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BITE PATTERNS OF TAIWAN VENOMOUS AND NON-VENOMOUS SNAKES[1]

Part I

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ABSTRACT

The bite patterns made by solenoglyphs (habu and bamboo snake) and proteroglyphs (krait and cobra) are easily distinguished: the small-teeth marks of the upper jaw in the patterns of proteroglyphs are on a level with the fang punctures, whereas in those of the solenoglyphs these marks are not. Distinguishing the patterns made by the habu and bamboo snake or krait and cobra is somewhat difficult, but a careful study of the distances between the fang punctures and the range of the size for each kind of snake recorded in the discussion make the distinction somewhat easy.

The almost perfect patterns were rarely produced because the sites bitten by the snake were not always favorably located for the bite. Clothing and swelling can obscure the picture.

By examination of the bite patterns and study of the symptoms caused by the different kinds of venoms (hemotoxic or neurotoxic), the physician may determine quickly which species the victim was attacked by.

The patterns of the non-venomous snakes are characterized by six rows of small teeth marks, four of them in one group, two of them in another.

It is well known that in many cases, the teeth marks left on the victim may greatly puzzle even an experienced herpetologist. In regard to this difficulty Pope and Perkins (1) stated that "Perfect interpretation of a bite is accomplished only by working out a clear picture of its pattern", and "A careful study of the bite may reveal the approximate location of the pocket of venom, the size of the snake and even its generic identity".

In view of the above statement, it is very important for the physician as well as the victim to know the bite patterns in order to render the kind of medical aid, hemotoxic or neurotoxic, proper for the occasion.

There are no available publications on Taiwan dealing with snake bite patterns. The purpose of this study is therefore to supply this need.

It includes the study of bite patterns of four common venomous snakes: 1) *Trimeresurus mucrosquamatus* (habu), 2) *Trimeresurus stejnegeri stejnegeri* (bamboo snake), 3) *Bungarus multicinctus* (krait), 4) *Naja*

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naja arta (cobra); and one non-venomous snake; 5) *Zaocys dhumnades oshimai* (Taiwan rat snake).

MATERIALS AND METHODS

The living snakes used for marking the bite patterns are shown in TABLE I:

TABLE I

Number, sex and measurement of living specimens used for bite patterns

Name of snake	No. of specimen	Sex	Locality	Total length (cm)
I. Habu	No. 1	♂	Puli	103.5
	No. 2	"	"	102.0
	No. 3	♀	Taipei	98.0
	No. 4	"	"	88.0
	No. 5	♂	Puli	83.0
II. Bamboo Snake	No. 1	♀	Puli	92.0
	No. 2	"	"	80.0
III. Krait	No. 1	♂	I-Lan	128.0
	No. 2	♀	"	96.0
	No. 3	"	"	89.0
IV. Cobra	No. 1	♀	Puli	119.0
	No. 2	"	"	118.0
	No. 3	♂	"	85.0
V. Taiwan Rat Snake	No. 1	♂	Puli	113.0*
	No. 2	"	"	124.0*
	No. 3	"	"	112.5*

* Snout to vent

In order to understand the bite patterns, it is necessary to know the normal dentition. Hence five skulls, one each of the above snakes, with their variation of the small-teeth counts, were prepared by the bacterial rotting method and then degreased in petroleum ether and bleached in a 3% solution of hydrogen peroxide.

To obtain the bite patterns, large cylinders of permoplast (dia. 4 cm, length 15 cm) representing the human wrist were used for the larger snakes, smaller cylinders (dia. 2.5 cm, length 15 cm) for the smaller ones (kraits). The cylinder was wrapped in a piece of very thin typing paper produced locally. Into one end of the cylinder, a bamboo handle about 50 cm long was inserted. The snake was taken out of its cage and placed on the floor. An assistant then held a cylinder horizontally or vertically in front of the snake. Not all snakes, especially the cobras, struck spontaneously; stimulation with electricity of 220V., A.C. for a few seconds was used in such cases. Usually, seizing the snakes with a long forceps (50 cm long) at some distance posterior to the neck, to simulate an accidental step, would produce the desired result. After the bite, the paper was flattened out on a glass-plate for photographing. In the same way, a hand (22 cm long, 10 cm broad, 2.5 cm thick) was modelled as an object for biting. If the punctures of the fangs and marks of about all the small teeth were on the paper the pattern was regarded as perfect.

RESULTS

I. *The Skull and Normal Dentition*

The cranial elements of the skull and the normal dentition for each snake are shown in *Figs. 1-10*. The normal dentition for each species is tabulated in the following tables, these symbols being used: I=Functional fang; +=Diastema; O=without small solid maxillary teeth at posterior end of the maxilla; L=Left; R=Right.

TABLE II

Number of teeth in T. mucrosquamatus

T. mucrosquamatus	Maxillary	Palatine	Pterygoid	Dentary
No. 10 ♀	I+0 (L.) I+0 (R.)	....	6 (L.) 6 (R.)	12 (L.) 11 (R.)
No. 17 ♂	I+0 (L.) I+0 (R.)	....	7 (L.) 7 (R.)	12 (L.) 11 (R.)
No. 50 ♀	I+0 (L.) I+0 (R.)	....	7 (L.) 7 (R.)	12 (L.) 12 (R.)
No. 646 ♂	I+0 (L.) I+0 (R.)	....	7 (L.) 7 (R.)	12 (L.) 12 (R.)
No. 647 ♀	I+0 (L.) I+0 (R.)	....	6 (L.) 6 (R.)	11 (L.) 11 (R.)

This species is characterized by the absence of palatine teeth. The maxilla bears one functional canalized fang only. Pterygoid teeth 6-7, subequal; dentary teeth 11-12, gradually decreasing in size posteriorly.

