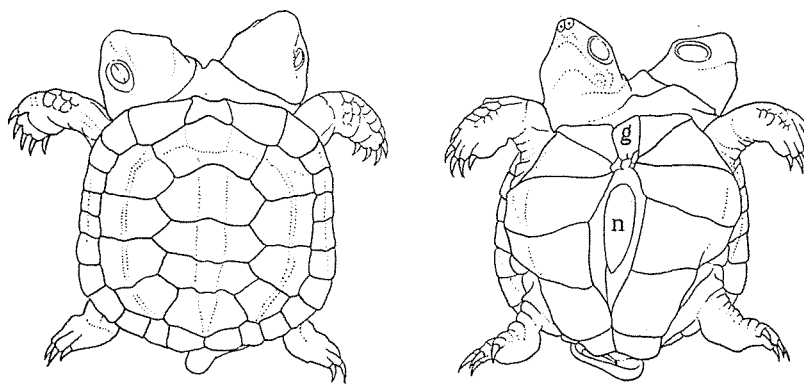


Fig. 12. The derodymous specimen of *Geoclemys reevesii*, A—Dorsal view, B—Ventral view; g—supernumerary gular shield, n—navel.

and 0.35 cm in width (n). The two heads are divergent about 70 degrees, the angle between the median axis of the body and the axis of each head being about 30 degrees on the right side and about 40 degrees on the left. The heads are slightly twisted around the median axis of the body, the right head clockwise and the left head counterclockwise in the frontal view.

The axial skeleton is bifurcated in the cervical region; the other skeletal parts are single.

Situs inversus viscerum involving the heart and alimentary canal occurs in the right half of the duplicated part of the body (Fig. 13 A).

The anterior part of the alimentary canal is doubled, and the two

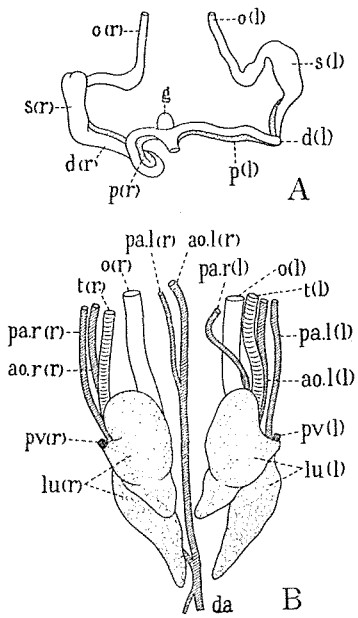


Fig. 13 A. Anterior part of the alimentary canal of the derodymous specimen of *Geoclemys reevesii*, ventral view. d—duodenum, g—gall bladder, o—œsophagus, p—pancreas, s—stomach.

B. Respiratory system and pulmonary arteries of the same, ventral view. ao—aortic arch, d—dorsal aorta, lu—lung, o—œsophagus, pa—pulmonary artery, pv—pulmonary vein, t—trachea, r—ripht, l—left.

branches are united at the posterior end of the duodenum. The posterior part of each œsophagus turns to the lateral side, and opens into a stomach which is curved backward. Between the pyloric portion and the duodenum, the alimentary canals make a few windings, and are drawn together, to be united at the posterior end of the duodenum. The two pancreas are fixed by the mesentery to the canals from the pylorus to the end of the duodenum. A large liver consisting of two lobes, and a gall-bladder situated at the point of union of the two duodena, are found.

There are two separate respiratory systems, one for each half of the body (Fig. 13 B). Each trachea (t) runs along the outer side of the œsophagus, and enters the lungs (lu) which are situated in the dorso-ventral relation, the ventral one slightly anterior to the dorsal one. The anterior part of the ventral lung is wedged in between the muscles of the neck and the heart; it is very thin, and looks functionless. The dorsal lung, on the other hand, is expanded beneath the carapace. A pair of pulmonary arteries (pa) are connected to the left pair of lungs, while the right pair receive the right pulmonary artery from the right heart only, as the left pulmonary artery does not reach the lungs, and fuses with the left aortic arch of the right heart.

