

# RECORDS

of the

# INDIAN MUSEUM

(A JOURNAL OF INDIAN ZOOLOGY)

Vol. XXXIX, Part II

JULY, 1937

|                                                                                                                    | Page |
|--------------------------------------------------------------------------------------------------------------------|------|
| <b>Trois Cyclopides (Crustacés Copépodes) Nouveaux de l'Inde.</b>                                                  |      |
| <i>K. Lindberg</i> .. .. .                                                                                         | 99   |
| <b>On a Collection of Indian Earthworms of the family Lumbricidae.</b>                                             |      |
| <i>L. Černosvitov</i> .. .. .                                                                                      | 105  |
| <b>Notes on the Larva and Pupa of <i>Amphipsyche indica</i> Martinov</b>                                           |      |
| [Insecta : Trichoptera]. <i>H. A. Hafiz</i> .. .. .                                                                | 113  |
| <b>Changes in the Internal Structure of the Air-bladder of <i>Pangasius pangasius</i> (Ham.) during growth.</b>    |      |
| <i>K. Krishnan Nair</i> .. .. .                                                                                    | 117  |
| <b>On three Chalcidoid parasites of Cotton borer Beetles from South India.</b>                                     |      |
| <i>T. V. Ramakrishna Ayyar and M. S. Mani</i> .. .. .                                                              | 125  |
| <b>On a new species of <i>Neoechinorhynchus</i> parasitic on <i>Mugil cephalus</i> Linn. from the Chilka Lake.</b> |      |
| <i>T. N. Podder</i> .. .. .                                                                                        | 129  |
| <b>Skull of <i>Varanus monitor</i> (Linn.).</b>                                                                    |      |
| <i>K. N. Bahl</i> .. .. .                                                                                          | 133  |
| <b>Indian Earthworms. I. The Genus <i>Pheretima</i>.</b>                                                           |      |
| <i>G. E. Gates</i> .. .. .                                                                                         | 175  |

Calcutta :

PUBLISHED BY THE DIRECTOR, ZOOLOGICAL SURVEY OF INDIA

1937

Price Rupees Three and annas eight or six shillings

# TROIS CYCLOPIDES (CRUSTACÉS COPEPODES) NOUVEAUX DE L'INDE.

K. LINDBERG.

(Planches II et III.)

Dans son traité complet sur les cyclopidés paru en 1929 F. Kiefer donne une liste de 20 espèces du groupe *Varicans-Bicolor* rangées dans le sous-genre *Microcyclops* de Claus et caractérisées principalement par la cinquième patte n'étant formée que d'un seul article pourvu d'une soie ; une forte soie attachée au bord latéral du cinquième segment thoracique représentant celle de l'article basal disparu. A cette liste il faut joindre 8 espèces décrites pendant ces dernières années. De ce total de 28 il n'y a guère que 2 qui, autant qu'il soit connu à présent, sont des espèces cosmopolites, les autres ayant presque toutes été rapportées de régions tropicales et sous-tropicales et plus de la moitié, c'est-à-dire 15, de l'Afrique seule. En vue de ces chiffres il est assez surprenant que de ce groupe, qui semble particulièrement bien représenté dans les pays chauds, on n'en connaît encore que 3 espèces de la Péninsule Indienne, et, comme l'a fait déjà remarquer Kiefer, en ce qui concerne le *C. (M.) bicolor* et le *C. (M.) varicans*, rapportés par Sewell et par Gurney il n'est pas tout à fait certain qu'il s'est réellement agi des espèces typiques.

Au cours de récoltes récentes j'ai trouvé 2 espèces et une variété nouvelles appartenant à ce groupe, dont je donne ici la description.

## **Cyclops (Microcyclops) diminutus, sp. nov.**

*Description* — Très petite espèce, de forme trapue.

Longueur des deux femelles portant des ovisacs de 550  $\mu$  et de 570  $\mu$  ; largeur maxima de 190  $\mu$  et de 210  $\mu$ . Rapport entre la longueur du céphalothorax et celle de la queue (abdomen + furca sans soies apicales) de 1 à 2.2 et de 1 à 2.3. Rapport entre la longueur du céphalothorax et sa largeur de 1 à 1.82 et de 1 à 2. Longueur du premier segment céphalothoracique légèrement supérieure à sa largeur. Parties latérales du bord postérieur des deuxième, troisième et quatrième segments thoraciques légèrement prolongées en pointe, de sorte que ces segments sont bien délimités les uns des autres ; par contre, la limite est peu distincte entre le premier et le deuxième segments céphalothoraciques. Le cinquième segment thoracique porte une longue soie sur son bord latéral et celui-ci est prolongé et un peu élargi distalement. Premier segment abdominal un peu moins long que sa largeur proximale ; il présente dans sa partie proximale une forme arrondie et globuleuse dans le sens antéro-postérieur ; il se rétrécit graduellement dans sa partie distale. Longueur du segment génital inférieure à celle des trois segments abdominaux suivants réunis. Les deuxième et troisième segments abdominaux sont de longueur à peu près égale ;

le quatrième segment est considérablement moins long. Le bord distal du quatrième segment abdominal porte sur sa face ventrale une rangée continue de fines épines. L'opercule anal est de dimensions normales. Branches de la furca très légèrement divergentes. Leur longueur est de très peu inférieure à celle des troisième et quatrième segments abdominaux réunis ; chez l'un des animaux elles étaient de 2·7 fois aussi longues que larges, chez l'autre de 3·1 fois aussi longues que larges. La soie latérale externe divise la branche de la furca dans la proportion d'environ 47 à 15. La longueur des soies apicales était chez les deux spécimens (du dedans en dehors) 62 : (?) : 150 : 30 $\mu$  et 67 : (?) : 153 : 25 $\mu$ . La soie apicale externe est forte et courte, la soie apicale interne est plus de deux fois aussi longue que la soie apicale externe ; elle est très mince ; les deux soies apicales médianes sont bien développées ; la soie apicale médiane interne se trouvait cassée chez les deux animaux à une certaine distance de son extrémité ; son épaisseur montrait cependant qu'elle devait être considérablement plus longue que la soie apicale médiane externe. Première antenne à 10 articles ; rabattue elle dépasse légèrement le milieu du premier segment céphalothoracique ; le deuxième article est le plus court et le premier le plus long. Branches des pattes natatoires à 2 articles ; l'article terminal des exopodites est muni de 5 soies ; la formule des épines est de 3. 4. 4. 3. Article terminal de l'endopodite de la quatrième paire de pattes environ 3 fois aussi long que large ; il porte 3 soies sur son rebord interne et 2 épines apicales dont l'interne, déviée en dedans, est considérablement plus longue et plus forte que l'épine externe, leur longueur respective se trouvant chez les deux animaux dans le rapport de 1 à 0·6. L'épine apicale interne est moins que la moitié de la longueur de l'article qui la porte. Bord libre de la lamelle réunissant la base de la quatrième paire de pattes presque droit sans élevures latérales ; celui de la troisième paire est muni d'un petit tubercule de chaque côté. La cinquième patte n'est formée que d'une soie assez courte munie de très petits poils. Le réceptacle séminal ressemble à celui du *C. bicolor*, mais les bras latéraux de la partie distale sont plus longs que ceux de la partie proximale. Les ovisacs sont accolés contre l'abdomen et ne dépassent pas l'extrémité de la furca.

Oeufs relativement grands mais peu nombreux, de 4 à 6 dans chaque sac. La couleur n'a pas été observée, les animaux n'ayant été examinés qu'après la mort. Mâle inconnu. (Figs. 1, 2, 3, 4, 5).

*Habitat*.—Un étang, à végétation aquatique très abondante, à Cansaulim (Goa) Inde Portugaise. Récolté au mois de novembre.

*Remarques*.—Par suite de la structure de la cinquième patte, se réduisant à une seule soie, il s'agit d'un membre du sousgenre *Microcyclops* de Claus du genre *Cyclops*, Müller. Il se rapproche le plus du *C. (M.) attenuatus* Sars, mais s'en différencie par les branches de la furca étant considérablement plus courtes et inférieures en longueur à celle des troisième et quatrième segments abdominaux réunis. Il s'en distingue aussi par la configuration différente du segment génital dont la largeur proximale est notablement plus grande que la largeur distale et enfin par le rapport différent entre la longueur des épines apicales de l'enp. 4.

**Cyclops (Microcyclops) tricolor, sp. nov.**

*Description.*—Petite espèce de forme trapue ; longueur de la femelle adulte de 665  $\mu$  à 715  $\mu$  ; largeur dépassant un peu le tiers de la longueur totale du corps ; céphalothorax formant environ les deux tiers de la longueur du corps, et la queue (abdomen + furca sans soies apicales) un tiers. Céphalothorax de forme ovoïde à l'état vivant ; chez les animaux tués à la formaline il devient un peu plus allongé ; il est à peu près 2 fois aussi long que large (chez 3 femelles adultes ce rapport était de 1.84 : 1, 2 : 1, 2 : 1). Premier segment céphalothoracique considérablement plus long que large. Limites entre les bords latéraux des segments céphalothoraciques beaucoup moins prononcées que chez l'espèce précédente. Cinquième segment thoracique portant de chaque côté une longue soie munie de poils ; bord latéral ne présentant qu'une faible ébauche de prolongement distal. Largeur proximale du segment génital surpassant la longueur du segment ; il se rétrécit graduellement du côté distal. Proximale, l'épaisseur du segment génital dans le sens antéro-postérieur, de même que celle du céphalothorax, est considérable, donnant un aspect fortement globuleux à ces parties du corps. Longueur du segment génital légèrement inférieure à celle des 3 segments abdominaux suivants réunis. Les deuxième et troisième segments abdominaux sont de longueur à peu près égale entre eux ; le quatrième est de longueur moindre. Rebord distal du quatrième segment abdominal portant sur sa face ventrale une rangée de petites épines. Opercule anal de dimensions normales. Branches de la furca nettement divergentes. Elles surpassent en longueur celle des troisième et quatrième segments abdominaux réunis. Elles sont environ 3 fois aussi longues que larges. La soie latérale externe divise la branche de la furca dans la proportion d'environ 64 à 18. La soie apicale externe est forte et assez courte ; la soie apicale interne est un peu plus de deux fois aussi longue et très mince ; les deux soies apicales médianes sont bien développées. La longueur des soies apicales était chez deux spécimens (du dedans au dehors) : 92, 225, 175, 43  $\mu$  et 87, 218, 173, 42  $\mu$ . Première antenne à 11 articles ; rabattue elle dépasse le milieu du premier segment céphalothoracique ; le cinquième est l'article le plus court et le premier le plus long. Branches des pattes natatoires bi-articulées. La formule des épines est de 3. 4. 4. 3 ; le nombre des soies de l'article terminal des exopodites est de 5. Article terminal de l'endopodite de la quatrième paire de pattes environ 3 fois aussi long que large ; épine apicale interne longue et forte, toujours plus de 3 fois aussi longue que l'épine apicale externe, elle atteint parfois 4 fois la longueur de celle-ci. Les deux soies proximales du rebord interne de l'article terminal sont assez courtes ; la longueur de l'épine apicale interne surpasse la moitié de la longueur de l'article. Le bord libre de la lamelle réunissant la quatrième paire des pattes est presque droit ; il présente des élevures latérales au niveau des autres paires. Cinquième patte formée seulement d'une soie munie de petits poils. Réceptacle séminal ressemblant dans les grandes lignes à celui de l'espèce précédente. Ovisacs accolés contre l'abdomen, n'atteignant pas l'extrémité de la furca ; ils contiennent chacun de 6 à 10 oeufs, assez gros. Couleur bigarrée jaune—orange dans les parties centrales du

céphalothorax, noirâtre et rose—saumon ailleurs ; oeufs très foncés, vert—noir. Mâle inconnu (Figs. 6, 7, 8, 9, 10).

*Habitat.*—Récolté au mois de novembre en très petit nombre, dans une carrière abandonnée, remplie d'eau, à surface couverte de *Lemna* à Pandharpour (Deccan), en compagnie de *M. leuckarti* et de *M. rylovi vermifer*.

*Remarques.*—La seule espèce dont se rapproche le *C. (M.) tricolor* est le *C. (M.) linjanticus*, Kiefer, récolté dans l'Afrique du Sud. Il s'en distingue par les caractères indiqués au tableau comparatif ci-dessous.

*C. LINJANTICUS.*

*C. TRICOLOR.*

|                                                                              |                                                                                                                                                       |
|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| Branches de la furca 3-5 fois aussi longues que larges.                      | Branches de la furca plus courtes ; environ 3 fois aussi longues que larges.                                                                          |
| Soie apicale médiane interne 4 fois aussi longue qu'une branche de la furca. | Soie apicale médiane interne n'atteint pas 4 fois la longueur d'une branche de la furca.                                                              |
| Ressemble beaucoup dans sa configuration à <i>C. bicolor</i> .               | Se distingue nettement du <i>C. bicolor</i> tant par la configuration du cinquième segment thoracique que par celle de la furca et de ses appendices. |

**Cyclops (Microcyclops) varicans, pachyspina, subsp. nov.**

*Description.*—Espèce relativement grande et robuste. Longueur de la femelle adulte de 700  $\mu$  à 760  $\mu$  ; largeur de 280  $\mu$  à 285  $\mu$ . Rapport entre la longueur du céphalothorax et celle de la queue de 1.76 : 1 à 2.2 : 1. Rapport entre la longueur et la largeur du céphalothorax de 1.60 : 1 à 1.73 : 1. Longueur du premier segment céphalothoracique inférieure ou égale à sa largeur ; il dépasse en longueur celle des 4 segments suivants réunis. Cinquième segment thoracique portant sur le rebord latéral une longue soie courbée. Premier segment abdominal moins long que large proximalelement ; il se rétrécit graduellement dans sa partie distale ; sa longueur est inférieure à celle des 3 segments abdominaux suivants réunis. Branches de la furca parallèles ou très légèrement divergentes ; elles surpassent un peu la longueur des troisième et quatrième segments abdominaux réunis. Le rapport entre leur longueur et leur largeur est de 3.2 : 1 à 3.6 : 1. La soie apicale externe est forte et relativement longue ; la soie apicale interne est très mince et considérablement moins que 2 fois la longueur de la soie apicale externe. La longueur des soies apicales était chez trois femelles adultes (du dedans au dehors) : 63, 342, 217, 37  $\mu$  ; 67, 342, 234, 47  $\mu$  ; 77, 334, 234, 47  $\mu$ . Pennation des soies médianes hétéronyme (de même que chez les deux espèces précédantes). Première antenne à 12 articles ; les troisième et sixième sont les plus courts, et les premier, huitième et neuvième les plus longs. Rabattue, la première antenne atteint le rebord postérieur du premier segment céphalothoracique. Branches des pattes natatoires bi-articulées ; formule des épines de 3. 4. 4. 3. Article terminal de l'endopodite de la quatrième paire des pattes plus de 3 fois et près de 3 fois et demi aussi long que large ; ce rapport étant le plus souvent de 3.4 : 1. Epine apicale interne très fortement élargie dans sa partie proximale ; elle est notablement plus courte que l'article

qui la porte ; ce rapport étant de 1 : 1.52 à 1 : 1.62. Epine apicale externe beaucoup moins bien développée. Le rapport entre la longueur de l'épine apicale interne et celle de l'épine apicale externe est environ de 1.6 : 1 à 1.7 : 1. Cinquième patte formée seulement d'une soie pennée attachée à un article basal bien développé. Je n'ai pas observé d'épine sur le rebord interne de l'article. Réceptacle séminal ressemblant dans les grandes lignes à celui du *C. (M.) varicans*. Ovisacs dirigés au dehors et pouvant dépasser l'extrémité de la furca ; ils contiennent chacun de 15 à 18 oeufs de grosseur moyenne. La couleur n'a pas été observée à l'état vivant. Mâle inconnu. (Figures 11, 12, 13, 14, 15).

*Habitat*.—L'étang à Cansaulim (Goa) dans lequel fut trouvé le *C. (M.) diminutus* déjà décrit. Seulement quatre femelles adultes furent récoltées dans le mois de novembre.

*Remarques*.—Le microcyclope qui vient d'être décrit se rapproche beaucoup du *C. (M.) varicans* mais s'en distingue notamment par la configuration de l'article terminal de l'enp. 4 qui est plus allongé, et par la structure très particulière de l'épine apicale interne de cet article, cette épine étant très fortement épaissie dans sa partie proximale.