TABLE III

Number of teeth in T. s. stejnegeri

T. s. stejnegeri	Maxillary	Palatine	Pterygoid	Dentary
No. 1 ♂	I+0 (L.) I+0 (R.)	5 (L.) 5 (R.)	14 (L.) 15 (R.)	14 (L.) 13 (R.)
No. 2 ♀	I+0 (L.) I+0 (R.)	5 (L.) 5 (R.)	14 (L.) 15 (R.)	14 (L.) 14 (R.)
No. 3 ♀	I+0 (L.) I+0 (R.)	5 (L.) 5 (R.)	13 (L.) 14 (R.)	14 (L.) 13 (R.)
No. 4 ♂	I+0 (L.) I+0 (R.)	5 (L.) 5 (R.)	14 (L.) 13 (R.)	14 (L.) 14 (R.)
No. 5 ♂	I+0 (L.) I+0 (R.)	5 (L.) 5 (R.)	14 (L.) 14 (R.)	14 (L.) 14 (R.)

The maxilla bears one functional canalized fang only. Palatine teeth uniformly 5, subequal; pterygoid teeth 13-15, posterior ones smaller, others subequal; dentary teeth 13-14, gradually decreasing in size posteriorly.

TABLE IV

Number of teeth in B. multicinctus

B. multicinctus	Maxillary	Palatine	Pterygoid	Dentary
No. 9 ♂	I+4 (L.) I+4 (R.)	13 (L.) 12 (R.)	13 (L.) 12 (R.)	17 (L.) — (R.)
No. 71 ♂	I+4 (L.) I+3 (R.)	13 (L.) 13 (R.)	13 (L.) 13 (R.)	18 (L.) 18 (R.)
No. 72 ♂	I+4 (L.) I+3 (R.)	12 (L.) 13 (R.)	11 (L.) 12 (R.)	17 (L.) 17 (R.)
No. 73 ♀	I+4 (L.) I+4 (R.)	12 (L.) 12 (R.)	12 (L.) 11 (R.)	16 (L.) — (R.)
No. 649 ♀	I+4 (L.) I+4 (R.)	13 (L.) 13 (R.)	11 (L.) 12 (R.)	17 (L.) 17 (R.)

The maxilla bears one functional grooved fang at its anterior end and three or four small solid maxillary teeth at its posterior end; palatine teeth 12-13, subequal; pterygoid teeth 11-13, gradually decreasing in size posteriorly; dentary teeth 16-18, those at both ends smaller, others subequal in size. The maxillae (right maxillae of Nos. 71 and 72) with three solid maxillary teeth may be considered abnormal.

TABLE V

Number of teeth in N. n. atra

N. n. atra	Maxillary	Palatine	Pterygoid	Dentary
No. 43 ♀	I+1 (L.) I+1 (R.)	8 (L.) 7 (R.)	— (L.) — (R.)	14 (L.) 14 (R.)
No. 319 ♂	I+1 (L.) I+1 (R.)	8 (L.) - (R.)	17 (L.) 17 (R.)	14 (L.) — (R.)
No. 347 ♀	I+1 (L.) I+1 (R.)	8 (L.) 8 (R.)	16 (L.) 16 (R.)	14 (L.) — (R.)
No. 349 ♀	I+1 (L.) I+1 (R.)	7 (L.) - (R.)	16 (L.) 16 (R.)	14 (L.) 14 (R.)
No. 350 ♂	I+1 (L.) I+1 (R.)	7 (L.) 7 (R.)	17 (L.) 17 (R.)	14 (L.) 14 (R.)

The maxilla bears one functional grooved fang at its anterior end and one small solid maxiallary tooth at its posterior end. Palatine teeth 7-8, decreasing in size posteriorly; pterygoid teeth 16-17, those at both ends smaller, others subequal; dentary teeth 14, decreasing in size posteriorly.

TABLE VI
Number of teeth in Z. d. oshimai

Z. d. oshimai	Maxillary	Palatine	Pterygoid	Dentary
No. 630 ♂	26 (L.) 25 (R.)	20 (L.) 19 (R.)	24 (L.) 25 (R.)	26 (L.) 27 (R.)
No. 631 ♂	26 (L.) 26 (R.)	18 (L.) 19 (R.)	26 (L.) — (R.)	25 (L.) 25 (R.)
No. 632 ♂	26 (L.) 26 (R.)	— (L.) 19 (R.)	28 (L.) 28 (R.)	26 (L.) 26 (R.)
No. 648 ♂	26 (L.) 26 (R.)	20 (L.) 20 (R.)	— (L.) — (R.)	— (L.) — (R.)
No. 650 ♂	25 (L.) 25 (R.)	18 (L.) 19 (R.)	27 (L.) 27 (R.)	— (L.) — (R.)

The maxillary teeth 25-26, becoming gradually larger posteriorly; palatine teeth 18-20, those at both ends smaller, other subequal; pterygoid teeth 24-28, subequal anteriorly, but progressively smaller toward the rear; dentary teeth 25-27, gradually decreasing in size posteriorly.

II. The bite patterns

To obtain the satisfactory bite patterns, the experiment for each kind of snake had to be repeated more than 50 times. Tremendous variations were obtained. The results described below are the almost perfect and common patterns.

1. Bite patterns of habu

The cylinders (dia. 4 cm, length 15 cm) and hands (22 × 10 × 2.5 cm) were held horizontally or vertically in front of the snake.