The circulatory system is doubled for the most part. There are two hearts lying side by side. Of these, the left heart is smaller than the right heart, and its right auricle is very small. The right heart is shaped like a mirror image of the left heart, i. e., the left auricle receives the venous blood from the sinus venosus, while the right auricle is connected with the pulmonary veins (Fig. 14 A).

The condition of the main blood vessels is shown schematically in Fig. 14 B. In the left system the right aortic arch is entirely missing, so that there are three main anterior trunks originating from the ventricle, namely, the left aortic arch, the innominate artery and the common pulmonary

artery. The left aortic arch goes to the mesentery, giving off branches to the left portion of the liver and the alimentary canal. The innominate artery divides into two branches—the subclavian arteries, of which the left one enters the left fore limb, while the right one is continuous to the left subclavian artery issued from the right heart. The common carotid arteries originate from the subclavian arteries, and run forward in the neck region of the left head. The common pulmonary arteries divide each into two pulmonary arteries which are distributed to the left pair of lungs.

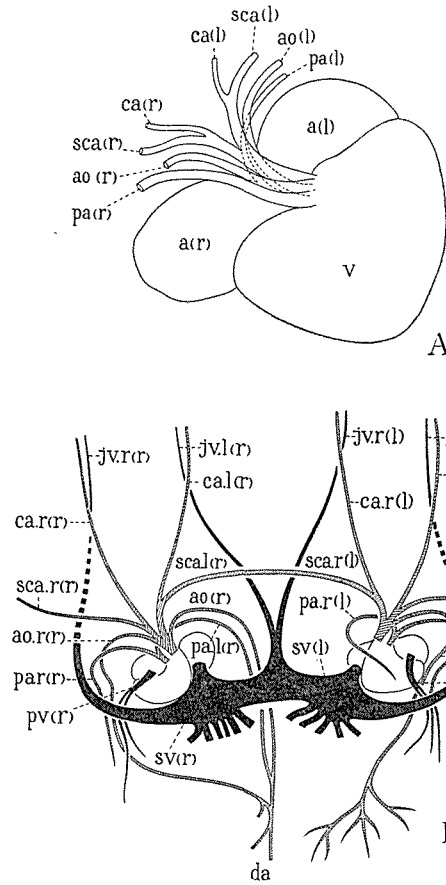


Fig. 14 A. Right heart of the derodymous specimen of *Geoclemus reevesii* ; ventral view. a—auricle, ao—aortic arch, ca—carotid artery, pa—pulmonary artery, sca—subclavian artery, v—ventricle, r—right, l—left.

B. Schema of main trunks of blood vessels of the same. sv—sinus venosus; other abbreviations are the same as in A.

In the right system, both aortic arches occur and are fused into a dorsal aorta which runs beneath the vertebral column, giving off arteries to the greater part of the posterior region of the body. The innominate, subclavian and carotid arteries resemble the corresponding arteries in the left system. The left subclavian artery is continuous to the right subclavian artery of the left system as described above. There are two pulmonary arteries, of which the left one does not reach the lung, and joins the left aortic arch of the right system at a short distance in front of the junction of the two aortic arches.

Veins can not be observed clearly. The sinus venosus looks duplicate and confluent with each other, receiving each the posterior and anterior venae cavae and the hepatic veins. The right anterior vena cava of the right system and the left anterior vena cava of the right system fuse together in front of the sinus venosus.

The urogenital system is entirely single.

KUWANO (1902) gives a precise description of the anatomy of a full-grown two-headed tortoise, *Clemmys japonica*. His specimen, a derodymus, belongs to the same type as the present specimen, although the viscera show duplication of a greater degree, but no situs inversus.

What is most remarkable in his specimen is the state of the circulatory system. There are two hearts, both quite ordinary in appearance, and two pairs of aortic arches. The latter are united two by two into two aortae which are united again with each other into a single dorsal aorta. The condition of the anterior arteries is almost the same as in the present specimen; the right subclavian artery of the left system is continuous to the corresponding artery on the left side of the right system. The pulmonary arteries, however, are paired in each system.