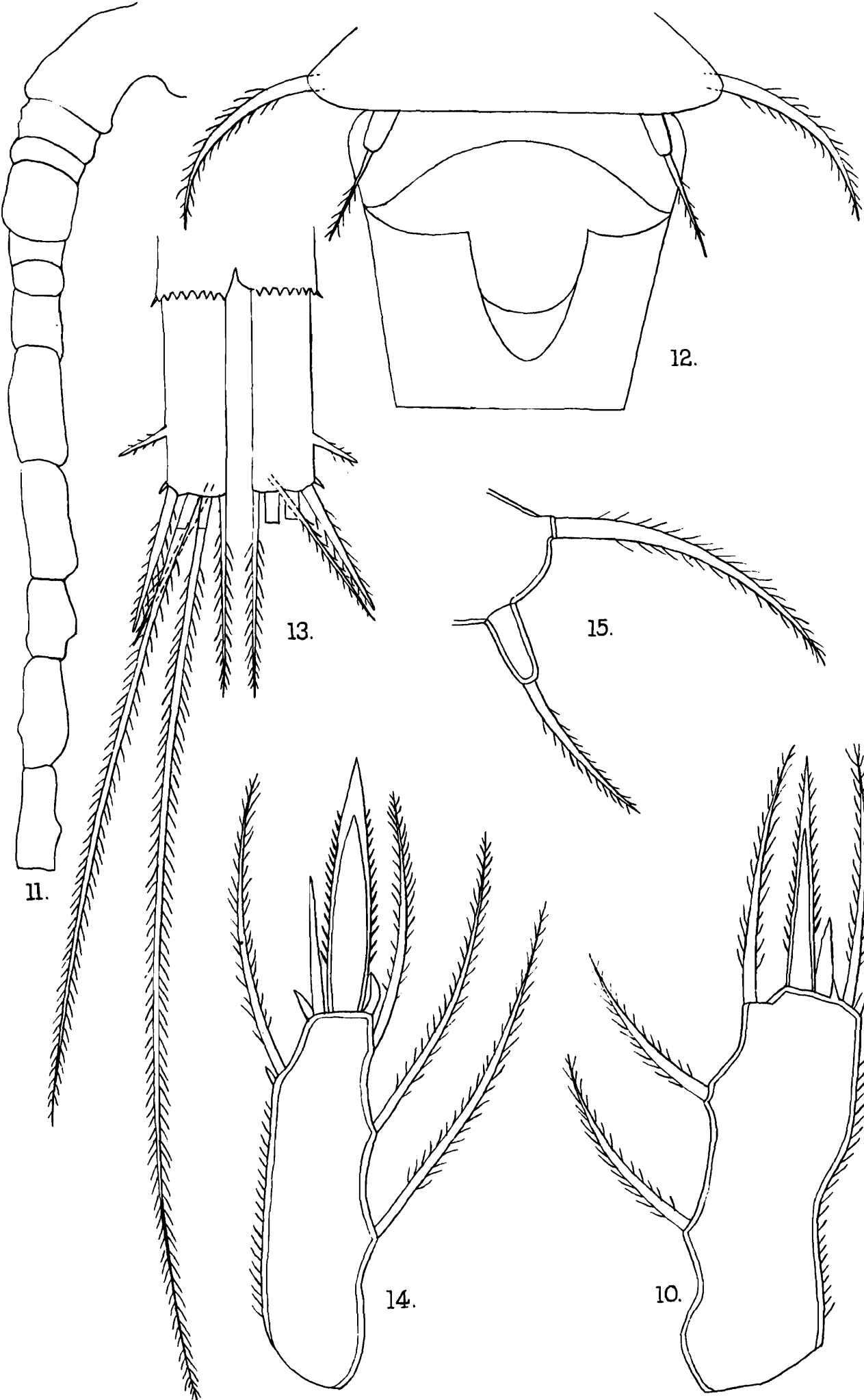
#### Planche II.

- |                             |                                                             |
|-----------------------------|-------------------------------------------------------------|
| 1. <i>C. (M.) diminutus</i> | ♀ Première antenne.                                         |
| 2. <i>C. (M.) diminutus</i> | ♀ Segment génital.                                          |
| 3. <i>C. (M.) diminutus</i> | ♀ Furca.                                                    |
| 4. <i>C. (M.) diminutus</i> | ♀ Lamelle réunissant base de la troisième paire des pattes. |
| 5. <i>C. (M.) diminutus</i> | ♀ Article terminal de l'enp. 4.                             |
| 6. <i>C. (M.) tricolor</i>  | ♀ Première antenne.                                         |
| 7. <i>C. (M.) tricolor</i>  | ♀ Segment génital.                                          |
| 8. <i>C. (M.) tricolor</i>  | ♀ Furca.                                                    |
| 9. <i>C. (M.) tricolor</i>  | ♀ Première paire des pattes.                                |

#### Planche III.

- |                                                      |                                 |
|------------------------------------------------------|---------------------------------|
| 10. <i>C. (M.) tricolor</i>                          | ♀ Article terminal de l'enp. 4. |
| 11. <i>C. (M.) varicans</i> var. <i>pa-chyospina</i> | ♀ Première antenne.             |
| 12. <i>C. (M.) varicans</i> var. <i>pa-chyospina</i> | ♀ Segment génital.              |
| 13. <i>C. (M.) varicans</i> var. <i>pa-chyospina</i> | ♀ Furca.                        |
| 14. <i>C. (M.) varicans</i> var. <i>pa-chyospina</i> | ♀ Article terminal de l'enp. 4. |
| 15. <i>C. (M.) varicans</i> var. <i>pa-chyospina</i> | ♀ Cinquième patte.              |





# ON A COLLECTION OF INDIAN EARTHWORMS OF THE FAMILY LUMBRICIDAE.

By DR. L. CERNOSVITOV, *Zoological Institute, Charles University, Prague.*

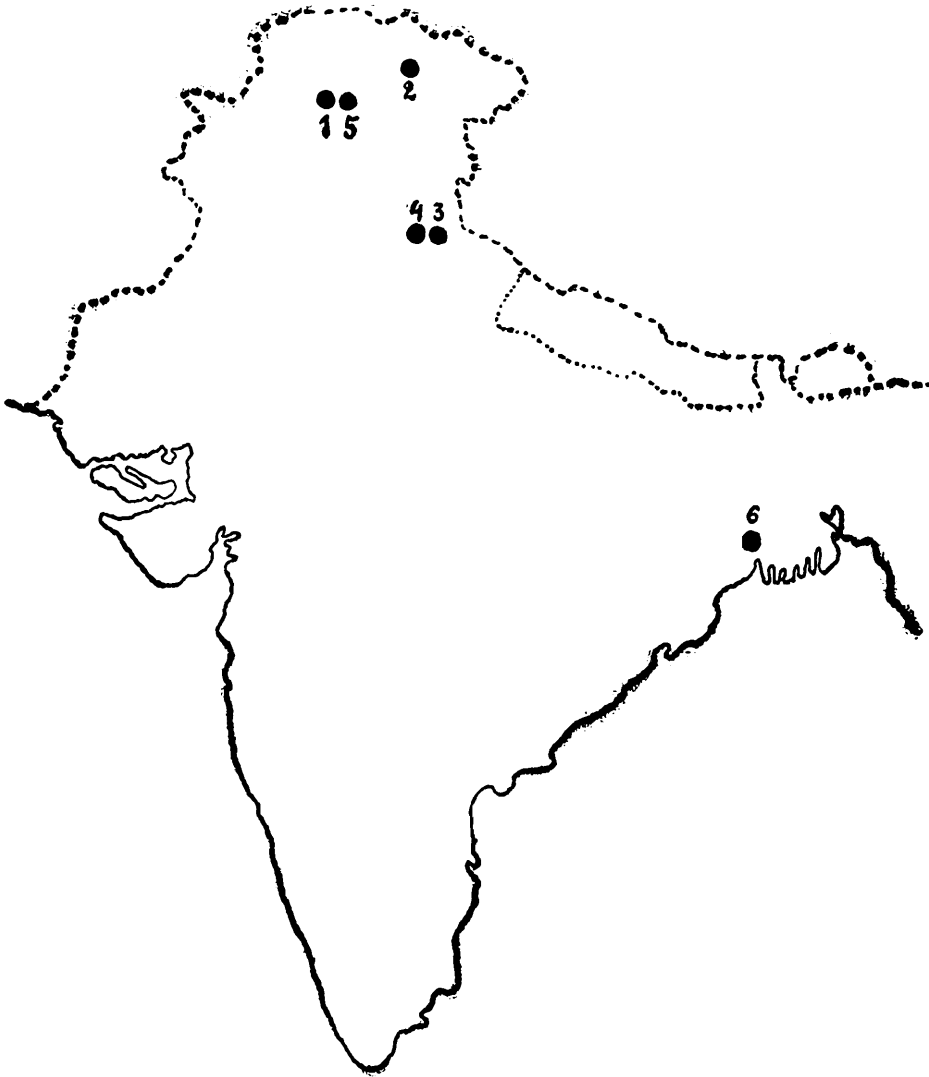
Terrestrial forms constitute the bulk of Indian Oligochaete fauna. All the Indian families, with the exception of the family Lumbricidae, belong to tropical families, which show a connection of the Indian fauna with Australia and New Zealand (all Megascolecidae), Malay Archipelago (the genera *Pheretima* and *Desmogaster*), Madagascar (the genus *Howascolex*), Africa (the genera *Gordiodrilus* and *Dichogaster*) and Central America (the family Diplocardiidae). The territory of the endemic species of the family Lumbricidae includes Middle and Central Europe, North Africa and a part of North America (the eastern part of the United States). In Asia endemic species are known from Palestine, Syria, Turkey, Persia, Caucasus, Turkestan, Tian-Shan, Tibet, Japan and India.

The northern limit of the territory of endemic species of Lumbricidae in North America and Europe coincides with the limit of glaciation during the Ice Age, and their present-day distribution may be explained by the influence of the ice cap which covered the northern part of Europe and North America (Michaelsen 1903, Černosvitov 1932 ; 1935a). The exact limits of the Lumbricid territory in Asia are not well known and the study of any fresh material, therefore, is not without interest. A few endemic species of Lumbricidae are known from Tian-Shan, Tibet and Japan. The Indian fauna includes only 4 such species—*Bimastus indicus* (Mich.), *Eophila mariensis* (Steph.), *Dendrobaena kempfi* (Steph.) and *Allolobophora prashadi* (Steph.). They are all concentrated in the Himalayas and the range of only one—*Bimastus indicus* (Mich.)—extends as far as Calcutta. This species is considered by Stephensen (1923, 1930) as the southernmost outpost of Lumbricidae, having spread in a southerly direction from the north—the Himalayas proper representing the line of separation between the Palaearctic and Oriental faunas of Earthworms.

In the following pages I deal with a collection of Lumbricidae belonging to the Indian Museum. My thanks are due to Dr. B. Prashad, Director of the Zoological Survey of India, for the opportunity of examining it.

Amongst the 11 species identified there are two peregrine species which are recorded for the first time from India ; these are *Eiseniella tetraedra* (Sav.) f. *typica* and *Octolasion cyaneum* (Sav.). Two other—*Allolobophora jassyiensis* (Mich.) and *Eophila himalayana*, sp. nov.—are apparently Palaearctic forms, though the latter may be endemic in India ; both the species, however, are found in Western Himalayas (Punjab)

and this supports the general conclusions of Stephenson on the distribution of Indian Lumbricidae (*vide* map, text-fig. 1).



TEXT-FIG. 1.—Map showing the distribution of endemic Indian Lumbricidae: 1. *Allolobophora jassysensis*, 2. *Allolobophora prashadi*, 3. *Dendrobaena kempfi*, 4. *Eophila himalayana*, 5. *Eophila mariensis*, and 6. *Bimastus indicus*.

In the following list of the Indian Lumbricidae species marked with an asterisk are truly endemic species, while the others are the so-called peregrine species which are widely distributed almost all over the world, and are, therefore, of no importance in zoogeographic discussions.

*List of Indian Lumbricidae.*

- Eiseniella tetraedra* (Sav.) forma *typica*.
- Eisenia foetida* (Sav.).
- Eisenia rosea* (Sav.).
- Dendrobaena rubida* (Sav.).
- Dendrobaena subrubicunda* (Eisen).
- \* *Dendrobaena kempfi* (Steph.).
- Allolobophora caliginosa* (Sav.) forma *typica*.
- Allolobophora caliginosa* (Sav.) forma *trapezoides* (A. Dug.).
- \* *Allolobophora prashadi* (Steph.).

- \* *Allolobophora jassyensis* (Mich.).
- \* *Eophila mariensis* (Steph.).
- \* *Eophila himalayana*, sp. nov.
- Bimastus tenuis* (Eisen).
- Bimastus eiseni* (Lev.).
- Bimastus parvus* (Eisen).
- \* *Bimastus indicus* (Mich.).
- Octolasion lacteum* (Örley).
- Octolasion cyaneum* (Sav.).
- Lumbricus rubellus* Hoffm.

**Eiseniella tetraedra** (Sav.) forma **typica**.

- Kumaon Hills, Dhobi Ghat, 2 miles east of P. W. D. Bungalow. Dr. H. S. Pruthi coll., 2 specimens.
- Kumaon Hills, The Lake, Naini Tal; alt. 6,359 ft. Dr. H. S. Pruthi coll., 2 specimens.

This species has not been recorded from India but is widely distributed all over. One of the specimens examined had a regenerated anterior part of the body: the male pores were situated on segment xii and the clitellum on segments xxi-xxvi.

**Eisenia foetida** (Sav.).

- Kodaikanal, Palni Hills, S. India. Dr. S. L. Hora coll., 19+11+37 specimens.
- Kodaikanal, Palni Hills, S. India—from dung heap. Dr. S. L. Hora coll., 34+33 specimens.
- Kodaikanal, Palni Hills, S. India—along edge of a stream near Golf Link on way to Pillar Rocks. Dr. S. L. Hora coll., 41 mostly mature specimens.
- Fern Hills, Nilgiris, S. India. Dr. S. L. Hora coll., 21 specimens.
- Simla, W. Himalayas; alt. 6,000—7,000 ft. Dr. B. Chopra coll., 7+3 specimens.
- Dharmasala, Punjab—from a heap of cow-dung. Dr. S. L. Hora coll., 4 specimens.

**Eisenia rosea** (Sav.).

- Cart Road, Murree, W. Himalayas, Punjab. Dr. H. S. Pruthi coll., 5 specimens.
- Dhar, Murree Sub-Divn., W. Himalayas, Punjab. Dr. H. S. Pruthi coll., 1 specimen.
- Simla, W. Himalayas. 1 specimen.
- Kodaikanal, Palni Hills, S. India—on the way to Pillar Rocks. Dr. S. L. Hora coll., 1 not fully mature specimen.
- Rambhur River bank at Rambhur, Rambhur Valley, Chitral. Dr. B. Chopra coll., 1 specimen not fully mature.

**Dendrobaena subrubicunda** (Eisen).

- Simla, W. Himalayas; alt. 6,000—7,000 ft. Dr. B. Chopra coll., 2 specimens.

The two specimens examined differ in some respects from the European individuals, chiefly in the arrangement of the setae. This species has been recorded from India and is widely distributed in other parts of the world (Europe, Siberia, North and South America), and I am, therefore, not inclined to regard the two aberrant specimens from India as representing a new variety. I include a brief description of these specimens for future reference.

Length 82 and 76 mm. Segments 114. Prostomium epilobous ( $\frac{1}{2}$ ) or almost tanylobous. Anterior part of the body compressed dorso-ventrally, posterior end rounded. Skin pigmented strongly only on dorsal surface, posterior end very slightly pigmented. Setae widely paired,  $ab=cd$ ,  $aa=2ab$ ,  $bc=1\frac{1}{2} ab$  (in European specimens  $bc=2cd$ ,  $cd=ab$ ,  $aa=1\frac{2}{3} ab$ .) Ventral surface of segment xvi is glandular and the setae  $ab$  are situated on prominent papillae. Clitellum on segments xxvi-xxxi. Tubercula of puberty on segments xxviii-xxx.