Figs. 11-12 are almost perfect patterns; fang punctures and small-teeth marks of both jaws show. They were made by specimens No. 2 and No. 1, respectively, on a horizontal cylinder. In *Fig. 12,* the shaded area around the fang punctures represents spilled venom. If a snake was repeatedly used on the same day, the venom did not always appear at the last strike. The small-teeth marks of the left and right upper jaws in *Fig. 11* and the left only in *Fig. 12* are not well separated, clearly indicating that the upper jaws shifted downward and backward during the bite. The small-teeth marks (3 in number) of the right upper jaw in *Fig. 12* and those of each lower jaw in both pictures are distinct. No small-teeth marks of the upper jaws are seen in *Fig. 13,* which was produced by specimen No. 1 when biting a vertical cylinder. A few small-teeth marks of the lower jaws are present in this strike. Apparently it indicates that to bite a vertical object is somewhat difficulty, although the snake may tilt its head. In *Fig. 14,* only one fang puncture can be seen; it was made by specimen No. 3 biting a vertical cylinder. It is distinctly shown that this strike was a pure stab, not a bite, because there are no small-teeth marks of the upper and lower jaws. One can recognize immediately that in *Fig. 15* the subject was bitten twice. The lower two fang punctures and the left 3 small-teeth marks of the left upper jaw were produced by the first bite, then the upper jaw moved toward the right side and upward. Therefore the upper two fang punctures and the middle 4 and right 3 small-teeth marks were made by the second bite. During the second bite the lower jaws did not move. This pattern was produced by specimen No. 2 on a horizontal cylinder. *Fig. 16* was an almost perfect pattern on the palm and back of the hand, which was struck by specimen No. 3 biting a hand held horizontally.

2. Bite patterns of bamboo snake

For demonstration of the strike of the bamboo snake, most of the cylinders (dia. 4 cm, length 15 cm) were held horizontally.

Fig. 17, comparable to *Fig. 12,* may be recognized as an almost perfect pattern. Examination of the small-teeth marks of the upper jaws, gives an impression that the upper jaws scratched some during bite. The small-teeth marks of the lower jaws are distinct. This pattern was produced by specimen No. 2. In *Fig. 18,* only the small-teeth marks of the left upper jaw appear; no indication of the small-teeth marks of the right upper jaw can be found on the paper. The strike may have been so fast that the right upper jaw did not touch the paper. This pattern was made by specimen No. 1. The pattern seen in *Fig. 19* shows only two fang punctures; one can immediately see that it was a pure stab. And it was made by specimen No. 1 striking a vertical cylinder. *Fig. 20,* like *Fig. 15,* involves two bites by specimen No. 2.

3. Bite patterns of krait

Thinner cylinder (dia. 2.5 cm, length 15 cm) were used because the mouth of this species is comparatively small. All of the cylinders and hands (22 $\times$ 10 $\times$ 2.5 cm) were held horizontally.

Figs. 21 and *22,* based on specimens No. 1 and No. 2 respectively, may be recognized as almost perfect patterns. The patterns made by the krait are different from those produced by the first two kinds of snakes because some of the small-teeth marks of the upper jaws are on the same level as the fang punctures. In *Fig. 23,* two additional small-teeth marks behind each fang puncture can clearly be seen. No doubt they were caused by the small teeth behind the fang. As shown in the skull, generally there are four small teeth at the posterior end of the maxilla. The marks of the lower jaws show that the paper was torn. *Fig. 24* is an almost perfect pattern on the hand. The last two pictures were made by specimen No. 1.

4. Bite patterns of cobra

For convenience of strike, all of the cylinders (dia. 4 cm, length 15 cm) and hands (22 $\times$ 10 $\times$ 2.5 cm) were held horizontally.

Figs. 25 and *26* are almost perfect patterns. An additional small-tooth mark was found behind the right fang puncture in *Fig. 26.* This tooth mark might have been made by the small tooth at the posterior end of the maxilla. The presence of a small tooth on the maxilla is characteristic of this subspecies. One can immediately judge that *Fig. 27* was the result of a series of continuous bites. In both the upper and lower parts of this pattern, the lowest marks were made by the first bite. All of the above pictures were produced by specimen No. 1. The almost perfect patterns (*Fig. 28*) on the hand were produced by specimen No. 3.

5. Bite patterns of Taiwan rat snake

Fig. 29 is a near perfect bite pattern. It was produced by specimen No. 1 biting a cylinder (dia. 4 cm, length 15 cm) held horizontally. This pattern is characterized by the six rows of small-teeth marks, four of them in one group and two in another. It is not hard to understand the arrangement of this pattern, if one remembers the dentition of this snake.

In *Fig. 30,* there is an additional row of small-teeth marks on the left side of the upper group; the left upper jaw may have moved slightly toward the left during the attack. The small-teeth marks of the lower jaws are not discrete, obviously because the jaws were pulled upward. This pattern was also produced by specimen No. 1. The almost perfect pattern on the hand (*Fig. 31*) was produced by specimen No. 3.

It is of great interest to see the snakes actually biting the cylinders (*Figs. 32-35*).

DISCUSSION

First it must be explained why the bite patterns made by the habu and bamboo snake have the fang punctures a little anterior to the small-teeth marks of the upper jaw. According to Klauber (2), the fang tilting mechanism in rattlesnakes involves several bones, combining a sliding and hinge linkage. He diagramed and described the mechanism by which the change in the angle between the frontal-parietal-supratemporal and the quadrate tilts the maxilla with its fang forward into the biting position. Since the rattlesnakes, the habu and the bamboo snake all belong to the *solenoglypha,* the tilting mechanism in them is the same.

Fig. 36 shows a habu's fang erect and the position of some bones of the linkage. In examination of this picture, one can easily understand why the bite patterns of the solenoglyphs show the fang punctures anterior to the small-teeth marks of the upper jaw.