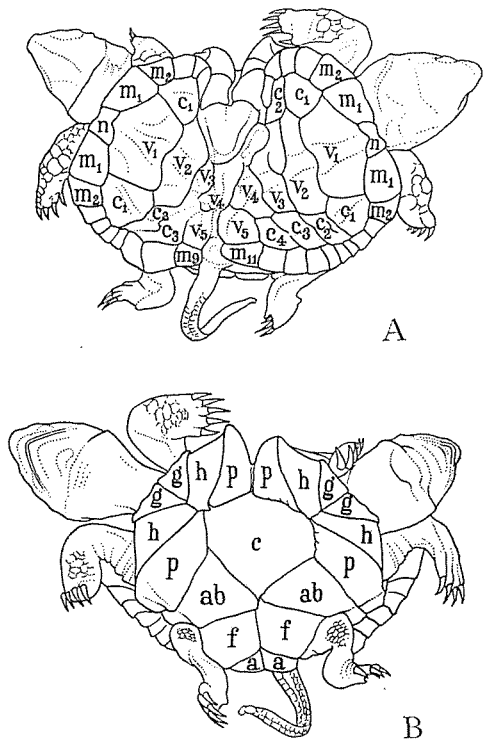


Fig. 15 A. The psodymous specimen of *Geoclemys reevesii*; dorsal view showing shields on the carapace. c_1–c_4—the 1st-4th costal, m_1–m_{11}—the 1st - the 11th marginal, n—nuchal, V_1–V_5—the 1st - the 5th vertebral.

B. The same, ventral view showing plastral shields. a—anal, ab—abdominal, c—shieldless central area, f—femoral, h—humeral, p—pectoral.

B. *Psodymus of Geoclemys reevesii*

(Pl. IV, figs. 3 and 4)

A young specimen, three months old. The anterior half of the body is doubled, being provided with two pairs of anterior limbs. The shell measures about 3.2 cm in width and 2 cm in length. The carapace is deeply notched in the middle of both anterior and posterior margins. These notches are united by an irregular furrow which divides the carapace into two almost symmetrical halves, though the right half is slightly larger than the left. The axes of the two halves are divergent about 120 degrees.

On the right side, the carapace (Fig. 15 A) is furnished with one nuchal (n) and five vertebral shields (v) arranged on the middorsal line, and four costal (c) and eleven marginal (m) shields on the outer side, and two costal and six marginal shields on the inner side of the median shield row. On the left side, on the other hand, there are one nuchal and five marginal

shields on the middorsal line, three costal and nine marginal shields on the inner. Besides these, there are a few shields in the furrow on the median line; they are, however, too irregular to be identified definitely.

On the ventral side of the shell, there is a whitish shieldless area in the centre of the plastron (Fig. 16 B, C). The plastral shields are disposed symmetrically, and there is no abnormal shield or any furrow. The posterior shields, i. e., the abdominals (ab), femorals (f) and anals (a), are paired; the femoral and anal pairs cover the single hind lobe of the plastron. On the other hand, the anterior shields, namely, the pectorals (p), humerals (h) and gulars (g), are arranged in pairs in each half of the body.

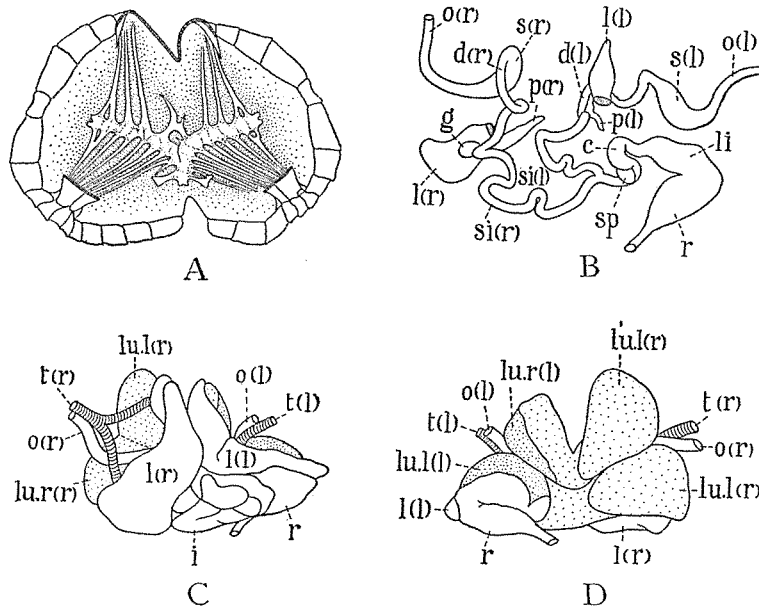


Fig. 16 A. Ventral view of the carapace of the psodymous specimen of *Geoclemys reevesii*, showing bifurcation of the vertebral column.