***Allolobophora caliginosa* (Sav.) forma *trapezoides* (A. Dug.).**

- Fern Hills, Nilgiris, S. India. Dr. S. L. Hora coll., 1 specimen.  
 Bara Hotar, Murree Sub-Divn., W. Himalayas, Punjab—under stones.  
 Dr. H. S. Pruthi coll., 1 specimen.  
 On hills sides at Jotla, Kangra Dist., Punjab—under stones. Dr. S. L. Hora coll., 1 specimen.  
 Kufri, Simla Hills, W. Himalayas; alt. 8,400 ft. Dr. B. Chopra coll., 15 specimens.  
 Simla, W. Himalayas: alt. 6,999—7,000 ft. Dr. B. Chopra coll., 4 specimens.  
 Asni River near Junga, Simla Hills, W. Himalayas; alt. 4,000 ft. Dr. B. Chopra coll., 1 specimen.  
 Simla, W. Himalayas. 3 specimens.  
 Kunusk, Chitral. Dr. B. Chopra coll., 17 specimens.  
 Rambhur River bank at Rambhur, Rambhur Valley, Chitral. Dr. B. Chopra coll., 1 specimen.  
 Under stones along banks of an irrigation channel off the Pallarga stream close to its junction with the Rambhur River, Rambhur Valley, Chitral.  
 Dr. B. Chopra coll., 17 specimens.  
 A cultivated field near Uts or "Hot Springs", Lutkuh Valley, Chitral.  
 Dr. B. Chopra coll., 21 specimens.  
 Under stones along banks of a small stream above Charun, Mastuj Valley, Chitral. Dr. B. Chopra coll., 1 specimen.  
 Ramram Gol below Arandu, Chitral. Dr. B. Chopra coll., 1 specimen.

In the large number of specimens from Chitral the spermathecae are obliterated in the muscle sheath. In dissections such specimens presented no spermathecae, but these were discovered in sections of the body wall. Such a case I described recently (1935b) in *Eophila cryptocystis* and Pool (1936) has shown that *Allolobophora dubiosa* (Örley) which was described as having no spermathecae really has these organs, but they are embedded in the muscles of the body wall. That permits us to doubt if in other species such as *Allolobophora acystis* (Mich.), *A. prashadi* (Steph.), *A. ribaucourti* Bretsch., *A. agatschiensis* Mich., and some others, the spermathecae are not so deeply embedded in the muscles that they cannot be seen in dissected specimens.

***Allolobophora jassyensis* (Mich.).**

- Topa, Murree Sub-Divn., W. Himalayas, Punjab; alt. 7,250 ft.—under stones.  
 Dr. H. S. Pruthi coll., 2 specimens.

This species is widely distributed. We have no records about the occurrence of *A. jassyensis* from India, but it is known from Europe [Rumania (Jassy), Switzerland, South Russia (Mariupol Dist.)], Palestine, Egypt (Cairo), Turkestan (Tashkent), Caucasus (Baku, Lenkoran Dist.) and West Tian-Shan (Pokem River).

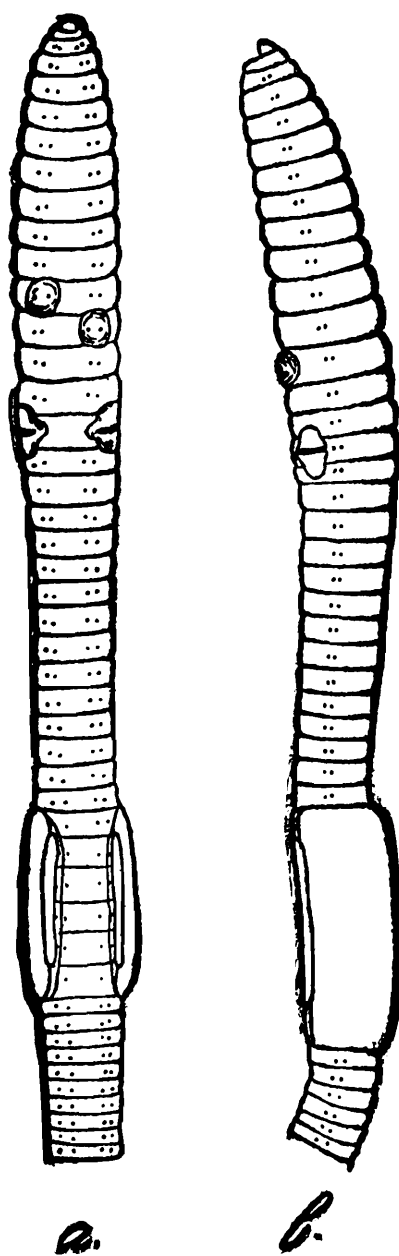
I had the opportunity of studying only two specimens from the Punjab. The largest of these is 76 mm. in length and 5 mm. thick and has 150 segments. Intersegmental furrows well marked. Setae

paired very closely,  $ab > cd$ ,  $ab$  a little larger than  $bc$ , behind the clitellum  $aa = 1\frac{1}{2} bc$ . Prostomium epilobous ( $\frac{1}{3}$ ). The setae  $ab$  on the x, xi, xxvii and xxviii or only xxvii segments situated on glandular papillae. The dissepiments 7/8-9/10 strongly thickened, 6/7 and 10/11 only slightly. Clitellum in both specimens extends over segments xxvii-xxxvi, and the tubercula of puberty over segments xxxi-xxxiv. In the larger specimen only two pairs of seminal vesicles are developed, as was observed by Michaelsen (1910) in specimens from Turkestan.

***Eophila himalayana*, sp. nov.**

Simla, W. Himalayas ; alt. 6,000—7,000 ft. Dr. B. Chopra coll., 2 specimens.

Length of mature specimens 52 and 63 mm. diameter of anterior end about 2.5 mm., posterior end about 2 mm. Body rounded through-



TEXT-FIG. 2.—*Eophila himalayana*, sp. nov.  
a. ventral view, b. side view of the anterior part of a specimen.

out. Segments about 128, large with well marked intersegmental furrows. Colour of alcoholic specimens yellowish, only the clitellum

dorsally reddish; skin without pigment. Prostomium epilobous ( $\frac{1}{2}$ ). No dorsal pores could be discovered before the clitellum. Setae small, closely paired. Anteriorly  $ab$  a little larger than  $cd$ ,  $aa=3ab$ ,  $bc=2\frac{1}{2}ab$ , posteriorly ventral and dorsal pairs are more widely paired than anteriorly,  $ab$  a little larger than  $cd$ ,  $aa=2ab$ ,  $ab=bc>cd$ ,  $dd=\frac{1}{3}u$ .

The ventral setae ( $ab$ ) of segment xi in one specimen only on the left side of the body on prominent elevated rounded glandular papilla of a lighter colour than the surrounding skin. In other specimen on one side of the body the setae of segment xi on the other of the segment xii on similar papillae (text-fig. 2a).

Septa in the anterior part of the body not thickened. Last hearts in segment xi. Gizzard in segments xvii, xviii. Intestine with calciferous glands in segments xi-xiii.

Clitellum saddle-shaped, with indistinct intersegmental furrows, extending over segments xxx-xxxv (=6). Puberty "walls" well marked, extending over the segments  $\frac{1}{2}$  xxx- $\frac{1}{2}$  xxxv, close over the lines of setae  $b$ . Male pores in the form of big transverse slits on segment xv with large elevated glandular areas extending on segments xiv and xvi, and obliterating the intersegmental furrows (text-figs. 2 a, b).

Two pairs of free testes and funnels in segments x, xi. Two pairs of very small, simple seminal vesicles in segments xi, xii. Two pairs of spermathecae opening in intersegmental furrows 9/10 and 10/11 in line of setae  $cd$ . The ampullae are large, sessile, without a prominent duct.

The new species of *Eophila* described above is allied to *E. tyrtea* (Ribauc.), but differs in the presence of spermathecae, form of male pores and position of first dorsal pore.

### ***Bimastus tenuis* (Eisen).**

Kodaikanal, Palni Hills, S. India. Worms seen to live in tubes formed by their slime. Dr. S. L. Hora coll., 60 specimens.

Fern Hills, Nilgiris, S. India. Dr. S. L. Hora coll., 8 specimens.

Asni River near Junga, Simla Hills, W. Himalayas; alt. 4,000 ft. Dr. B. Chopra coll., 1 specimen.

Among the great number of examined specimens from the first locality I found some with well developed spermathecae, this is not often the case in *B. tenuis*, as it normally does not possess these organs. One specimen presented 2 pairs of fully developed spermathecae in the line of setae  $c$ , the other only one and one duct without the ampulla on the left side of the body in intersegmental furrows 9/10 and 10/11. Three other specimens had on the left or right side only one spermatheca with the ampulla situated in intersegmental furrow 9/10 or 10/11. Similar cases have been described by Smith (1917, 1928) and the author (1935a, 1936) in specimens from the United States and France and by Eisen and Michaelsen in *B. norvegicus* (Eisen) which I (1935a, 1936) regard as a synonym of *B. tenuis* (Eisen).

The clitellum in Indian specimens usually extends over segments xxvi-xxx, but in one case (from Asni River, Simla Hills) over segments xxiv-xxx. The tubercula of puberty are developed in many cases, especially in the specimens with well developed spermathecae; they usually extend over segments xxix-xxx.

**Bimastus parvus** (Eisen).

A cultivated field near Uts or "Hot Springs", Lutkuh Valley, Chitral.  
Dr. B. Chopra coll., 1 specimen.

Ramram Gol below Arandu, Chitral. Dr. B. Chopra coll., 5 specimens.

**Octolasion cyaneum** (Sav.).

Murree near Sunny Bank, W. Himalayas, Punjab; alt. 6,500 ft. Dr. H. S. Pruthi coll., 2 specimens.

Cart Road, Murree, W. Himalayas, Punjab. Dr. H. S. Pruthi coll., 1 specimen.

This species is widely distributed in Europe, but has also been found in Australia and South America (Argentina). From India it is being recorded for the first time.

**Octolasion lacteum** (Örley).

Dhar, Murree Sub-Divn., W. Himalayas, Punjab. Dr. H. S. Pruthi coll., 9 specimens.

Cart Road, Murree, W. Himalayas, Punjab. Dr. H. S. Pruthi coll., 4 specimens.

## LITERATURE.

- Černosvitov, L. (1932).—Die Oligochaetenfauna der Karpathen. II Die Lumbriciden und ihre Verbreitung. *Zool. Jahrb.* LXII, p. 525.
- Černosvitov, L. (1935a).—Monographie der tschechoslovakischen Lumbriciden. *Arch. prir. vyzk. Čech.* XIX, No. 1.
- Černosvitov, L. (1935b).—Zur Kenntnis der Oligochaetenfauna des Balkans. IV Höhlen-Oligochaeten aus Jugoslawien. *Zool. Anz.* CXI, p. 265.
- Cernosvitov, L. (1936).—Oligochètes des grottes artificielles du Nord-Est de la France. *Arch. zool. exper. et general.* LXXVIII, 1, p. 1.
- Michaelsen, W. (1903).—*Die geographische Verbreitung der Oligochaeten.* Berlin.
- Michaelsen, W. (1910).—Zur Kenntnis der Lumbriciden und ihrer Verbreitung. *Ann. Mus. Acad. Imp. Sci. Petersbourg* XV
- Pool, G. (1936).—Eiseniella tetraedra (Sav.) Ein Beitrag zur vergleichenden Anatomie und Systematik der Lumbriciden. *Acta Zoolog.* XVIII, p. 1.
- Smith, F. (1917).—North American Earthworms of the family Lumbricidae in the collections of the United States National Museum. *Proc. U. S. Nat. Mus.* LII, p. 1.
- Smith, F. (1928).—An account of changes in the Earthworm fauna of Illinois and a description of one new species. *Ill. Dep. Reg. and Educ. Div. Nat. Hist. Surv.* XVII, No. 10.
- Stephenson, J. (1923).—*Oligochaeta* in the *Faun. Brit. India* Series,
- Stephenson, J. (1930).—*Oligochaeta.* Oxford,



# NOTES ON THE LARVA AND PUPA OF *AMPHIPSYCHE INDICA* MARTYNOV [INSECTA: TRICHOPTERA].

By H. A. HAFIZ, *Ph.D. (London), D. I. C. (London), Assistant Superintendent, Zoological Survey of India, Calcutta.*

## INTRODUCTION.

Large numbers of larvae and pupae of a Trichopteran of the family Hydropsychidae were found attached to the walls of the main storage tanks and filter-beds of the main water pumping station at Pulta which is situated on the southern bank of the river Hooghly about seventeen miles north of Calcutta. They were met with during May, 1936, in the course of an investigation of the biology of the aquatic fauna of the main pumping station undertaken by the Zoological Survey of India at the instance of the Calcutta Corporation. The adults of the species, which were sent to Dr. A. B. Martynov, Moscow, have been identified as *Amphipsyche indica* Martynov<sup>1</sup>. The earlier stages of no species of the genus *Amphipsyche* McLachlan have, so far as I am aware, been described, and as *A. indica* appears to have some importance in connection with the filter-beds, I have thought it opportune to record my observations on its biology and describe its larval and pupal stages.

I am obliged to Dr. A. B. Martynov, U.S.S.R., for the identification of the adult Caddis-flies, and to Dr. Baini Prashad, Director, Zoological Survey of India, for help in preparing this paper for the press.

## DESCRIPTION.

*Larva* (Text-fig. a).—Length 12 mm., width 3 mm. General colouration greenish approaching Roman green dorsally; ventrally somewhat lighter. All horny parts of head and thorax yellowish brown with black markings in the lateral margins of pro-, meso-, and metathorax. Thorax as a whole paler than head, which is dark brown; dorsal surface flattened forming a broad disc or the false clypeus, beset with numerous closely placed bristles and enclosed by a heavy horse-shoe-shaped carina. The carina crosses the true clypeus near its apex, but does not distinctly set off the small triangle characteristic of genera like *Macronema* Pict. Long bristles at the anterior corners of head just above the lateral eyes, which are of a dark brown colour. Mandibles dark brown, with long stiff hairs at the outer margin posteriorly. Right mandible with five teeth on its inner margin, fifth situated about the middle (Text-fig. b). Left mandible with six teeth, fifth and sixth situated close together about the middle (Text-fig. c). The first tooth in both the mandibles is raised above the second and pointed; the rest in one plane and blunt; sixth tooth of left mandible with a dent in the middle.

Legs yellowish brown, beset with numerous hairs. Coxae with black markings at points of attachment to body. Short accessory claws present in all legs. Accessory claws of prolegs absent.

---

<sup>1</sup> Martynov, A. B., *Rec. Ind. Mus.*, XXXVII, p. 199 (1935).

Thoracic and abdominal tracheal gills present. Anal gills absent. The following table shows the distribution and arrangement of gills on the left side of the larva :

| Thoracic segments. |            |            | Abdominal segments. |      |      |      |      |      |            |            |
|--------------------|------------|------------|---------------------|------|------|------|------|------|------------|------------|
|                    | II         | III        | I                   | II   | III  | IV   | V    | VI   | VII        | VIII       |
| D.                 | <i>nil</i> | 1          | <i>nil</i>          | 2, 1 | 2, 1 | 2, 1 | 2, 1 | 2, 1 | 2, 1       | 2          |
| L.                 | <i>nil</i> | <i>nil</i> | 1                   | 2    | 2    | 2    | 2    | 2    | 2          | <i>nil</i> |
| V.                 | 1          | 1          | 1                   | 1    | 1    | 1    | 1    | 1    | <i>nil</i> | <i>nil</i> |

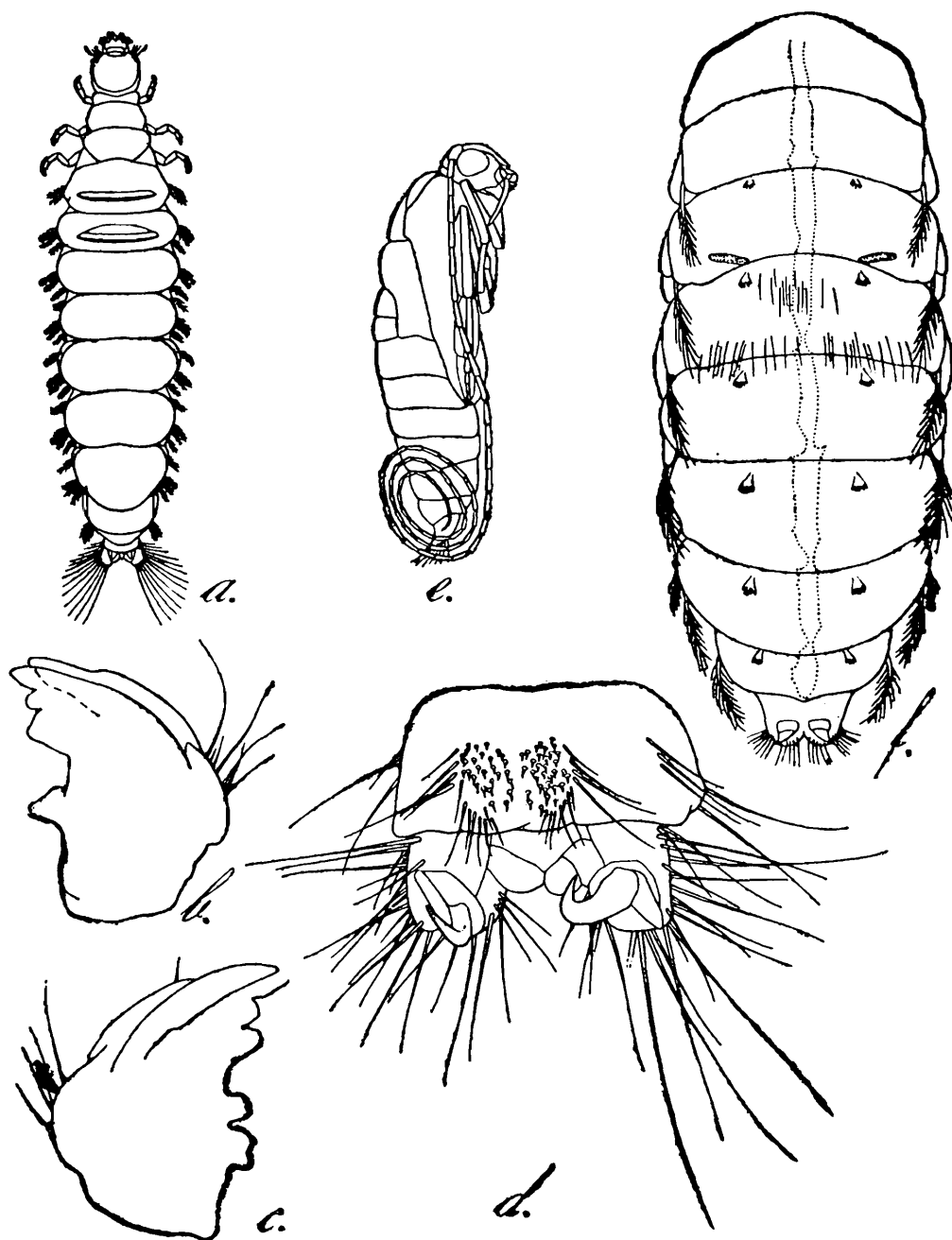
D.=Dorsal ; L.=Lateral (half-way between D. and V.) ; V.=Ventral ; 1.=single filamentous gill, and 2.=gill composed of two separate filaments.