Bogert (3) stated that in cobras there is no perfect tilting mechanism, because the prefrontal is rigidly attached to the frontal and the maxilla is not hinged at its attachment to the prefrontal. In the present study, it was found that the attachment of the above bony elements in kraits is very similar to that of the cobra. Both the cobra and krait are members of *proteroglypha.* Because their maxilla is fixed and cannot be extended forward during the act of biting and because some of the palatine teeth are located on a level with the fangs (*Figs. 6* and *8*), some of the small-teeth marks are on a level with the fang punctures in the bite patterns.

The distance between the first small-tooth marks of the upper jaw and the fang punctures may be helpful in distinguishing the pattern made by the habu from that made by the bamboo snake. The absence of the palatine teeth is a unique feature of the habu's skull. Hence the distance between the first tooth mark of the upper jaw and the fang puncture is longer than that of the bamboo snake in the typical patterns, the skull of the bamboo snake possessing the palatine teeth, as shown in the following table.

TABLE VII

Distance between first tooth marks of upper jaw and fang puncture, and related body length in habu and bamboo snake

Name	No. of specimen	Distance (mm)	Body length (cm)
Habu	No. 1	10.0	103.5
	No. 2	10.0	102.0
	No. 4	7.8	88.0
	No. 5	7.8	83.0
Bamboo snake	No. 1	5.6	92.0
	No. 2	4.8	80.0

The total length of the bamboo snake on this island very rarely reaches 80 cm. According to Maki (4) the range for the adults is 47.3-77.7 cm. In Mao's record (5), the range for this snake is 43.1-74.8 cm. Consequently in most cases of its bites the distance between the first tooth mark of the upper jaw and the fang puncture will be smaller than the record here reported.

The distance between fang punctures may be used to distinguish the pattern made by the krait from that made by the cobra. In the same way, it will be also valuable to apply this characteristic to the patterns of the habu and bomboo snakes, as shown in the following table.

TABLE VIII

Distance between fang punctures correlated with body length for krait, cobra, habu and bamboo snake

Name	No. of specimen	Distance (mm)	Body length (cm)
Krait	No. 1	12.2	128.0
	No. 2	10.0	96.0
	No. 3	9.0	89.0
		Range 9.0-12.2	89.0-128.0
Cobra	No. 1	13.5	119.0
	No. 2	13.5	118.0
	No. 3	11.0	85.0
		Range 11.0-13.5	85.0-119.0
Habu	No. 1	18.2	103.5
	No. 2	18.2	102.0
	No. 3	17.6	98.0
	No. 4	14.6	88.0
	No. 5	12.0	83.0
		Range 12.0-18.2	83.0-103.5
Bamboo snake	No. 1	12.6	92.0
	No. 2	9.8	80.0
		Range 9.8-12.6	80.0-92.0

In the above table, the range of the distance between the fang punctures is 9.0-12.2 mm in the krait and 11.0-13.5 mm in the cobra. As to size, the dimension of both species listed in the table may be regarded as being in the normal range. Although Maki (4) recorded a krait as long as 167.0 cm, individuals of this length are rarely seen on this island. Omitting this large specimen and the young ones in his record, his adult range will be 40.4-139.8 cm. The normal range for the adult cobra in Mao's (6) record is 65.9-118.6 cm. Generally the habu is much bigger than the bamboo snake, therefore the distance between fang punctures in the habu should be greater (12.0-18.2 cm) than in the bamboo snake (9.8-12.6 cm). In most cases, the distance between fang punctures in the bamboo snake should be smaller than the range here reported, because individuals are generally smaller than those listed in the table mentioned previously.

In addition, the number of the small-teeth marks of the upper jaw may also be employed to differentiate the patterns of krait and cobra. In the results obtained, the patterns of the krait usually have more small-teeth marks of the upper jaw. This is apparently due to the krait's more numerous palatine teeth (12-13). In the cobra, the range of the palatine teeth is 7-8.

Finally it may be concluded that the bite patterns made by the solenoglyphs and proteroglyphs are easily distinguished by the small-teeth marks of the upper jaws. Distinguishing the bite patterns of the habu and bamboo snake or krait and cobra may be difficult for a layman or physician. However a careful study of the measurements of the distance between the fang punctures and of the dimensions of each kind of snake will be very helpful.

It must be emphasized here that the teeth marks left on the victim rarely show a perfect pattern. The snake seldom has a chance to bite under optimum conditions for itself. Clothing obscures the patterns in many cases, and so does swelling. Therefore the bitten area must be examined very carefully. Anyway, the bite patterns help the physician to confirm or determine the species, particularly if blostered by symptoms.

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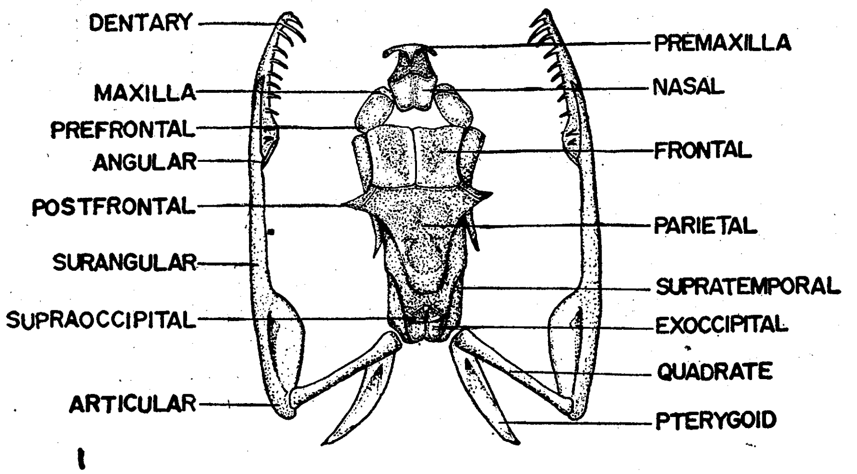
LEGEND OF FIGURES

Figs. 1-10. Dorsal and ventral views of cranial elements of the skull for each species of snakes *Figs. 1-2*, habu; *Figs. 3-4*, bamboo snake; *Figs. 5-6*, krait; *Figs. 7-8*, cobra; *Figs. 9-10*, Taiwan rat snake.