B. Alimentary canal of the same, ventral view. c—cæcum, d—duodenum, g—gall bladder, l—liver, li—large intestine, o—œsophagus, p—pancreas, r—rectum, s—stomach, si—small intestine, sp—spleen.

C, D. Other visceral organs of the same; C, Ventral view, D, Dorsal view. i—intestine, lu—lung, t—trachea.

The vertebral column is bifurcated in the posterior part of the trunk region, in front of the sacrum (Fig. 16 A). There are ten ribs on each outer side and five ribs on each inner side. The 9th rib on the outer side of the right half is vestigial, and is united with the 8th rib near the proximal end. The 5th ribs on the inner sides of both halves are short and broad, and united with each other subterminally.

The anterior half of the alimentary canal (B) is doubled; the canal is bifurcated at the posterior end of the small intestine. The large intestine,

the cæcum and the rectum are single. A spleen (sp) is situated close to the cæcum. There are two livers (l), but a single gall-bladder (g) attached to the right duodenum. The two livers are connected by a cord-like tissue which possibly represents a hepatic duct. The left liver is smaller than the right, and situated dorsal to the left heart. There are two pancreas (p), each close to the corresponding duodenum.

The hearts are two, one for each half of the body, and are located in the ordinary position. Both of them seem to be normal. Blood vessels could not be observed clearly.

A respiratory system occurs in each half of the body (Fig. 16, C, D). The lungs in the left half are undersized, and apparently functionless. The lungs belonging to the right half consist of two lobes each and are greatly expanded into the body cavity of the left half of the body, and come in contact with the lungs of the left half.

The urogenital system is single throughout.

This psodymous tortoise is similar to the specimen recorded by SEURAT (1925) and CAULLERY (1931), at least in its external feature and in the condition of the skeleton. The vertebral column is bifurcated near the sacrum in all the specimens, but the psodymus reported by DERICKSON (1927) comes nearer the derodymus than the present specimen, as it is provided with a single pair of fore limbs. Thus, there is apparently no strict correlation between the degree of duplicity in the vertebral column and the duplicity of the fore limbs.

Summary and Remarks

1. In reptiles, the partial duplicity is commoner than the complete duplicity. Of the former, a few different types of anadidymus (duplicitas anterior) have been recorded, but no katadidymus (duplicitas posterior) is known.

2. The degree of duplicity varies to certain extent according to the groups of reptiles. In snakes, the doubling of the axial skeleton is restricted to the anterior part of the body. In the case of rhinodymus reported by BOETTGER (1890), where the doubling is of the smallest extent, there are four nasal plates and four nasal openings. In the cases of duplicity of greater extent, opodymus, the head is bifurcated near the level of the eyes and the specimen is provided generally with three eyes. In the most frequent cases of derodymus, the vertebral column is bifurcated in the neck region, forming two heads. Even in the most extreme case the bifurcation does not extend beyond the middle of the body. JOHNSON (1901) states that "the point of bifurcation is most likely to occur in the cephalic half of the snake, between 6 and 13 percent of the entire length from the end." To various cases of double-headed snakes the terms "atelodymus" and "dérodymus" are often applied. These are concerned with the duplicity of the same type but in different degrees as pointed by STROHL (1925). In tortoises, on the other hand, there is no record of the rhino- or opodymus, and

most of the recorded double monsters seem to belong to the derodymus. The point of bifurcation may go farther backwards than in snakes, resulting in the thoracodymus or psodymus.

All the cases found in lizards, thus far recorded, seem to be derodymi.