The single filamentous "Dorsal" abdominal gills situated near the posterior margins of their respective abdominal segments and dorsad of the other "Dorsal" gills which are composed of two distinct filaments. The ninth abdominal segment bears ventrally two somewhat oval patches of short, spike-like, dark brown bristles ; those forming the outer fringe are considerably longer than the middle ones (Text-fig. *d*).

*Pupa* (Text-fig. *e*).—Length 10 mm., width 2.5 mm. The pupae when removed from their sheaths are dull greenish to dirty whitish. Head and thorax not chitinized. Eyes large and well developed. Legs white, well developed and compactly placed on the ventral side. Antennae whitish, long, and closely pressed against the sides of the entire length of the body, ends curled up into coils at the posterior extremity. White leaf-like developing wings closely pressed against the sides of the thorax. The two oval patches of bristles on the ninth abdominal segment present in the larval stage have disappeared. Abdominal gills present though somewhat degenerate. Fourth abdominal segment dorsally hairy. Abdominal segments 3, 4, 5, 6, 7 and 8 bear dorsally on either side of the mid-dorsal line near the upper margin a pair of minute reddish pectinate structures lying flatly on the segments with the teeth of the combs pointed backwards. Segment 3 near the lower margin with a pair of narrow obliquely situated patches of minute reddish bristles in addition to the pair of pectinate structures (Text-fig. *f*). Long stiff hairs on the anal segment posteriorly. Mouth parts fairly well developed ; mandibles folded on each other transversely like the blades of a penknife, with the right one anterior to the left.

*Larval and pupal cases*.—Length 11 mm., diameter 3.5 mm. The cases of both the larvae and the pupae are cylindrical and somewhat arched in the middle. They are made of some tough material, with minute sand grains mixed in it. Posterior end rounded and closed. Anterior end closed with a firmly attached disc-like plate in the pupae only. Both the disc and the rounded posterior end are provided with a number of minute slits in their middle. The cases are attached side by side like a honey-comb in two to three tiers,

Large mats of these cases were found attached to the sides and bottom of the outlet channel which discharges water from the final settling tank



*Amphipsyche indica* Martynov.

a. Dorsal view of larva,  $\times 4$ ; b. right mandible of larva,  $\times 40$ ; c. left mandible of larva,  $\times 40$ ; d. ventral view of the posterior extremity of larva showing the two ovalish patches of bristles on the 9th abdominal segment and the prolegs,  $\times 30$ ; e. side view of pupa,  $\times 5$ ; f. dorsal view of the abdominal segments of pupa showing the position of pairs of pectinate structures and patches of bristles on the third segment,  $\times 12.5$ .

to the various filter-beds. Along with these mats of cases, some of them measuring 18 inches by 12 inches, colonies of the fresh water sponge, *Corvospongilla lapidosa* Ann., were found adhering to the sides and bottom of the outlet channel. A few larvae were also found living in the channels of the sponges. Large numbers of dead larvae and pupae were found in the intake chambers of the filter-beds. A few pupae were collected from the walls of the filter-beds. The larvae invariably perished in

aquaria in the laboratory and hence their feeding habits could not be studied.

Dense swarms of the adult *A. indica* were observed on 15th May 1936 at about 6-15 P.M. just before dark flying low over thick growth of plants in the compound of the water-works in the neighbourhood of the filter-beds and the final settling tank. Comparatively larger numbers of these were also attracted to light on this particular night.

The larva of *A. indica* shows characters common to the subfamily Macronematinae but differs from the genus *Macronema* Pict. in the absence of the small triangle set off on the dorsal surface of the head, where the carina or the false clypeus crosses the true clypeus near its apex. The closely related genus *Hydropsyche* Pict. differs from *Amphipsyche* McLachlan in the absence of the carina.

#### REFERENCE TO LITERATURE.

1. Iwata, M.—Trichopterous larvae from Japan, *Annot. Zool. Japon.*, XI, pp. 203-233, 341-351 (1927-28).
2. Krafka, J.—A key to the families of Trichopterous larvae, *Canad. Ent.*, XLVII, pp. 217-225 (1915).
3. Lestage, J.—Trichoptera, in Rousseau's, *Larves et Nymphes aquatiques des Insectes d'Europe*, pp. 343-964 (1921).
4. Miall, L. C.—*The Natural History of Insects* (London : 1912).

# CHANGES IN THE INTERNAL STRUCTURE OF THE AIR-BLADDER OF *PANGASIUS PANGASIUS* (HAM.) DURING GROWTH.

By K. KRISHNAN NAIR, B.A.

(From the Laboratories of the Zoological Survey of India.)

In the course of his taxonomic studies, Dr. S. L. Hora<sup>1</sup> found considerable variation in the form of the air-bladder of *Pangasius pangasius* (Ham.), and from an examination of the material in different stages of growth he was able to reconcile the divergent accounts of its structure by Taylor,<sup>2</sup> Day,<sup>3</sup> and Bridge and Haddon.<sup>4</sup> Further, when dealing with the correlation between the disposition of the liver and the kidney and the form of the air-bladder in *Pangasius*, he<sup>5</sup> indicated that under the pressure of the growing kidneys, the form of the air-bladder undergoes a series of changes. Dr. Hora's studies were, however, limited to the modifications in the external form of the air-bladder, but he recognised the need for a detailed study of the internal structure of the organ during growth. Being unable to devote much time to morphological work, Dr. Hora very kindly entrusted his material to me, and helped in collecting material of other stages from the Calcutta markets. I have thus been able to dissect specimens ranging in length from 91 mm. to 885 mm. In the following account of the structure of the air-bladder, I have followed the terminology of Bridge and Haddon. All the drawings reproduced here were made by me with the help of a Camera Lucida.

I am very grateful to Dr. Baini Prashad, Director, Zoological Survey of India, for affording me the necessary facilities for work in his department. The work has been carried out under the supervision and guidance of Dr. S. L. Hora, to whom I am indebted for the material, valuable suggestions and constant encouragement. My thanks are also due to Dr. T. N. Poddar, Professor of Biology, Carmichael Medical College, Calcutta, for his help in procuring a part of the material, and to Babu D. N. Bagchi, the senior Artist of the Zoological Survey of India for helpful suggestions in connection with the preparation of the illustration.

## DESCRIPTION OF THE MATERIAL.

1. *Size of specimen* : 91 mm. in total length. (Text-fig. 1, *a* and *b*).

The air-bladder of a specimen 91 mm. in total length (fig. 1) consists of a large anterior portion which is like a normal bladder, and also of a posterior portion which is in the form of a caecum. The anterior portion is broad in front and oval behind. The posterior portion is very small

---

<sup>1</sup> Dr. Hora very kindly allowed me to see his manuscript on the revision of the Schilbeidae which is to be published in the *Records of the Indian Museum*.

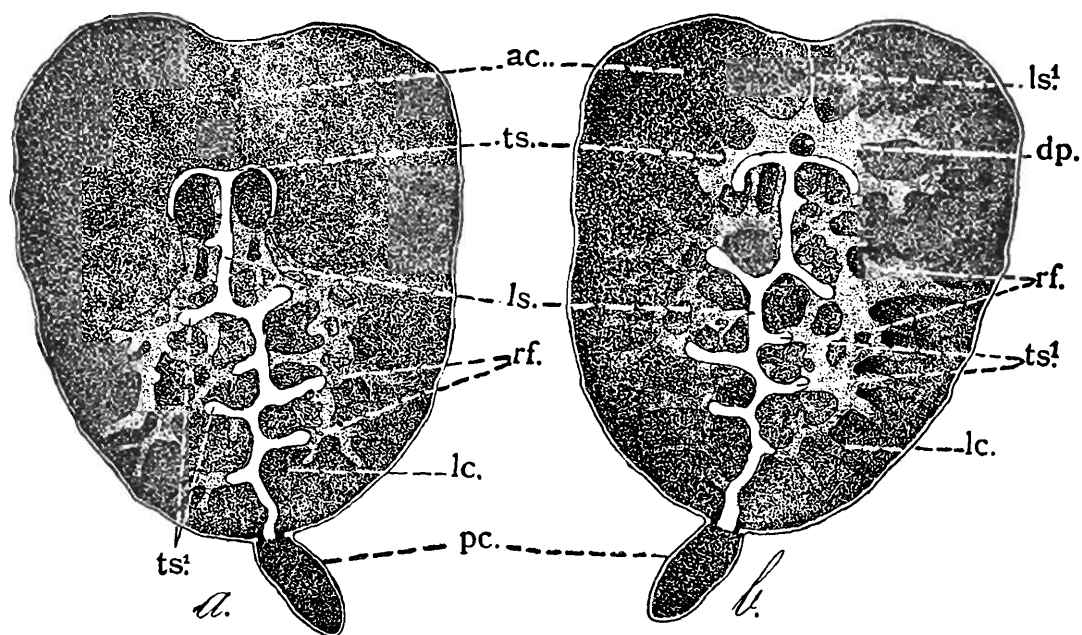
<sup>2</sup> Taylor, *Gleanings in Science*, p. 171 (1830).

<sup>3</sup> Day, *Proc. Zool. Soc. London*, p. 709 (1871).

<sup>4</sup> Bridge and Haddon, *Trans. Roy. Soc. London* (B) CLXXXIV, pp. 214-219 (1894).

<sup>5</sup> Hora, *Proc. Nat. Inst. Sci. India*, III, pp. 31-43 (1937).

and is covered dorsally by the kidneys but exposed ventrally. The anterior portion is divided internally into one short but broad anterior chamber (*ac.*) situated in front of the transverse septum (*ts.*) and two lateral chambers, (*lc.*) one on either side of the longitudinal (*ls.*) septum.



TEXT-FIG. 1.—Air-bladder of a specimen of *Pangasius pangasius* (Ham.) 91 mm. in total length.  $\times 4$ .

a. Dorsal half. b. Ventral half.

*ac.* = the anterior chamber; *ar.* = annular ridges; *dp.* = opening of the ductus pneumaticus into the bladder; *lc.* = lateral chamber; *ls.* = primary longitudinal septum; *ls.*<sup>1</sup> = secondary longitudinal septum; *pc.* = caecum; *rf.* = root-like bundles of fibres; *ts.* = primary transverse septum; *ts.*<sup>1</sup> = secondary transverse septa; *vp.* = vertical pillars.

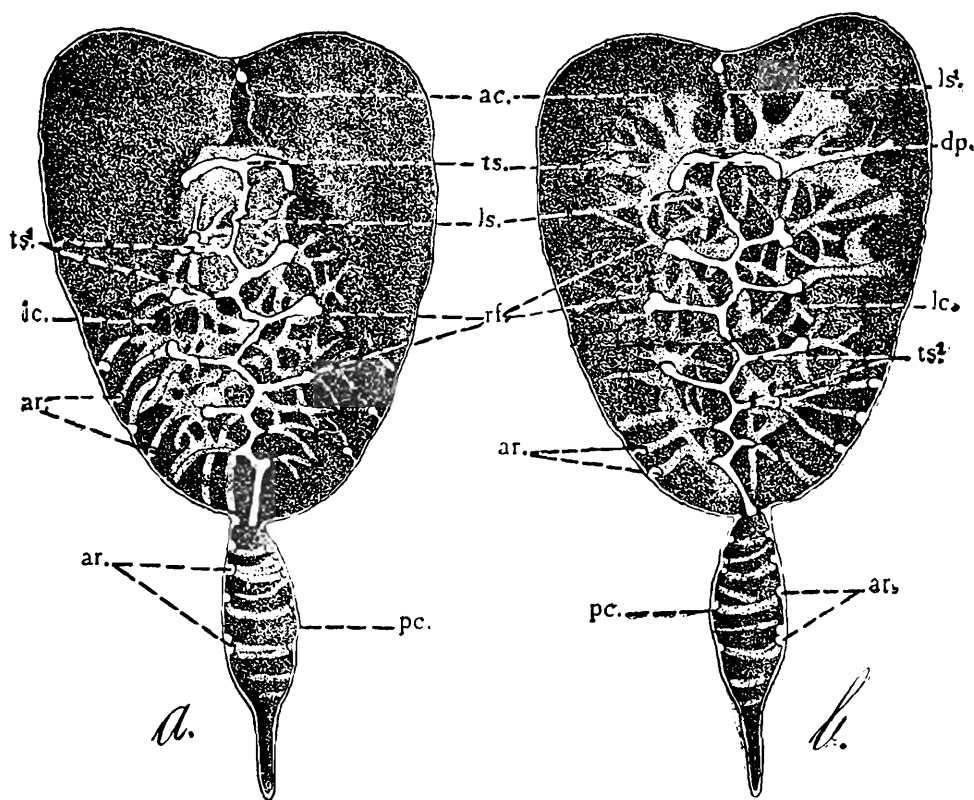
From the thick transverse septum, another thin longitudinal septum (*ts.*<sup>1</sup>) grows forward and meets the anterior wall of the bladder. This new septum is confined to the ventral half of this portion of the bladder, and hence it does not bring about a division of the anterior chamber into two. This structure, which may be termed the secondary longitudinal septum, is not recorded by Bridge and Haddon. There is in addition a hollow pneumatic duct which connects the bladder with the oesophagus. The duct (*dp.*) opens into the bladder on its ventral wall just in the middle and in front of the primary transverse septum. The cavities of the two lateral chambers are subdivided and greatly broken up by the formation of numerous secondary transverse septa (*ts.*<sup>1</sup>) which grow out from the sides of the primary longitudinal septum and laterally terminate before reaching the outer walls of the chambers. The secondary septa are further strengthened, and the spaces they enclose additionally sacculated by the growth of root-like bundles of fibres (*rf.*) which extend in between the septa. The growth of the root-like fibres is more vigorous in the ventral half of the bladder (fig. 1 b) than in the dorsal. In the ventral half very little space is left free, as most of the area is occupied by septa and fibrous tissue.

The posterior portion of the bladder, *i.e.*, the caecum (*pc.*), communicates anteriorly with both the lateral chambers but terminates blindly

behind. The communication is effected by two holes, one on either side of the longitudinal septum. The walls of the caecum are free from ridges or any other thickenings. It may also be noted that the walls of the posterior portion of the bladder are somewhat thickened and more opaque. The two antero-lateral pockets bulge dorsally and possess transparent walls. At this stage, the walls of the air-bladder are in contact with the lateral cutaneous areas, there being no layer of fat between the two. Anteriorly the right half of the bladder is a little longer than the left. The kidneys extend along the sides of the bladder to more than half of its length.

2. *Size of specimen* : 143 mm. in total length (Text-fig. 2, a and b).