Figs. 11-31. Bite patterns. Natural size except those on the hands. See text for explanations. *Figs. 11-16*, habus; *Figs. 17-20*, bamboo snakes; *Figs. 21-24*, kraits; *Figs. 25-28*, cobras; *Figs. 29-31*, Taiwan rat snakes.

Figs. 32-35. Snakes biting the cylinders. *Fig. 32*, habu; *Fig. 33*, a habu (No. 3) in the act of extricating its fangs, when they sank deeply into the permoplst cylinder; *Fig. 34*, krait; *Fig. 35*, cobra.

Fig. 36. Showing the erect fang of a habu. See text for the tilting mechanism.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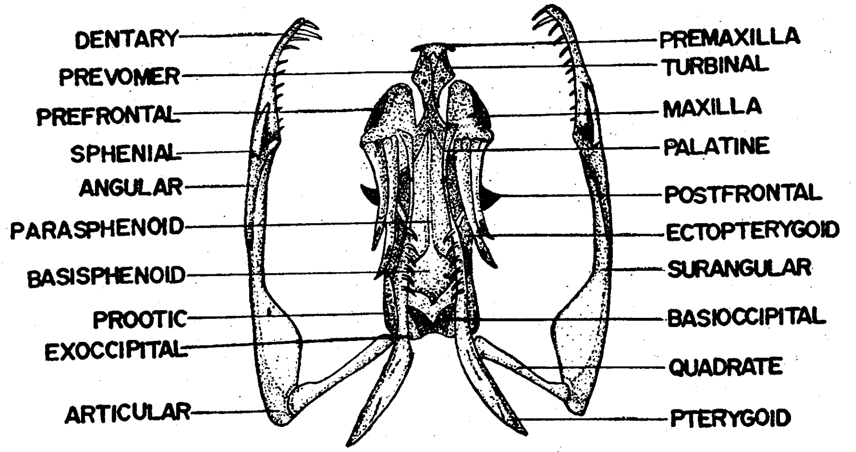
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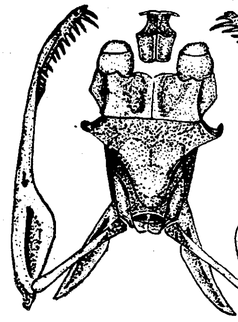

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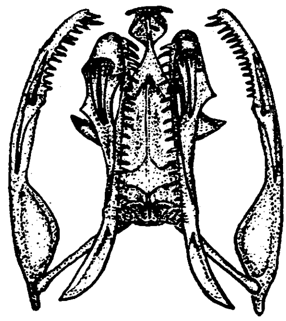

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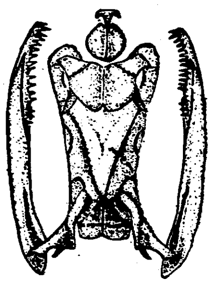

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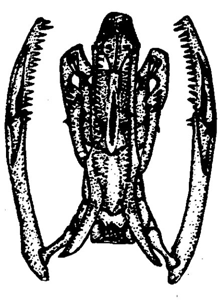

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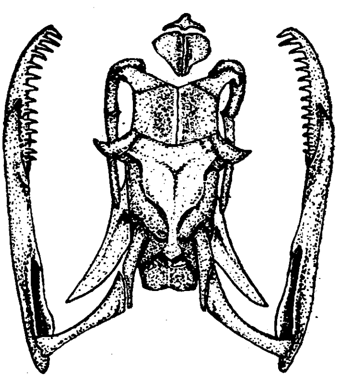

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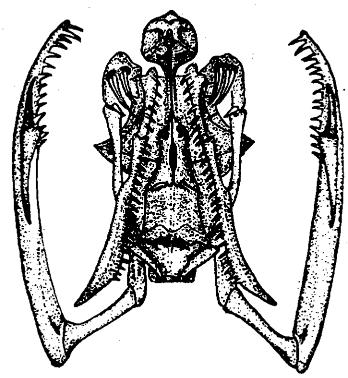

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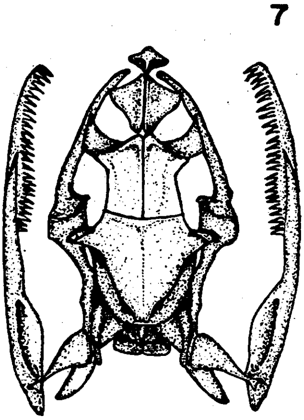

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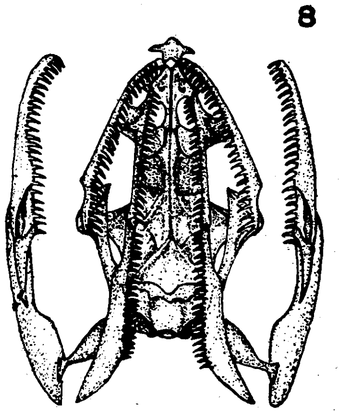