3. Only six cases of complete duplicity have been reported so far: one pygopagous tortoise (TOWNSEND, 1928), one craniopagous (?) lizard embryo (WILLIS, 1931-32) and four snakes of various degrees of duplicity. Of the latter, LASSERRE's (1880) two-headed snake seems to be a teratopagus because it has a longitudinal groove extending to the whole length. The double snake described by MITCHILL (1826) is of a more advanced degree of duplication, probably a cephaloderopagus. The two bodies are united only at the posterior end of the head and neck, and three eyes occur just as in the case of opodymus. The double-tailed snake described by STROHL (1925) belongs to the same type as the specimen of *Hemibungarus* in the present collection—the craniopagus. The two bodies are united along the anterior two-thirds of the length; the radiographs, however, show that the vertebral column is doubled throughout. The detailed statement of the cranium is lacking, but it is clear that it is not entirely single. The most problematical case is the snake reported by WYMAN (1826) which has two heads and two tails. The vertebral column is doubled at about the middle of the body, and is provided with a double set of ribs, but it is stated as single in front of this region and also behind it. The specimen was not dissected or radiographed, and it is not certain whether the vertebral column was really single, or it was made of two columns fused close together. As far as can be judged from the author's description, the duplicity represents a curious combination of the anakatadidymus and mesodidymus, so that the name "anakatamesodidymus" is to be applied to it. As WYMAN points, this type of duplicity has not been cited since.

4. The point of bifurcation is different in different organs, for instance, the degree of furcation of the axial skeleton does not necessarily coincides with that of the alimentary canal or that of the circulatory system. The furcation of these organs usually occurs on the more posterior level than what appears externally. In the anadidymi, the whole respiratory system is doubled in all the known cases; the doubling of the alimentary canal occurs on various levels, in the œsophagus, stomach or in the intestine. On the other hand, the urogenital system is not subjected to duplicition.

The condition of the circulatory system is varied. In some cases two hearts are found, of which the right one is usually larger than the left (REDI, DORNER, STROHL and HEASMAN); a heart of a double structure is known in a case of snake (VSEVOLOJSKY), while a single normal heart has been found in other cases. In the present cases, one normal heart is found in all the derodymous snakes, an abnormal heart occurs in the craniopagous snake and two hearts are found in both the derodymous and psodymous tortoises. HEASMAN (1933) has pointed out concerning his double-headed snake that "—there was a line, not a point, of bifurcation. This line was

curved and passed from the dorsal surface at the level of the first neck band through the vertebrae—and flattening out ran to the anus close to the ventral surface. Ventral to this line the animal was doubled, dorsal to it the animal was single." His statement holds true in some cases, but it can not be accepted as a general rule, because the alimentary canal may be doubled down to the duodenum while the heart remains single. It is true that the degree of duplicity in various organs depends chiefly upon their relative positions, but this rule does not always hold. The degree of susceptibility to duplication may be different in different organs, and this difference is probably related to the mechanism of development of each organ.

5. It should be noted that in most cases of duplicity found in reptiles, the two parts of the doubled body are almost equal in size with each other, while in birds the left body often shows a remarkable degenerative tendency (KOMAI and NAKAMURA's paper in the present series). In some internal organs, however, asymmetrical development is sometimes found; then the right half is always larger than the left. Prevalency of the right side has been observed in the circulatory system in some double monsters of snakes also (HEASMAN, 1933; the case C in the present study). It is remarkable, however, that situs inversus viscerum occurs in the right body of the dero-dymous tortoise described above. The fact that situs inversus viscerum is more commonly found in the right body, than in the left body, of a double monster is nearly established, especially in lower vertebrates, fishes and amphibians (cf. KOMAI's paper in this series).

Literature Cited

BARBOUR, E. H. 1888. A young tortoise, *Chrysemys picta*, with two heads. Amer. J. Sci., Ser. 3, Vol. 36.

—— 1896. A two-headed tortoise, *Chrysemys picta*. Science, Vol. 4.

BATESON, W. 1894. Materials for the Study of Variation.

BORGERT, H. 1896. Ueber eine zweiköpfige Kreuzotter. Verhndl. nat. Ver. Hamburg, Ser. 3, Bd. 4.

CANTONI, A. F. 1921. Casi di dicefalia in *Tropidonotus natrix*. Atti Soc. ligust. Sci. Nat., Anno 32.

CAULLERY, M. 1931 a. Remarques sur des cas de bicéphalie. Bull. Soc. Zool., T. 56.