The anterior portion of the air-bladder of a specimen 143 mm. in total length is similar in shape to the one described above, with the exception that the number of the secondary transverse septa (*ts.*<sup>1</sup>), which arise from the longitudinal septum (*ls.*), and of the root-like bundles of fibres (*rf.*) at the ends of the secondary transverse septa is greater.



TEXT-FIG. 2.—Air-bladder of a specimen of *Pangasius pangasius* (Ham.) 143 mm. in total length.  $\times 3\frac{1}{2}$ .

a. Dorsal half. b. Ventral half.

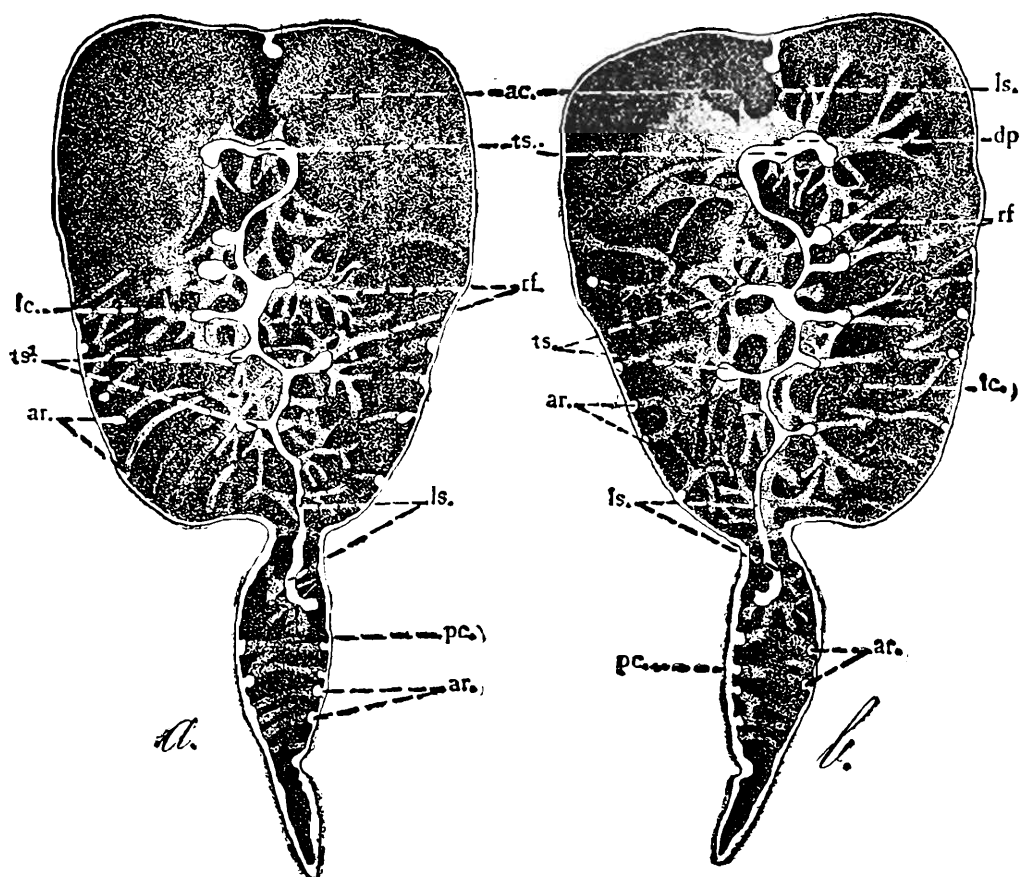
For lettering see explanation of text-figure 1.

These root-like bundles of fibres along with the few annular ridges (*ar.*), which are dorsoventrally placed along the sides of the bladder towards its posterior end, contribute to the obliteration of the space inside the bladder. The secondary longitudinal septum (*ls.*<sup>1</sup>), which was just noticeable in the earlier stage described above, is more prominent. It is in the form of a ring, placed dorsoventrally in the median portion of the anterior wall.

The posterior portion of the bladder (*pc.*) is now considerably longer and its posterior end almost extends to the base of the ventral fins. The tubular caecum is enclosed by the kidneys on the sides, but is exposed ventrally. It could also be seen at least in one place dorsally. The longitudinal septum does not extend into the caecum. The caecum is no longer a simple structure as its cavity is being filled up and the walls are further thickened and strengthened by a few annular ridges (*ar.*). Besides these ridges, there are other fibrous thickenings which arise from the ventral and dorsal walls. Towards the posterior end, the caecum is suddenly narrowed. The narrow region is devoid of ridges. There is very thin layer of fat between the bladder and the lateral cutaneous areas towards the posterior end of the latter, but towards its anterior end the fat layer is absent, and consequently the skin comes in contact with the bladder in that region.

3. *Size of specimen* : 181 mm. in total length, (Text-fig. 3, a and b).

In the anterior portion of the bladder, there are a number of secondary transverse septa (*ts.*<sup>1</sup>) and root-like fibrous growths (*rf.*). The annular ridges (*ar.*) along the sides are more numerous. Practically everywhere,



TEXT-FIG. 3.—Air-bladder of a specimen of *Pangasius pangasius* (Ham.) 181 mm. in total length.  $\times 2\frac{7}{10}$ .

a. Dorsal half. b. Ventral half.

For lettering see explanation of text-figure 1.

the walls of the bladder are thickened. Even the anterior chamber (*ac.*) is invaded by the fibrous roots of the primary transverse septum (*ts.*). In this stage the primary longitudinal septum (*ls.*) arises from the left extremity of the transverse septum, and not from the middle

of it, as is generally the case. The longitudinal septum, at this stage, extends into the cavity of the caecum for a very short distance.

The tubular caecum (*pc.*) originates entirely from the left half of the bladder instead of from the median point. It is covered on the sides by fairly thick layers of fat and extends as far as the base of the ventral fins. The walls of the caecum are strengthened by a number of annular ridges (*ar.*). A short distance in front of the posterior end, the wall on one side of the caecum is constricted. This may be an indication for the formation of an additional chamber.

There is a thin layer of fat between the walls of the bladder and the lateral cutaneous areas so that the walls are not directly in contact with the skin. There is an uneven layer of fat which covers the whole of the ventral surface of the bladder and a portion of the dorsal surface as well. The posterior half of the anterior portion of the bladder is somewhat compressed, probably owing to the lateral pressure exerted by the kidneys.

Judging from Bridge and Haddon's<sup>1</sup> description of the bladder, it seems probable that they had a specimen intermediate in size between the last two stages described above.

4. *Size of specimen : 205 mm. in total length.*

The air-bladder of a specimen 205 mm. in total length is similar in shape to the one described above, with the exception that the transverse septa, root-like fibres, and the length of the caecum are more pronounced. The tubular caecum extends backward to a fourth of the length of the anal fin and is externally divided into three chambers. The caecum is very much strengthened by annular ridges.

Day's<sup>2</sup> description of the air-bladder appears to correspond with the above description to a great extent.

5. *Size of specimen : 303 mm. in total length (Text-fig. 4, a and b).*

In a specimen 303 mm. in length, the air-bladder is long and narrow ; its walls are thick and hard. The anterior chamber (*ac.*) is very narrow and the lateral chambers (*lc.*) are filled with annular ridges (*ar.*) and fibrous thickenings. The longitudinal septum is absent as such, but it is broken up into a number of vertical pillars (*vp.*) which fill up the space inside the bladder. The longitudinal septum (*ls.*) is present only near the junction of the two portions of the bladder.

The tubular caecum is very long, about twice the length of the anterior portion of the bladder. The posterior half of the caecum is lodged within the ventral caudal musculature and the end of the caecum extends backward to more than a fourth of the length of the anal fin. The cavity of the caecum is almost filled by annular ridges, transverse and longitudinal thickenings.

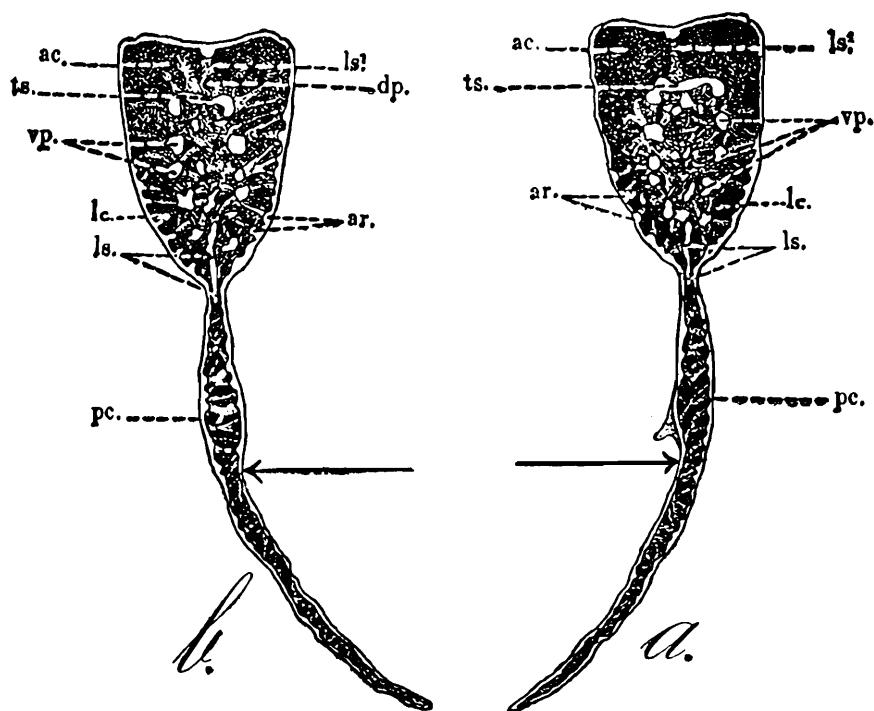
There is a thin layer of fat between the walls of the bladder and the lateral cutaneous areas. A layer of fat is also present on the ventral surface of the bladder. The caecum gives off a spine-like projection from its dorsal wall, at about its middle. The dorsal half of the bladder

---

<sup>1</sup> Bridge and Haddon, *Trans. Roy. Soc. London*, (B), CLXXXIV, pp. 214-219 (1894).

<sup>2</sup> Day, *Proc. Zool. Soc. London*, p. 709 (1871).

(fig. 4, *a*) is comparatively less invaded by the fibrous thickenings and annular ridges.



TEXT-FIG. 4.—Air-bladder of a specimen of *Pangasius pangasius* (Ham.) 303 mm. in total length.  $\times \frac{4}{5}$ . The portion of the caecum, beyond the arrow is accommodated in the caudal muscles.

*a.* Dorsal half. *b.* Ventral half.

For lettering see explanation of text-figure 1.

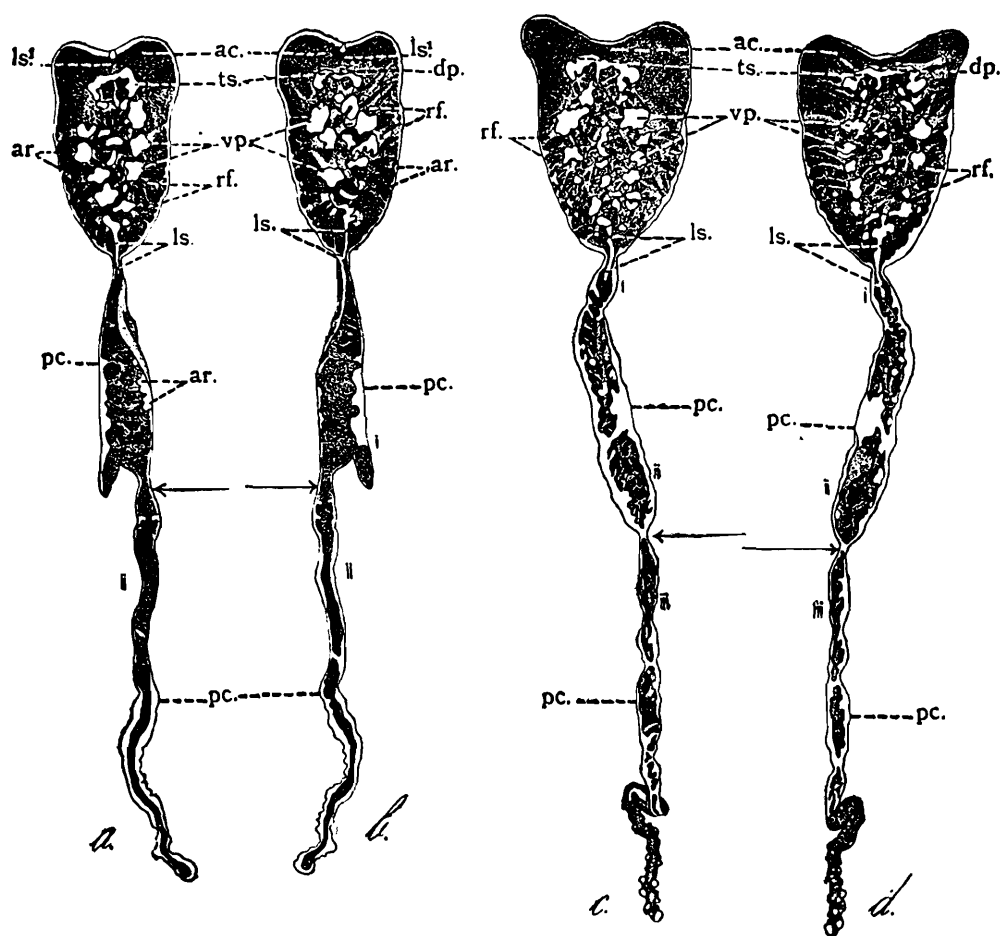
6. *Size of specimen : 353 mm. in total length.*

The air-bladder of this specimen is similar in all details to the one described above with the exception that the tubular caecum is definitely divided into two separate chambers by a constriction of the walls of the caecum. The caecum, which is folded on itself towards the posterior end, as shown in the case of the last stage, extends backward as far as the posterior end of the anal fin. The portion of the caecum, which is lodged in the muscles of the tail, is comparatively harder than the rest of it.

7. *Size of specimen : 460 mm. in total length (Text-fig. 5, *a* and *b*).*

The anterior chamber (*ac.*) is very narrow. The primary transverse septum (*ts.*) is very broad, and including its fibrous roots it is nearly as broad as the anterior chamber. There are no lateral compartments as such, for the space is filled by stout vertical pillars (*vp.*). These vertical pillars are roughly arranged in three rows, and probably represent the longitudinal septum in the middle and the end portions of the secondary transverse septa at the sides. A small portion of the longitudinal septum (*ls.*), the only remaining representative of the original primary longitudinal septum, extends into the caecum. The secondary longitudinal septum (*ls.*<sup>1</sup>) is still represented here in a degenerating stage. The fact that it is degenerating is clearly shown by its absence in a bladder of a larger specimen, as shown below. There are very stout annular ridges (*ar.*) along the sides which strengthen the walls of the

bladder. In the dorsal half of the bladder (fig. 5, *a*) there are two regions along the sides, towards the anterior end which have a free space. These



TEXT-FIG. 5. *a. & b.*—Air-bladder of a specimen of *Pangasius pangasius* (Ham.) 460 mm. in total length.  $\times \frac{3}{8}$ . *a.* Dorsal half. *b.* Ventral half.

*c. & d.* Air-bladder of another specimen of *Pangasius pangasius* (Ham.) 885 mm. in total length.  $\times \frac{3}{16}$ . *c.* Dorsal half. *d.* Ventral half.

The portion of the caecum, beyond the arrow is accommodated in the caudal muscles.

For lettering see explanation of text-figure 1.

portions bulge upward and are accommodated in bony recesses on the sides of the vertebral column.

The tubular caecum (*pc.*) is covered by a layer of fat for about half of its length, and extends as far back as three-fourths of the length of the anal fin. About the middle of its length, it gives off a short blind caecum towards the right side. The caecum at this stage is much complicated and is divided into more than one chamber. Of these chambers, only the first two (*i* and *ii*) are connected internally with each other and with the anterior portion of the bladder as well. There are numerous annular ridges (*ar.*) and other thickenings on the walls. The caecum is very long, shallow and tough, with the walls greatly thickened. Towards its posterior end, there are two places where the caecum is somewhat compressed.

There is a layer of fat between the walls of the bladder and the lateral cutaneous areas. The ventral surface of the bladder is covered by a

thick layer of fat which extends to half of the dorsal surface as well. The cavity of the pneumatic duct towards the oesophageal end is almost obliterated by the development of fibrous tissue from its walls. The bladder is relatively narrower and harder.

8. *Size of specimen : 536 mm. in total length.*

The structure of the air-bladder of a specimen 536 mm. in total length agrees, more or less, with the above description, except that the secondary longitudinal septum is altogether absent, and the caecum is definitely divided into two separate chambers, one broad and the other narrow. The whole of the narrow chamber is lodged in the caudal muscles. The caecum extends backward to about four-fifths the length of the anal fin. The walls of the bladder and the caecum are very hard and tough.