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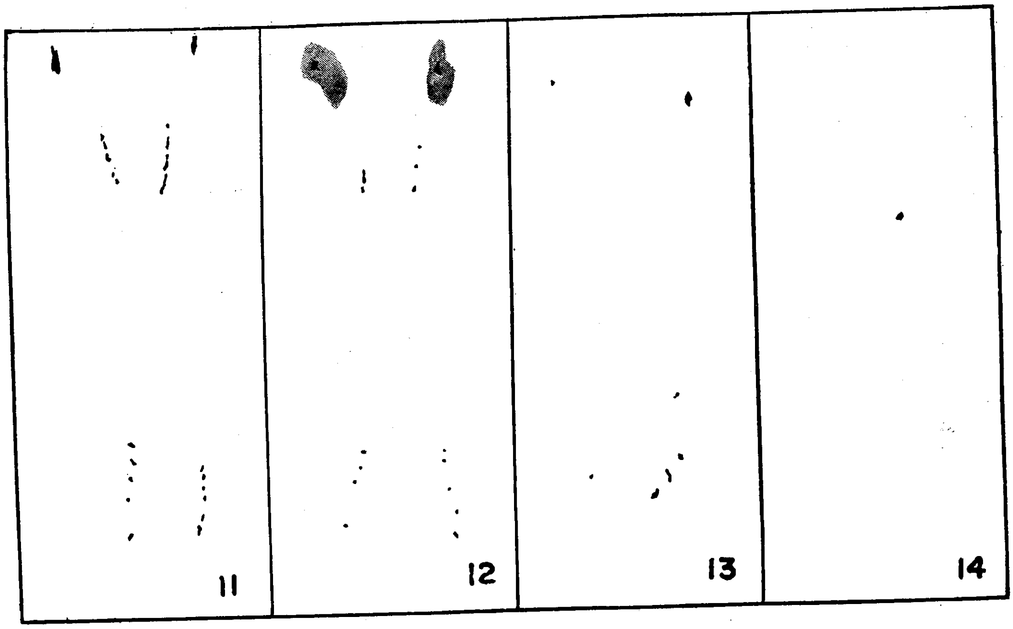

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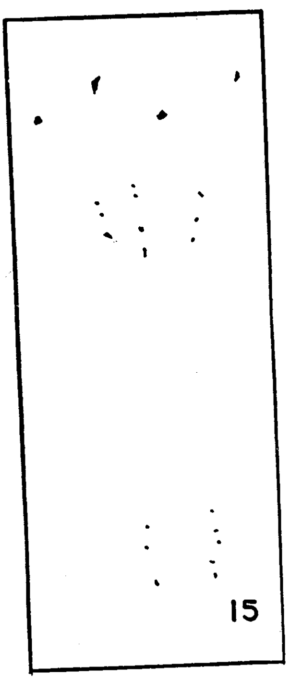

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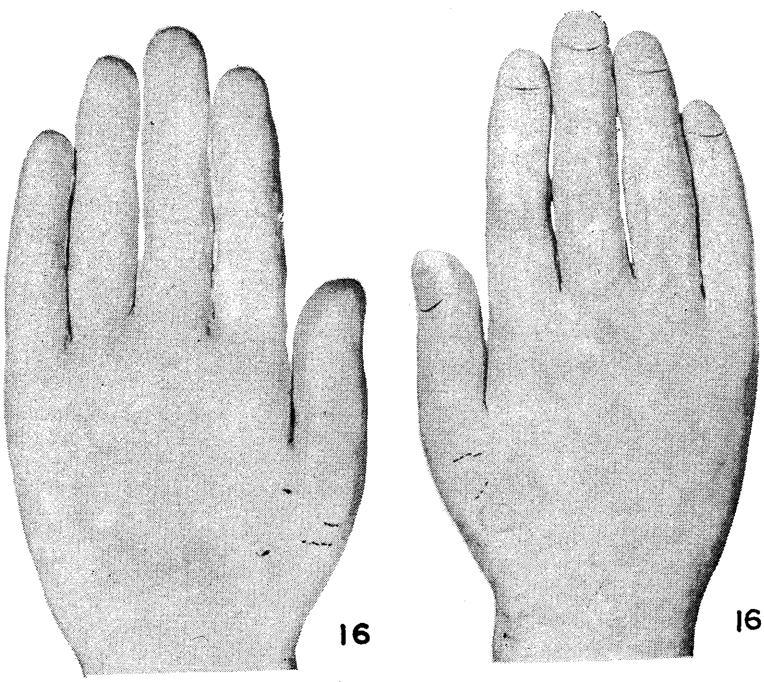

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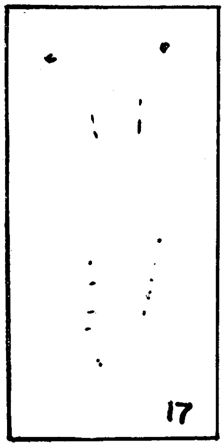

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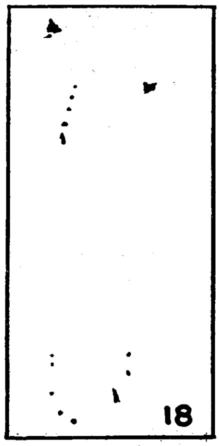

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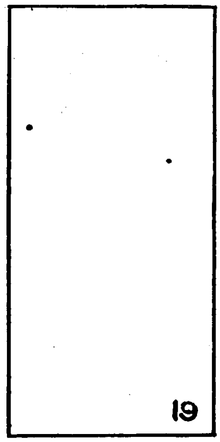

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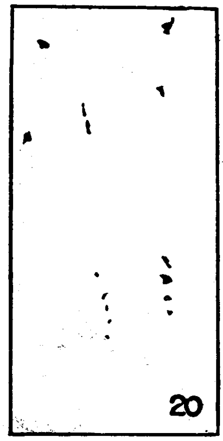