—— 1931 b. Addition à la bibliographie relative à la bicéphalie chez les serpentes. ibid.

CEDERSTROM, J. A. 1931. A two headed turtle. J. Heredity, Vol. 22.

CUNNINGHAM, B. 1927. Twoheads snakes. Scient. Monthly, Vol. 25.

DERICKSON, S. H. 1927. A twin turtle. ibid.

DORNER, A. 1873. Eine Kreuzotter mit zwei Köpfen. Zool. Garten, Bd. 14.

DUTROCHET, H. 1829. Observations sur une vipère à deux têtes. Anal. de travaux de l'Acad. roy. des Sci.

EDWARDS, 1751. Nat. Hist. of Birds, Pt. 4.

GATES, H. W. 1929. A two-headed snakes. J. Heredity, Vol. 20.

GEOFFROY ST. HILLAIRE, I. 1838. Hist. des Anom., II.

HEASMAN, W. J. 1933. The anatomy of a double-headed snake. J. Anat. London, Vol. 67.

HENNING, C. 1869. Eine zweiköpfige Eidechse. Cosmos, Paris, T. 21.

HILDEBRAND, S. F. 1930. Duplicity and other abnormalities in diamond-back terrapins. J. Elisha Mitchell Sci. Soc., Vol. 46.

INUKAI, T. 1929. Japanische Vipern mit zwei Köpfen. Transact. Sapporo Nat. Hist. Soc., Vol. 11.

JOHNSON, R. H. 1902. Axial bifurcation in snakes. Transact. Wisconsin Acad. Sci., Vol. 13.

KOMAI, T. & NAKAMURA, K. Types of duplicity found in chicks and ducklings. Present Series, No. 3.

KURODA, N. 1919. A two-headed snake (Jap.). Dobutsugakuzasshi. 31.

KUWANO, H. 1902. A two-headed tortoise (Jap.). Dobutsugakuzasshi, 14.

LASSERRE, 1880. Note sur une coulouvre à deux têtes. Bull. Soc. Hist. nat. Toulouse, T. 14.

LIGHT, V. E. 1925. A double turtle of the genus *Chrysemys*. Proc. Pennsylvania Acad. Sci., Vol. 1.

MITCHILL, S. L. 1826. Facts and considerations showing that the two-headed snakes of North America and other parts of the world, are not individuals of a distinct race, but universally monster. Amer. J. Sci., Vol. 10.

REDI, F, 1684. Osservazioni intorno agli animali viventi che si trovano negli animali viventi. Oper di F. Redi, III. Milano, 1810.

SEURAT, L. G. 1925. Un monstre double de tortue terrestre. Bull. Soc. Sci. nat. Afrique Nord, T. 16.

STROHL, J. 1925. Les serpents à deux têtes et les serpents doubles. Ann. Sci. Nat. (Zool.), Paris, X^{e} Ser., T. 8.

TOWNSEND, C. H. 1928. A double turtle. Bull. New York Zool. Soc., Vol. 31.

VELLARD, J. & PENTEADO, J. 1931. Un cas de bicéphalie chez un serpent (*Liophis almadensis*). Bull. de la Soc. Zool., T. 56.

VSEVOLOJSKY, NIC. DE, 1812. Sur un serpent à deux têtes (*Coluber natrix*) vivant. Mém. Soc. Imp. Naturalistes, Moscou, T. 3.

WILLIS, R. A. 1931-32. A monstrous twin embryo in a lizard, *Tiliqua scincoides*. J. Anat., London, Vol. 66.

WYMAN, J. 1862. Two specimens of monstrosity in serpents. Proc. Boston Soc. Nat. Hist., Vol. 9.

YOSHINAGA, T. 1901. A two-headed snake (Jap.). Dobutsugakuzasshi, 13.