9. *Size of specimen : 885 mm. in total length (Text-fig. 5, c and d).*

The anterior wall of the bladder has a tendency to fatty degeneration. The anterior portion of the bladder is oval in shape with posterior end slightly narrower. The short, but broad anterior chamber (*ac.*), is greatly reduced. The primary transverse septum (*ts.*) is not fully developed and lies immediately behind the anterior wall of the bladder. The secondary longitudinal septum is absent. The walls of the bladder are strengthened by annular ridges (*ar.*) and are very hard to the touch. A small length of the greatly reduced longitudinal septum (*ls.*) extends into the cavity of the caecum.

The posterior portion of the bladder (*pc.*) is very long and reaches almost to the end of the tail region. It is accommodated in the ventral caudal muscles which are very closely applied to it. The walls of the caecum are very thick and the cavity inside is nearly filled by a number of strong and stout ridges which arise without any orderly arrangement. Towards the posterior end, the caecum is folded on itself, and the outer walls are covered with many stout and strong knobs. The caecum may apparently be divided into eight chambers; only the first three (i, ii and iii) are in communication with one another, and with the anterior portion of the bladder. The other chambers of the caecum are variously filled with fibrous growths.

There is a layer of fat between the walls of the bladder and the lateral cutaneous areas. The ventral wall of the bladder is closely attached to the dorsal wall of the abdominal cavity. The anterior portion of the bladder is white and shining while the caecum is dirty white in appearance. The oval plates of the "elastic spring" apparatus are well accommodated in the two hollow spaces developed on the anterior wall of the bladder. These spaces are very thin though the whole bladder is very hard to the touch. The pneumatic duct has an opening (*dp.*) into the bladder, but its opening to the oesophagus is not clear. However, a very small hole, not larger than a pinprick, is seen on the wall of the oesophagus.

Judging from Taylor's<sup>1</sup> description of the bladder, it seems probable that he had a specimen intermediate in size between the last two stages described above.

<sup>1</sup> Taylor, *Gleanings in Science*, p. 171 (1830).

## ON THREE CHALCIDOID PARASITES OF COTTON BORER-BEETLES FROM SOUTH INDIA.

By T. V. RAMAKRISHNA AYYAR B.A., Ph.D., Late Government Entomologist, Agricultural Research Institute, Coimbatore, AND M. S. MANI, Assistant, Zoological Survey of India, Indian Museum, Calcutta.

While studying the bionomics of the Cotton Borer-beetles, *Sphenoptera gossypii* Kerr. and *Pemphres affinis* Fabr., in South India, the senior writer bred, among others, three interesting Chalcidoid parasites of these beetles. One of these, *Euderus gossypii* Ferr., is the well known parasite of *Sphenoptera gossypii* Kerr. in Sudan and Punjab; and the other two are new to science. In an earlier paper<sup>1</sup> Ayyer gave a brief account of the biology of the parasites and also discussed the possibilities of using them as natural control of the Cotton beetles, and in this paper the new species are described together with additional notes on all the species.

### Family PTEROMALIDAE.

#### Genus *Neocatolaccus* Ashmead.

1864. *Catolaccus*, (*partim*), Ashmead, *Bull. Ohio Expt. Sta.*, I, p. 161.  
1904. *Neocatolaccus*, Ashmead, *Mem. Carnegie Mus.*, I, (4), p. 320.  
1909. *Neocatolaccus*, Schmiedeknecht, *Gen. Ins.*, fas, 97, p. 356.  
1909. *Neocatolaccus*, Masi, *Boll. Lab. Zool. Portici*, III, p. 138.

The genus *Neocatolaccus* was erected by Ashmead in 1904 with *Catolaccus tylodermae* Ashm. as the type. Since then five more species have been described from different parts of the world: *australensis* Gir.<sup>2</sup> from Australia, *subviridis* Gir.<sup>3</sup> from Paraguay, *livii* Gir.<sup>4</sup> from Porto Rico, *syrphidis* Gir.<sup>5</sup> from Trinidad and *sphenopterae* Ferr.<sup>6</sup> from Sudan. No species of the genus has so far been described from India.

According to Ashmead and Schmiedeknecht there are in this genus three ring joints in the antennae in both the sexes. On behalf of Masi<sup>7</sup>, Crawford re-examined the type specimen of *N. tylodermae* (Ashm.) in the U. S. National Museum, Washington, and found only two ring joints in both sexes. Masi erected the genus *Pseudocatolaccus* for forms having three ring joints in the female and two in the male. Ashmead describes *Neocatolaccus* as having a distinct median carina on propodium, while according to Masi *Pseudocatolaccus* is without a carina. Females of the closely related genera *Metapachia* Westw. and *Parapteromalus*

---

<sup>1</sup> Ramakrishna Ayyar and Margabandhu, *Madras Agric. Journ.*, XXIV, pp. 102-107, (1936).

<sup>2</sup> Girault, *Mem. Queensland Mus.*, II, p. 306, (1913).

<sup>3</sup> Girault, *Archiv Naturgesch.*, LXXVI, A, Heft 6, p. 56, (1913).

<sup>4</sup> Girault, *Insec. Inscit. Menstr.*, IV, p. 112, (1916).

<sup>5</sup> Girault, *Ent. News*, XXVII, p. 403, (1916).

<sup>6</sup> Ferriere, *Bull. Ent. Res.*, XXII, p. 130, (1931).

<sup>7</sup> Masi, *Boll. Lab. Zool. Portici*, III, p. 138, (1909).

Ashm. have two ring joints and one propodial carina. Males of *Parapteromalus* have also two ring joints but no propodeal carina. In *Diglochis* Först. there are two ring joints and one propodial carina in both the sexes. It is possible that several of these genera might prove to be synonyms. Both *N. sphenopterae* Ferr. and the new species described below agree with *Pseudocatolaccus* in having three ring joints in the antennae but differ in the median carina on propodeum. As it has not been possible to correctly define the exact limits of these closely related genera in the absence of types, the new species is provisionally referred to the genus *Neocatolaccus*.

***Neocatolaccus indicus*, sp. nov.**

This new species bears a general resemblance to *N. sphenopterae* Ferr. but differs in the following characters :

Frons reticulately sculptured, the striations which diverge upwards from the lower border of clypeus rather sharply defined and prominent ; antennae inserted just at the level of the lower borders of eyes ; club of antennae longer than the two preceding segments combined ; parapsidal furrows continue a little beyond the middle of mesonotum, though not reaching its posterior edge ; spiracles on propodium small and almost rounded ; fore wings with a slight discal ciliation at base ; marginal vein less than half the length of submarginal vein.

*Female*.—2.7-3.0 mm. long. Head very dark green, almost black ; rounded in the front view ; frons swollen ; sculpture closely reticulate ; striations of clypeus very prominent ; cheek large, almost as broad as eyes ; the front ocellus placed at the apex of scapal furrows, the lateral ones closer to the front one than to the eye border. Antennae generally brown, inserted just at the level of the lower borders of eyes ; scape yellowish brown, thin, very slightly curved ; pedicel stouter apically than basally, about twice as long as wide ; ring joints three, the first two small and the third much wider and almost twice longer ; first funicular segment about twice the length of pedicel and somewhat stouter ; second funicular segment about half the length of first ; the following three segments somewhat shorter, but each nearly equal, and gradually growing wider apically ; club triarticulate, stouter and somewhat distinctly longer than the two preceding segments combined.

Thorax very dark green ; pronotum reticulately sculptured ; mesonotum wider than long, reticulately punctate, with parapsidal furrows reaching beyond its middle though not actually touching the posterior edge ; scutellum a little shorter than its posterior breadth, sculpture similar to that of mesonotum ; propodium shiny green, with prominent median carina and lateral spiracular sulci, spiracles small and almost rounded. Fore wings with a slight discal ciliation at base ; marginal vein somewhat less than half the length of the submarginal ; post marginal narrower and shorter than the marginal ; stigmal about two thirds the marginal. Legs generally brown or yellowish brown.

Abdomen oval, much pointed posteriorly, longer than thorax, third segment not short.

*Holotype*.—One female dissected on three slides, in the collections of the Zoological Survey of India, Indian Museum, Calcutta, No. 1572/H 3. Coll. T. V Ramakrishna and V Margabandhu, Coimbatore, 1932.

*Host*.—*Pempheres affinis* Fabr.

Family EULOPHIDAE.

***Euderus gossypii* Ferriere.**

1931. *Euderus gossypii*, Ferriere, *Bull. Ent. Res.*, XXII, p. 132.

This species was originally described by Ferriere from Sudan, Africa and Lyallpur, Punjab, as parasitic on the larva of *Sphenoptera gossypii* Kerr. in cotton stems. It is recorded here for the first time from South India; it was bred from the same host at Bellary in the month of February 1932.

***Euderus pempheriphila*, sp. nov.**

This new species is easily distinguished from the closely related *E. gossypii* Ferr. by the relatively stouter and longer club of antenna of female.

*Female*.—About 2 mm. long. Head very dark green, almost black, often more or less metallic green or blue, purplish on the vertex, transverse, rounded in front view, sparsely punctate and pubescent. Antennae inserted at the level of the lower borders of eyes; pedicel dark green; ring joint very short and transverse; first segment of funicle nearly equal to pedicel, but very slightly broader, somewhat longer than broad; the following three segments nearly equal to the first; also second as long as broad, third and fourth very slightly broader than long; club about one and half times the combined length of the third and fourth funicular segments, much broader, triarticulate, the third segment conically produced and with a small nipple-like spine apically.

Thorax dark green, shagreened; scutellum distinctly broader than long. Propodium very short in the median line and with a distinct median carina; spiracles rounded. Marginal vein slightly longer than submarginal, somewhat thicker basally than apically; post marginal vein distinctly longer than stigmal vein.

*Holotype*.—One female dissected on a slide, in the collections of the Zoological Survey of India, Indian Museum, Calcutta, No. 1573/H 3. Coll. T. V Ramakrishna, Coimbatore, 1932.

*Host*.—*Pempheres affinis* Fabr.

NOTE.—Ballard<sup>1</sup> refers to a Chalcid grub parasitising the larva of *P. affinis* at Coimbatore; it is possible he is referring to the larva of this species.

---

<sup>1</sup> Ballard, *Mem. Dept. Agric. Ind., Ent. Ser.*, VII, p. 245, (1921); *Rep. Proc. Fourth Ent. Meet. Pusa*, p. 24, (1921).



# ON A NEW SPECIES OF NEOECHINORHYNCHUS PARASITIC ON *MUGIL CEPHALUS* LINN. FROM THE CHILKA LAKE.

By T. N. PODDER, *M.Sc., M.B., Professor of Zoology, Carmichael Medical College, Calcutta.*

I recently examined the intestinal contents of a few fairly grown up specimens of *Mugil cephalus* Linn. from the Chilka Lake, Orissa, obtained from the local market. All the fishes examined were heavily infested with Acanthocephalan parasites. In one specimen the number of parasites was as high as 112. On examination these parasites proved to belong to a new species, which is described below under the name *Neoechinorhynchus chilkaensis*.

I take this opportunity of recording my sincere thanks to Dr. Baini Prashad, Director, Zoological Survey of India, Indian Museum, Calcutta, for the facilities for work; to Dr. Sunder Lal Hora, Assistant Superintendent, Zoological Survey of India, for the identification of the host and to Mr. M. N. Datta of the Zoological Survey of India for his valuable suggestions.

## ***Neoechinorhynchus chilkaensis*, sp. nov.**

The proboscis (fig. *a*), is globular in shape with a very short neck. It is covered with three rows of hooks, six in each row. The hooks of the anterior row are relatively much larger and stouter than those of the other rows. The proboscis sheath is a thin and single walled muscular sac attached to the base of the proboscis.

The nervous system consists of a single nerve ganglion with a few nerve fibres situated posteriorly within the wall of the proboscis sheath. These nerve fibres supply the body wall of the worm.

The body is lanceolate and cylindrical and devoid of spines. Its walls consist of a layer of cuticle outside, then the thick submucosa which is traversed by numerous canals and canaliculi which form the lacunar system (Verma and Datta, 1929)<sup>1</sup> which is followed by the transverse and longitudinal muscle fibres. The transverse canals of the lacunar system are very prominent giving the appearance to the body of pseudosegmentation.

In the body wall there are subcuticular nuclei 4-5 on the mid-dorsal side and 2 on the mid-ventral side of the worm.

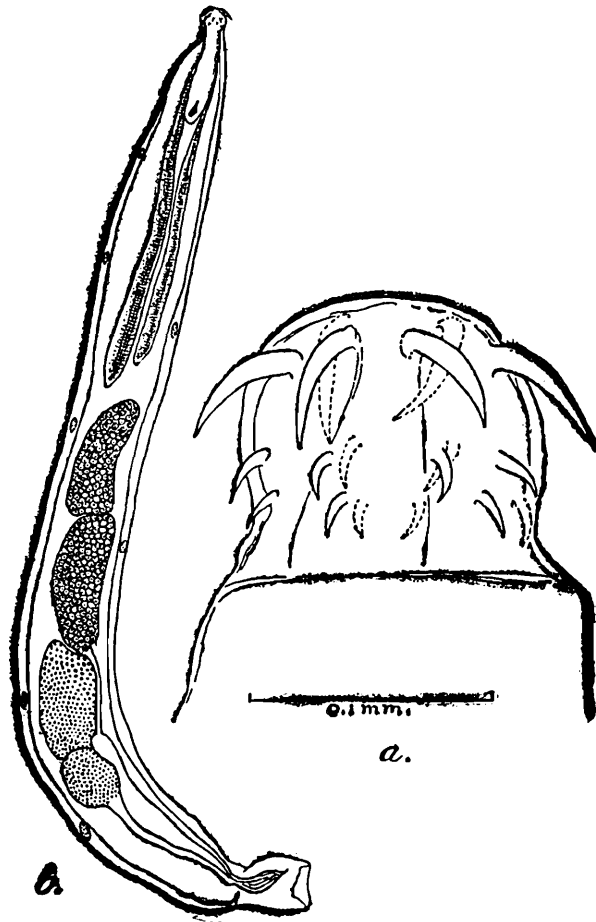
Male genitalia (fig. *b*), beginning just above the middle of the body, consist of a pair of ovoid testes, one behind the other, a pair of vasa efferentia, a vas deferens, a syncitial prostatic gland, a prostatic reservoir, a seminal vesicle, a muscular penis and a funnel-shaped bursa.

The vas efferens from each testis runs downwards and then swells a little near the angle formed by the posterior testis and the prostatic

---

<sup>1</sup> Verma, S. C. and Datta, M. N., Acanthocephala from Northern India, I. A new genus of Acanthocephala from a Calcutta fish. *Ann. Trop. Med. Parasit.* XXII, pp. 483-498, (1929).

gland before it joins with its fellow of the opposite side to form the vas deferens. This is a peculiarity of the genus *Neoechinorhynchus*.



*Neoechinorhynchus chilkaensis* sp. nov., (a) Proboscis showing arrangement of hooks. (b) Male specimen showing the genitalia,  $\times 20$ .

The prostatic gland is a syncitial mass and empties its contents into the prostatic reservoir and the prostatic duct from the reservoir running for a short distance ends into the muscular penis situated at the top of the eversible bursa.

The seminal vesicle is of considerable size and is a thin-walled oval structure tapering downwards, finally opening into the base of the penis. The duct from the vas deferens also opens into the penis along with the duct of the seminal vesicle.

Female genitalia consist of a uterine bell, uterus, vagina and the vulva. The uterine bell is a thin-walled funnel-shaped organ retained in position by means of the genital ligament attached to the base of the proboscis sheath. A few guard cells are situated at the posterior end of the uterine bell whose function is to control the passage of mature ova. The uterus is a flabby tube which opens into the vagina. The vagina is a short and thick muscular tube which has two bands of strong muscles known as the vaginal sphincters, whose function is to allow the ova to pass in a single file. The vulva is the external thickened portion near the vaginal orifice and is situated at the ventral aspect of the worm near the posterior end.