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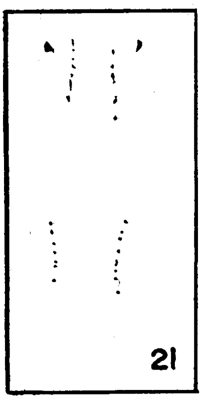

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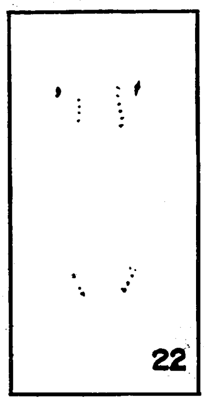

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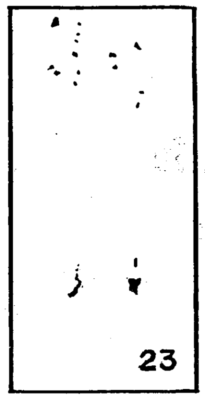

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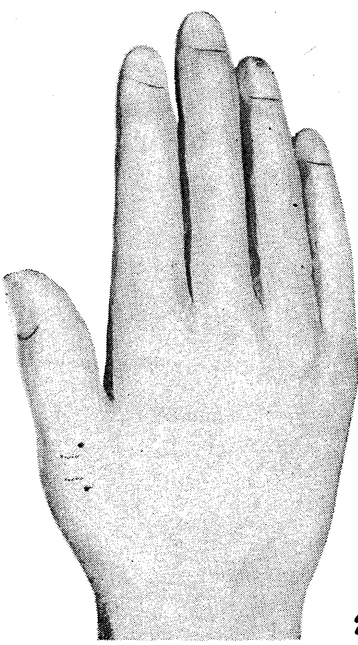

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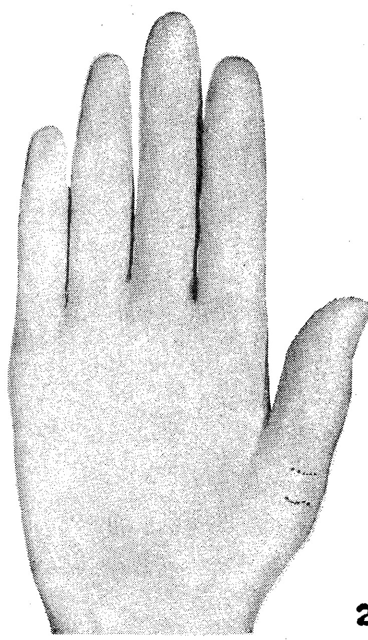

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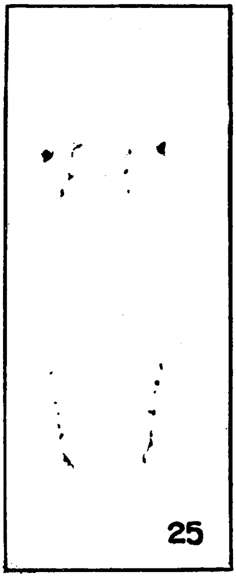

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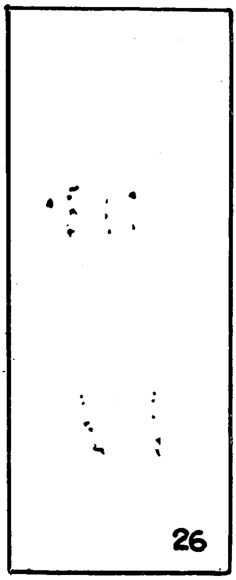

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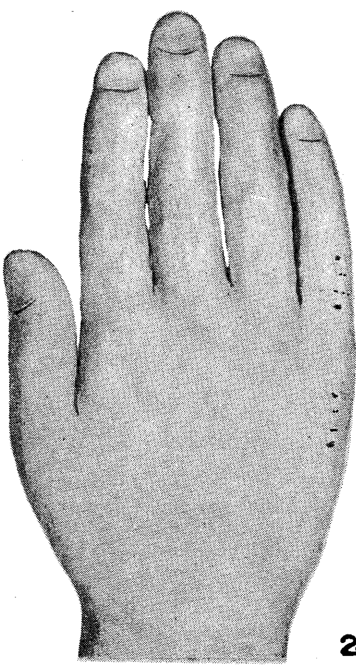

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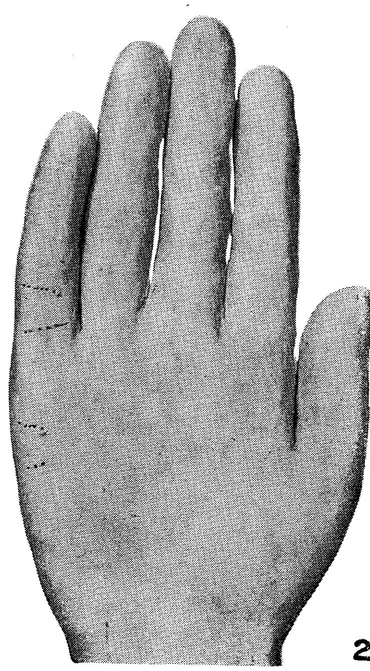

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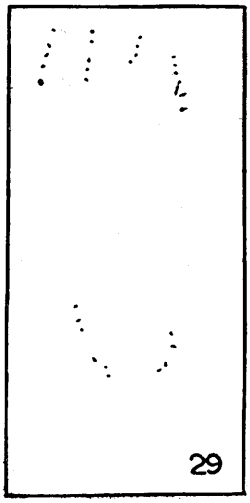