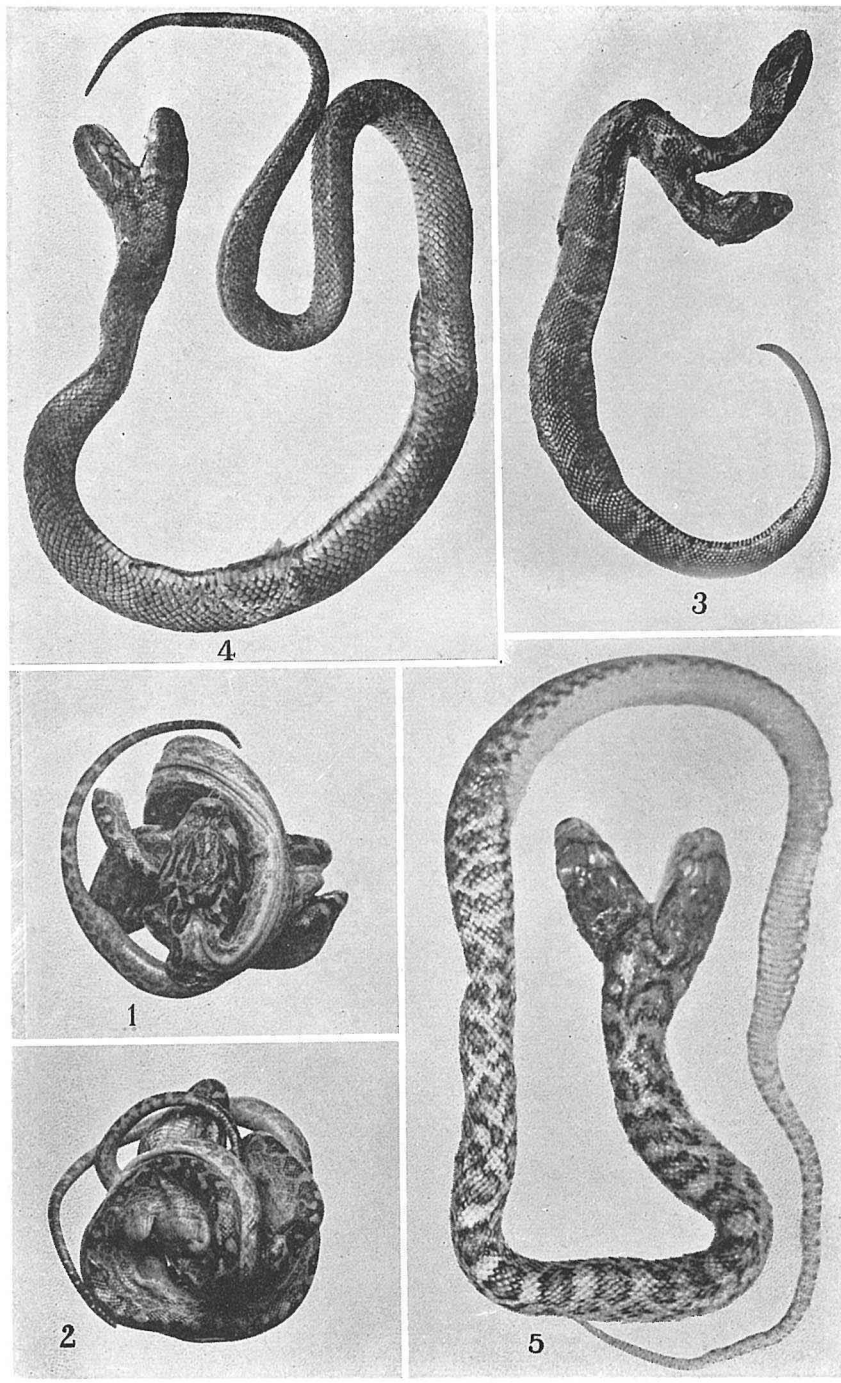
Explanationof Plates

Plate III

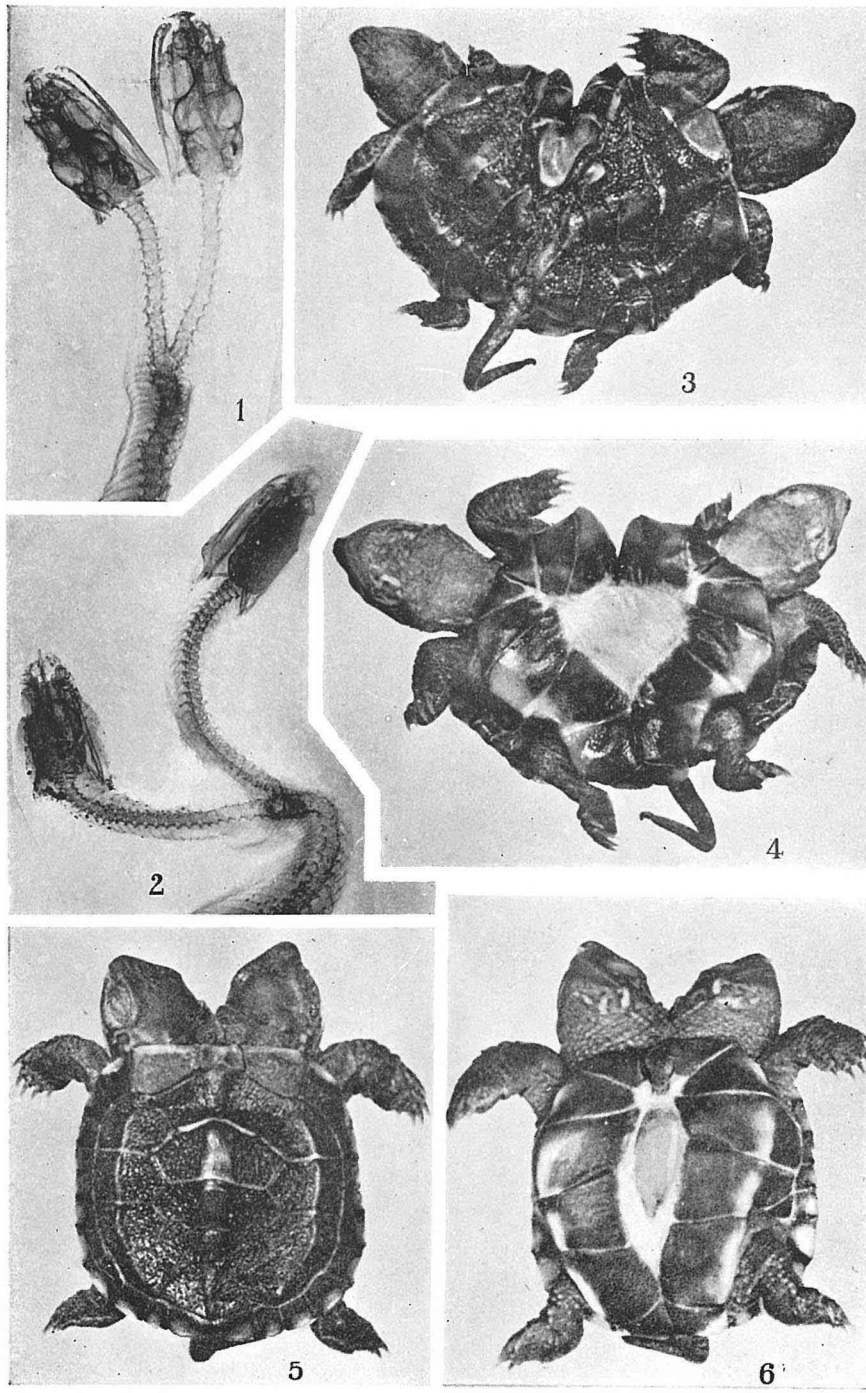
1. The craniopagous specimen of *Hemibungarus japonicus* from the dorsal side. ×4/5
2. The same from the ventral side. ×4/5
3. The derodymous specimen of *Agkistrodon halys blomhoffii*. ×4/5
4. The derodymous specimens of *Elaphe conspicillata*. ×4/5
5. The derodymous specimen of *Elaphe climacophora*. ×4/5

Plate IV

1. The radiograph of the derodymous specimen of *Elaphe conspicillata*.
2. The radiograph of the derodymous specimen of *Agkistrodon halys blomhoffii*.
3. The psodymous specimen of *Geoclemys reevesii*; from the dorsal side. ×1.2
4. The same; from the ventral side. ×1.2
5. The derodymous specimen of *Geoclemys reevesii*; from the dorsal side. ×1.2
6. The same; from the ventral side. ×1.2



K. Nakamura



K. Nakamura