*Measurements*.—Males 4.2—7.8 mm.  $\times$  0.20—1.03 mm.; Females 5.0—18.70 mm.  $\times$  0.31—1.08 mm.; Proboscis 0.121  $\times$  0.11 mm.; Proboscis hooks anterior row 0.07 mm.; middle row 0.03 mm.; basal row 0.027 mm.; Proboscis sheath 0.46  $\times$  0.14 mm.; lemnisci 1.85  $\times$  0.11 mm.; and 1.61  $\times$  0.11 mm.; Anterior testis 1.21  $\times$  0.53 mm.; Posterior testis 0.77  $\times$  0.59 mm.; Prostatic gland 1.69  $\times$  0.66 mm.; Prostatic reservoir 0.44  $\times$  0.26 mm.; Prostatic duct up to penis 1.03 mm.; vas deferens 1.14  $\times$  0.20 mm.; Penis 0.11  $\times$  0.4 mm.; Bursa 0.68  $\times$  0.57 mm.; Female genitalia, Uterine bell 0.11 mm.; Uterus 0.21 mm.; Vagina 0.06 mm.; Ova 0.023 mm.; (in the male specimen which is 7 mm. long the anterior end of the anterior testis is 3 mm. from the anterior end of the proboscis).

*Diagnosis*.—From the table of allied species of *Neoechinorhynchus* Datta (1936)<sup>1</sup> it is evident that the main points of difference between the closely related species of *Neoechinorhynchus* and the new species, are the size and shape of body of the male and female specimens, the size and position of the genitalia, the size of the hooks and the number of subcuticular nuclei.

In the new species the males are generally smaller than the females, the proboscis sheath is single layered, the hooks of the anterior row are much longer and stouter than those of the other rows, the central nervous system is situated at the posterior portion of the proboscis sheath, the prostatic gland is a single syncitial mass, subcuticular nuclei and lacunar system and specially the transverse canals are well developed.

*Host*.—*Mugil cephalus* Linn.

*Location*.—Small intestine.

*Locality*.—Chilka Lake, Orissa (Bought from Calcutta market).

Type specimens are deposited in the collections of the Zoological Survey of India, Indian Museum, Calcutta.

---

<sup>1</sup> Datta, M. N., Helminth parasites of fishes from North India, with special reference to Acanthocephala. *Rec. Ind. Mus.*, XXXVIII, pp. 211-229, (1936).



# SKULL OF *VARANUS MONITOR* (LINN.).

By K. N. BAHL, D.Sc. (Punj.), D. Phil. (Oxon.), F.R.A.S.B., F.N.I.,  
Professor of Zoology, University of Lucknow.

## TABLE OF CONTENTS

|                                                            | PAGE |
|------------------------------------------------------------|------|
| 1. Introduction                                            | 133  |
| 2. The Skull                                               | 135  |
| I. General characteristics                                 | 135  |
| II. The Cranium                                            | 135  |
| (a) The occipital region                                   | 135  |
| (b) The parietal region                                    | 144  |
| (c) The frontal region                                     | 147  |
| III. The Sense-Capsules                                    | 150  |
| (a) The auditory capsules                                  | 150  |
| (b) Bones in relation with the optic capsules              | 155  |
| (c) Bones in relation with the olfactory capsules          | 157  |
| IV. The Suspensorium                                       | 158  |
| V. The Palate and the Upper Jaw                            | 160  |
| VI. The Lower Jaw                                          | 164  |
| VII. Temporal arcades and fossae and other large vacuities | 167  |
| VIII. The Foramina of the skull                            | 168  |
| (a) Dorsal surface                                         | 168  |
| (b) Ventral surface                                        | 169  |
| (c) Lateral surface                                        | 169  |
| (d) Posterior surface                                      | 170  |
| (e) Longitudinal section                                   | 171  |
| 3. Streptostylism and Kinetism                             | 172  |
| 4. Summary                                                 | 173  |
| 5. List of References                                      | 173  |

## 1. INTRODUCTION.

The skull of *Varanus* forms a very suitable type of the Lacertilian skull and has therefore been figured in several current books on the comparative anatomy of vertebrates. For example, Bütschli (3, p. 274) figures the ventral, lateral and posterior aspects of the skull of *Varanus salvator*, but his description deals only with some of the leading features of the skull of Lacertilia as a whole as compared with the skulls of other reptiles. Similarly, Shimkewitsch (8, p. 122) gives the dorsal and ventral views of the skull of *Varanus niloticus*, but his description is very brief and includes only a few of the important characters of the skull. Amongst English authors, Reynolds (7, pp. 195 and 290) figures the dorsal, ventral and lateral views and also a longitudinal section of the skull of *Varanus varius*, but he too does not describe this skull as such, although he gives adequate descriptions of the skull of a chelonian and that of a crocodilian. Similarly, Thomson (11, p. 695) gives a diagram of the roof of the skull of a Varanid from a specimen, but his diagram is incompletely and even wrongly labelled and his description

is equally incomplete. Boulenger (1, p. 160), in the first edition of the *Fauna of British India* (Reptiles and Amphibia), gave rough sketches of the skull of *Varanus griseus*, which have been reproduced unaltered by Malcolm Smith (10, p. 396) in the second edition. These sketches are hardly complete and at places give a misleading idea of the relationships of bones and cartilages. Lastly, Goodrich (5, pp. 343 and 344), in his masterly work on the structure and development of vertebrates, gives the diagrams of Reynolds, but his account of the lacertilian skull is necessarily comparative and is based chiefly on that of *Lacerta*.

In all the first five books<sup>1</sup>, the diagrams are original, i.e., they have been specially drawn for each of these books. There are no standard diagrams in any memoir, from which they could be taken. Unfortunately, therefore, the diagrams vary and all of them are incomplete in several respects and even incorrect in some cases. As all these diagrams have apparently been made from dried skulls, the omission of important cartilaginous and even small bony parts of the complete skull is a specially weak feature of these diagrams. Further, no attention altogether has been paid to the large number of foramina through which the blood vessels and nerves pass.

In almost all the Indian Universities, *Varanus* is studied as a type of the Lacertilia; even where smaller types like *Calotes*, *Uromastix* or *Mabuia* are used for dissection, the skeleton studied is always that of *Varanus*. I began this work originally to identify the large number of foramina in the skull, but when I found that there was no satisfactory account of the skull, I decided to describe the complete skull, as I felt, firstly, that a description of the foramina alone would not be so useful as that of the whole skull, and, secondly, that I could correct and improve upon the diagrams which are extant in the commonly used text-books.

I have selected *Varanus monitor* (syn. *Varanus bengalensis*) as the type, as this species is the commonest and most extensively distributed throughout India, Ceylon, Assam and the greater part of Burma (10). In size it is the second largest species, the head and body being 750 mm. and the tail 1000 mm. The largest species is *Varanus salvator* (head and body 1000 mm. and tail 1500 mm.), but it is not found in the peninsula of India except in the extreme north-east, Eastern Bengal and the Eastern Himalayas (10). As the work involved a number of dissections and preparations displaying blood vessels and nerves, I have included a number of diagrams showing the relations of the bones with these structures in the hope that they would prove useful. Further, wherever possible, comparisons have been made with the skulls of *Sphenodon*, *Lacerta* and *Uromastix*.

I am indebted to Professor E. S. Goodrich of Oxford for kindly lending me Siebenrock's valuable paper on the skull of *Lacerta* from his private library. My best thanks are due to Mr. M. L. Bhatia who has rendered valuable assistance in the preparation of illustrations. Prof. A. H. Siddiqui has very kindly helped me in the dissections of some of the muscles.

---

<sup>1</sup> I have not attempted to make an exhaustive search of all the books dealing with skull of *Varanus*, but have quoted these six only as representative examples.

## 2. THE SKULL.

## I.—General characteristics.

The skull of *Varanus monitor* is pyramidal in shape, each of the dorsal, ventral and lateral surfaces being more or less triangular in outline; the posterior surface is also more or less triangular and forms, so to speak, the base of the pyramid, the apex being formed by the anterior pointed snout (united premaxillae). The skull is well ossified, although there are several tracts of cartilage even in the adult. It is a strong, compactly built structure, very well buttressed along its posterior and lateral aspects. The sutures between different bones remain clearly visible even in the adult, unlike these in *Lacerta* where they become obliterated in the adult skull.

The *cranium* or brain-box forms the axial part of the posterior two-thirds of the skull and is disposed, like the enclosed brain, in an obliquely elongated direction, higher in front and lower behind. The posterior part of the cranium enclosing the mid-brain and the hind-brain is more or less completely ossified but the anterior part surrounding the cerebral hemispheres and the diencephalon is ossified only dorsally, remaining partly membranous and partly cartilaginous along the greater part of its ventral and lateral aspects. At the extreme anterior end, however, the olfactory stalks are again enclosed completely in a bony tube. The *auditory capsules* are completely ossified and are intimately united with the occipital region of the cranium. The *orbits* are large and are well protected by bones; they are separated from each other by an extensive *inter-orbital septum*, which is largely cartilaginous but partly membranous. This septum lies beneath the anterior part of the cranial cavity all along its length and even extends forwards as the *internasal septum*. The *olfactory capsules* are also large and lie immediately in front of the cranial cavity; they are partially surrounded by bones latero-posteriorly but are mainly enclosed in large cartilaginous capsules along the greater part of their extent. The united pre-maxillae form the rostrum.

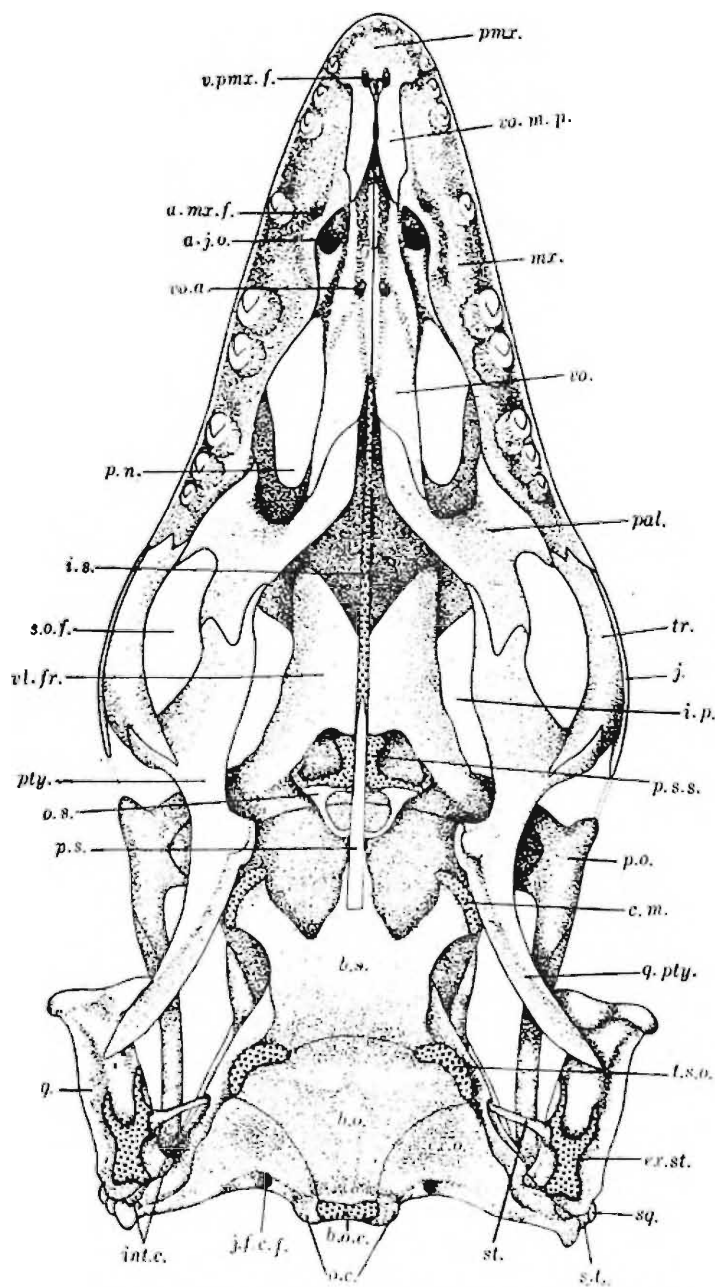
## II.—The Cranium.

(a) *The Occipital Region.*

The *occipital region* is almost completely ossified and lies dorsally at a lower level than the parietal and frontal regions in front. It consists of four bones, (a) the basi-occipital, (b) the paired ex-occipitals, and (c) the supra-occipital, all of which remain distinct and take part in surrounding the foramen magnum. The single median *occipital condyle* (figs. 1, 6) is crescentic in outline and is distinctly tripartite, the median piece being formed by the posterior end of the basi-occipital and the two lateral pieces by the posterior ends of the two ex-occipitals. The median basi-occipital piece of the condyle (*pars condyloidea*) is the smallest and is covered over by a thin, scale-like, elliptical piece of calcified cartilage which has a smooth surface and a milk-white appearance. The only other cartilage present in this region is the *cone-shaped cartilage* (*processus ascendens*) at the anterior border of the supra-occipital (*vide infra*). All

the four bones of the occipital region are ossifications of the chondrocranium (replacing bones).

The median *basi-occipital* (fig. 1) forms a more or less triangular flat plate, broad in front but narrow and pointed behind. Its anterior border,



TEXT-FIG. 1. A ventral view of the skull of *Varanus monitor* ( $\times ca. 2$ ).

*a.j.o.*, aperture for the Jacobson's organ; *a.mx.f.*, anterior maxillary foramen; *b.o.*, basi-occipital; *b.o.c.*, basi-occipital cartilage; *b.s.*, basisphenoid; *c.m.*, cartilaginous meniscus at the end of the basiptyergoid process of the basisphenoid; *ex.o.*, ex-occipital; *ex.st.*, extra-stapes (proportionately much enlarged); *int.c.*, intercalary cartilage; *i.p.*, incisura piriformis (interptyergoid fissure); *i.s.*, ventral border of the interorbital septum; *j.*, jugal; *j.f.c.f.*, combined jugular and condylar foramen; *mx.*, maxilla; *o.c.*, occipital condyle; *o.s.*, orbitosphenoid; *pal.*, palatine; *pmx.*, premaxilla; *p.n.*, position of the posterior nares; *p.o.*, postorbital; *p.s.*, para-sphenoid; *p.s.s.*, septum (planum) supra-septale; *pty.*, pterygoid; *q.*, quadrate; *q.ptly.*, quadrate process of the pterygoid; *s.o.f.*, sub-orbital fossa; *sq.*, posterior end of squamosal; *s.t.*, posterior end of supra-temporal; *st.*, stapes; *tr.*, transverse; *t.s.o.*, tuberculum spheno-occipitale; *vl.fr.*, ventro-lateral process of the frontal; *vo.*, vomer; *vo.a.*, vomerine aperture; *vo.m.p.*, vomero-maxillary process of the premaxilla; *v.pmx.f.*, ventral premaxillary foramen. Cartilages are shown with uniformly thick dots.

forming the base of the triangle, is crescentic in outline, being convex from side to side, and fits against the basisphenoid in front and the pro-otic on each side; the two lateral borders forming the two sides of the triangle are concave in outline and fit against the ex-occipital of each side; the posterior end of the bone corresponding to the apex of the triangle forms the median piece of the occipital condyle and also a very small part of the ventral boundary of the foramen magnum. The dorsal surface of the basi-occipital is depressed to form an oval area for the accommodation of the ventral surface of the medulla oblongata; in fact, the bone in this oval area is thin and appears translucent against transmitted light, the remaining portion of the bone being thick and opaque. On each of the two antero-lateral borders of the basi-occipital, between it and the pro-otic, there is a kidney-shaped cartilaginous tuberosity wedged in between these bones on each side: this is called the *tuberculum spheno-occipitale* (figs. 1 and 13). On this are inserted, on each side, strong tendons of two muscles, (1) the *musculus longus colli* and (2) the *musculus transversalis cervicis*<sup>1</sup>.

The paired *ex-occipitals* (figs. 1, 2 and 3) of the adult are irregularly shaped bones, each formed by a fusion of the ex-occipital proper with the opisthotic of its own side; each is, therefore, a compound bone, and, since it forms not only the side-wall of the cranial cavity but also a part of the auditory capsule and a prominent lateral process, the *paroccipital process*, it has been named by different workers as *pleuro-occipital*, *lateral occipital* or *oto-occipital*.