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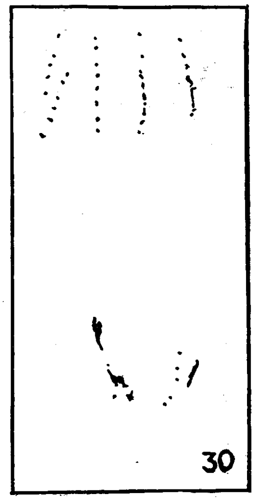

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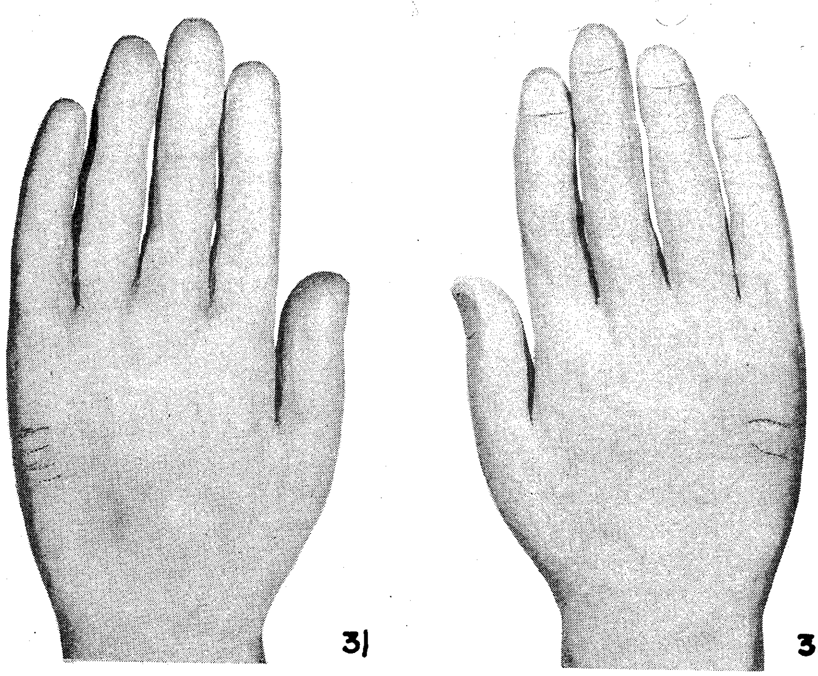

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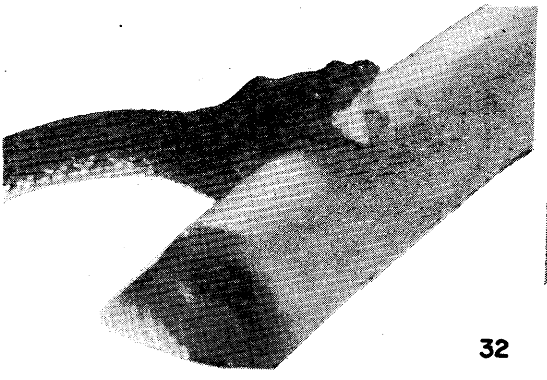

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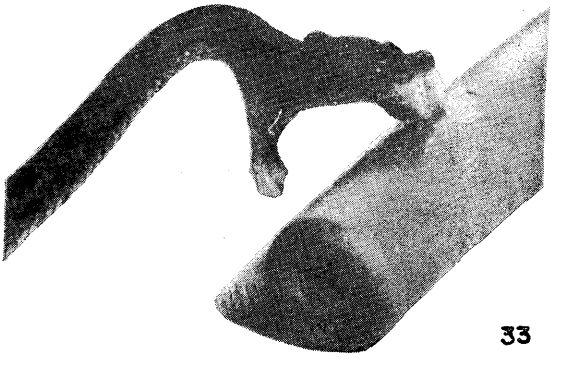

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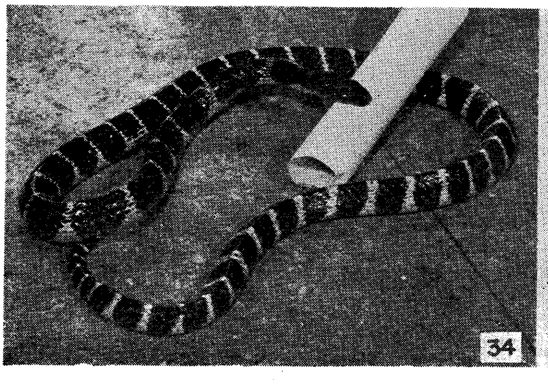

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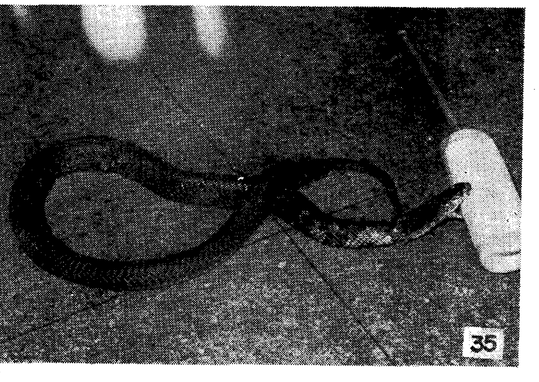

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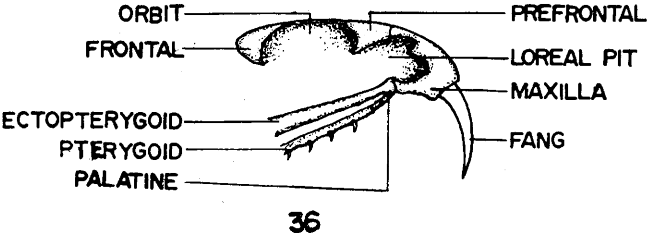
ORBIT
FRONTAL
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PTERYGOID
PALATINE
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LOREAL PIT
MAXILLA
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