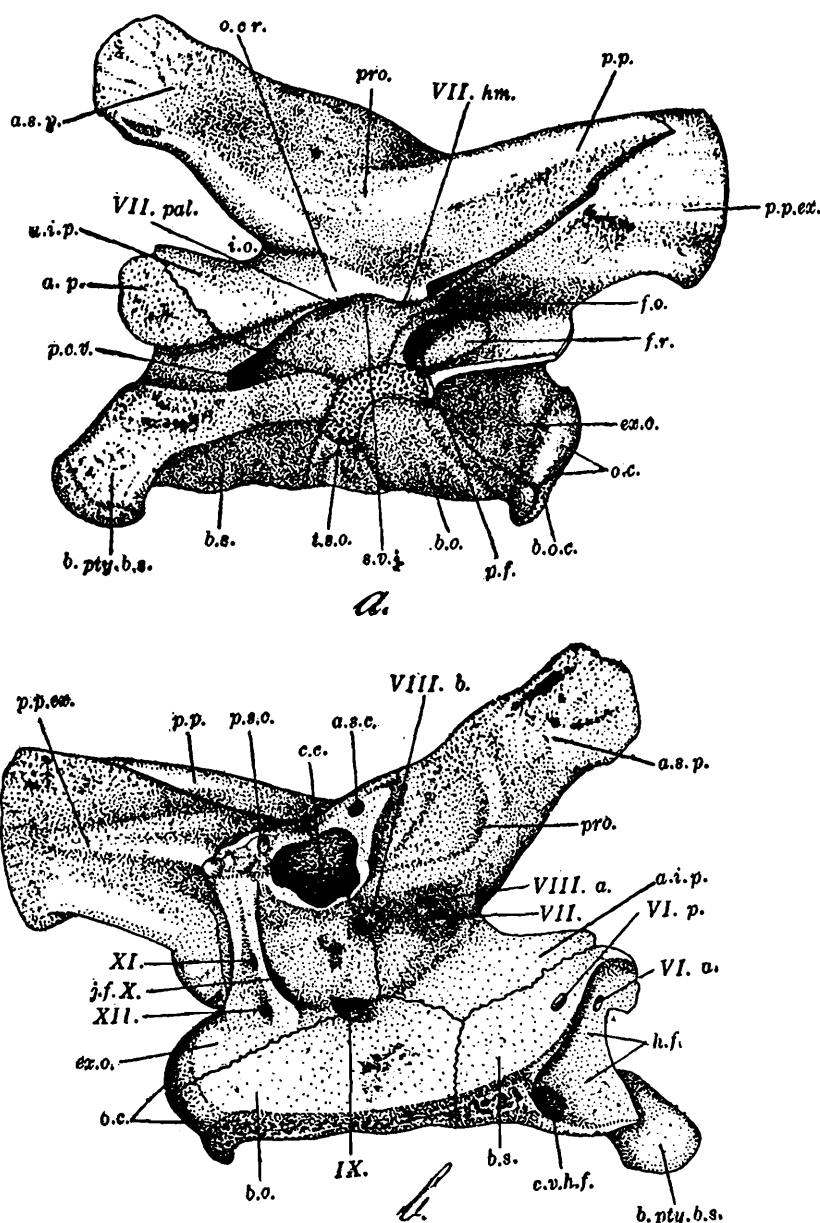
The ex-occipital proper is the small triangular plate lying ventrolaterally on each side of the basi-occipital (fig. 1), while the remaining larger part of the bone lying on the dorsal and outer side almost at a right angle to the ex-occipital proper represents the opisthotic. The ex-occipital part of the bone fits all along its inner border against the basi-occipital, while the opisthotic part fits anteriorly and externally against the pro-otic and dorsally against the posterior half of the supra-occipital. The ventral surface of the ex-occipital is depressed and forms the place of insertion of the *musculus rectus capitis inferior*. This muscle lies immediately above the *musculus longus colli* and arises from the hypophysial processes of the first four cervical vertebrae. The muscle-fibres are inserted directly on the ex-occipital without the formation of a tendon.

The boundary between the ex-occipital and opisthotic parts of the bone is clearly indicated on the *inner surface of the cranium* (seen in a

---

<sup>1</sup> As the nomenclature of these two muscles is uncertain, I am giving here their origin, extent and insertion. The *musculus longus colli* of each side is an elongated elliptical muscle inserted by a distinct tendon on the inner part of the tuberculum spheno-occipitale. The bodies of the two muscles lie closely pressed together in the neck, one on each side of the mid-ventral line, immediately dorsal to the oesophagus and ventral to the cervical vertebrae. Their fibres originate from the hypophyses of the first seven vertebrae. The *musculus transversalis cervicis* is inserted by a distinct tendon on the outer part of the tuberculum, but this tendon continues on its outer side into an aponeurosis inserted on the entire outer border of the ventral part of the ex-occipital. The body of the muscle itself consists of two parts: (1) a short anterior part which originates from the second vertebra and a part of the third, and (2) a long posterior part which originates from a part of the third and the fourth and fifth vertebrae. The muscle is attached to the outer surface of each neural arch along the line joining the pre- and post-zygapophyses.

longitudinal section) by a large crescentic slit-like aperture, the *jugular foramen* or *foramen lacerum posterius* (fig. 2 b), which lies between



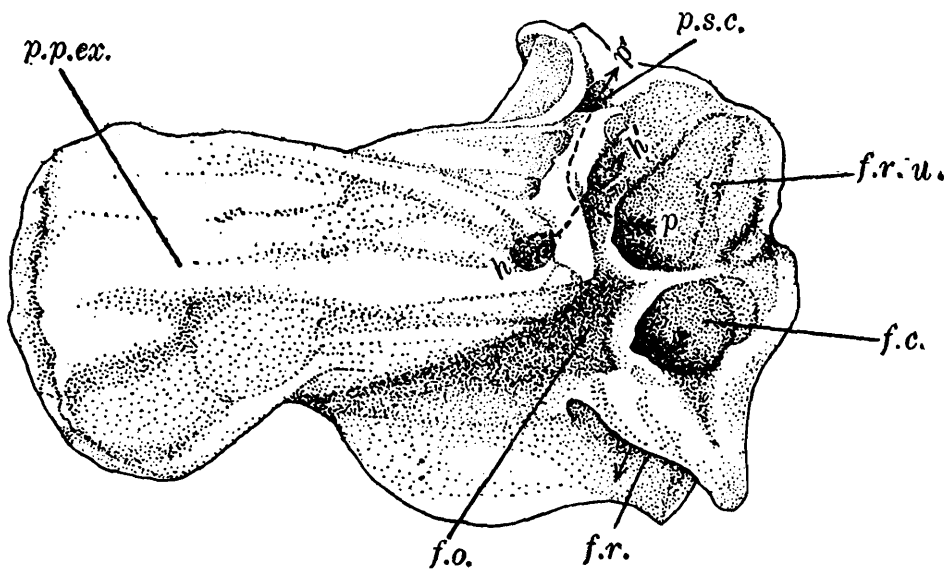
TEXT-FIG. 2. Two views of the basi- and ex-occipitals, the basisphenoid and the pro-otic. Cartilages are shown with uniformly thick dots ( $\times ca. 3$ ).

a. ventro-lateral view; b. in longitudinal section.

*a.i.p.*, anterior inferior process, *a.p.*, alar process; *a.s.c.*, channel for the anterior vertical semi-circular canal; *a.s.p.*, anterior superior process of the pro-otic; *b.o.*, basi-occipital; *b.o.c.*, basi-occipital cartilage; *b.s.*, basisphenoid; *b.pty.b.s.*, basi-ptyergoid process of the basisphenoid; *c.c.*, cavum capsularis in which is lodged the membranous labyrinth of the inner ear; *c.v.h.f.*, opening of the canalis vidianus into the hypophysial fossa (foramen caroticum internum) through which the intra-cranial branch of the internal carotid enters the cranial cavity; *ex.o.*, ex-occipital; *f.o.*, fenestra ovalis, into which fits the inner end of the *columella auris*; *f.r.*, fenestra rotunda, which is covered over in life by the *membrana tympani scundaria* and through which the glossopharyngeal nerve leaves the skull; *h.f.*, hypophysial fossa; *i.o.*, incisura otosphenoida for the Vth nerve; *j.f.x.*, jugular foramen for the exit of the jugular vein and the tenth cranial nerve; *o.c.*, occipital condyle; *o.cr.*, otosphenoidal crest; *p.c.v.*, posterior opening of the *canalis vidianus* through which the palatine branch of the facial nerve and the sympathetic and the internal carotid artery enter the basisphenoid bone; *p.f.*, perilymphatic foramen; *p.p.*, posterior process of the pro-otic; *p.p.ex.*, paroccipital process of the ex-occipital; *pro.*, pro-otic; *p.s.c.*, channel for the posterior vertical semi-circular canal; *s.v.f.*, sulcus venae jugularis; *t.s.o.*, tuberculum spheno-occipitale; *VI.a.*, anterior foramen for the exit of the sixth cranial nerve out of the basisphenoid; *VI.p.*, posterior foramen through which the VIth cranial nerve enters the basisphenoid bone; *VII.*, facial foramen through which the VIIth nerve leaves the cranial cavity; *VII.hm.*, posterior facial foramen for the exit of the hymomandibular division of the VIIth nerve; *VII.pal.*, anterior facial foramen through which the palatine branch of the VIIth nerve leaves the skull; *VIII.a.*, foramen acusticum anterius; *VIII.b.*, foramen acusticum posterius; *IX.*, foramen perilymphaticum or glossopharyngeal foramen; *XI.*, foramen for the exit of the spinal accessory nerve; *XII.*, foramen for the exit of the hypoglossal nerve.

the two parts of the bone in such a manner that the anterior wall of the foramen is formed by the opisthotic and its posterior wall by the ex-occipital. The jugular foramen transmits the vagus nerve (X), the *vena cerebialis posterior branch* of the internal jugular vein and the *occipital branch* of the occipito-vertebral artery. Immediately behind the jugular foramen lie two small rounded foramina (fig. 2 b), one above the other, on the inner surface of each ex-occipital: the lower of these two transmits the *hypoglossal nerve* (XII), while the upper lets through the *spinal accessory nerve* (XI). On piercing the cranial wall internally, these two foramina open into the large jugular foramen, so that on the outer surface of the cranium there is a single large oval foramen lying just outside the occipital condyle at the root of each paroccipital process. This is, therefore, the combined *foramen lacerum posterius (jugular foramen)* + the *condylar (hypoglossal) foramen* of the mammalian skull and also that of *Sphenodon* and lets through the internal jugular vein (*vena cerebialis posterior branch*) and the Xth, XIth and XIIth cranial nerves and lets in the *occipital branch* of the occipito-vertebral artery (figs. 1, 2 and 13).

The opisthotic part of the bone forms (1) the posterior part of the auditory capsule, and (2) a stout horizontal process, the *paroccipital process*, directed outwards and slightly backwards. This process on each side supports the supra-temporal above and the quadrate below. On the dorsal surface of the opisthotic part, at the root of the paroccipital process, there is a small foramen (figs. 2 b, 3 and 10) leading above and below into the passage for the *posterior vertical semi-circular canal* of the internal ear; while on the anterior vertical surface of the paroccipital process, at its root, lies the foramen leading behind and



TEXT-FIG. 3. Fronto-lateral view of the ex-occipital ( $\times ca. 7$ ).

*f.c.*, fenestra cochleae leading below into *f.r.*, the fenestra rotunda, the passage being shown by an arrow; *f.o.*, the posterior wall of fenestra ovalis; *f.r.u.*, recessus utriculi; *h-h'*, arrow passing through the channel for the horizontal semi-circular canal; *p-p'*, arrow passing through the channel for the posterior semi-circular canal; *p.p.ex.*, paroccipital process of the ex-occipital; *p.s.c.*, opening for the posterior semi-circular canal.

in front into the passage for the *horizontal semi-circular canal*. These two foramina can only be seen in the disarticulated bone (fig. 3);

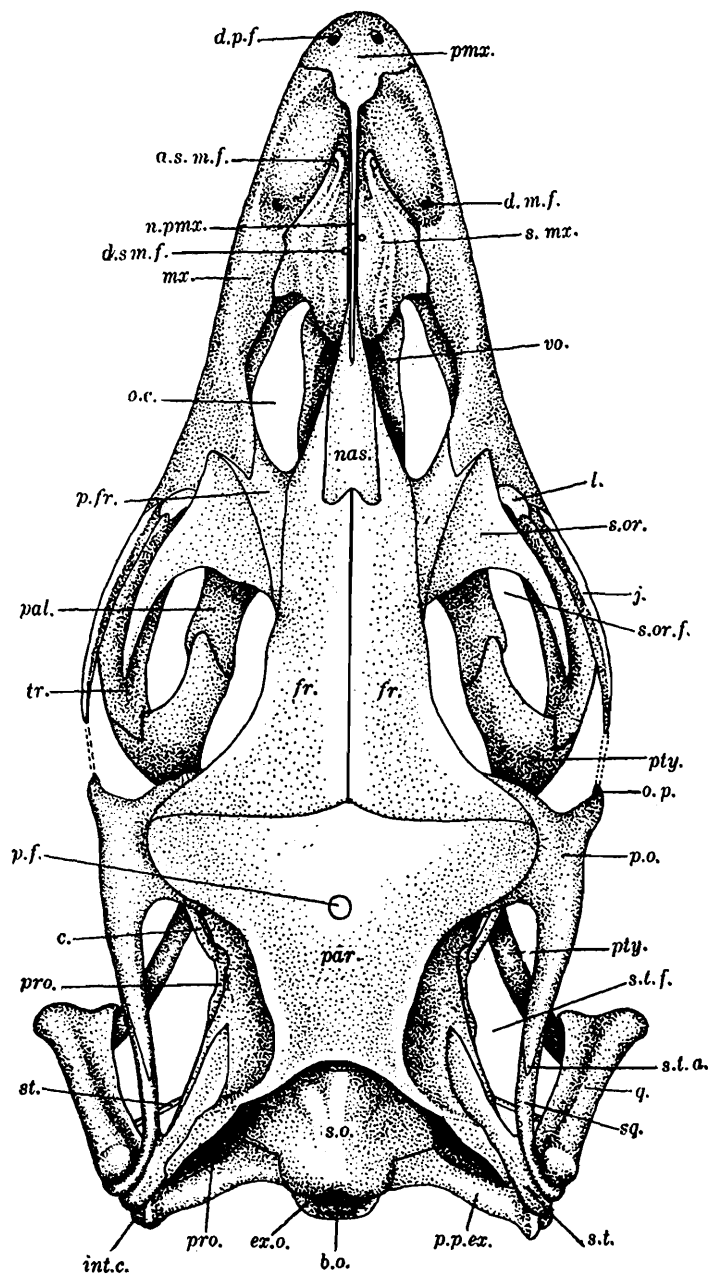
in the complete skull the first foramen is covered over by the supra-occipital and the second by the pro-otic. The anterior end of each opisthotic is excavated to form a fossa which extends upwards into the supra-occipital, and is continuous with a similar fossa on the postero-internal surface of the pro-otic, the fossae on these three bones together forming the cavity (*cavum capsularis*) of the auditory capsule (figs. 5 and 10) in which is lodged the membranous labyrinth of the internal ear. These fossae also can be seen separately only in a disarticulated skull.

The fossa of the opisthotic part of the auditory capsule presents a central recess, a large foramen on the inner and ventral side and another small one on the outer and dorsal side (fig. 3). The central recess lodges the *recessus utriculi* and the *ampulla posterior* leading into the posterior semi-circular canal; the outer and dorsal foramen leads into the passage for the horizontal semi-circular canal, while the inner and ventral foramen (*fenestra cochleae* or *perilymphatica*) provides for the passage of the *aqueductus perilymphaticus* into the *recessus scalae tympani* of the *fenestra rotunda*<sup>1</sup>. The *fenestra rotunda* (fig. 2 a), is a large, more or less elliptical, opening with an arched roof, lying on the outer lateral surface of the skull, between the outer convex border of the ex-occipital below and the *fenestra ovalis* above. It is closed in life by a thick membrane, the *membrana tympani secundaria*, which is really the outer wall of the *saccus perilymphaticus*, lying in a short space within the *fenestra rotunda*. This space is called the *recessus scalae tympani* and opens above through the *fenestra cochleae* into the *cavum vestibulare* (inner middle region of *cavum capsularis*) and inwards through the *aqueductus perilymphaticus* passing through the *perilymphatic foramen* into the subarachnoid spaces beneath the brain in the cranial cavity. The *glossopharyngeal nerve* leaves the cranial cavity through the *foramen perilymphaticus* (fig. 2b), runs along the posterior wall of the *recessus scalae tympani* imbedded in the wall of the perilymphatic membrane and emerges out of the *fenestra rotunda* into the cavity of the middle ear. The greater part of the *fenestra rotunda* is formed by the ex-occipital, which forms a process resembling an arched bridge, only the antero-ventral end being formed by the *tuberculum sphenoccipitale* (fig. 2 a). Similarly, the posterior part of the *fenestra ovalis*, lying immediately above the *fenestra rotunda*, is formed by the opisthotic, being closed anteriorly by the pro-otic. It should be noted that both the *fenestra ovalis* and *fenestra rotunda* lie at the bottom of a shallow pit bounded ventrally by the free lateral border of the ex-occipital and dorsally by the pro-otic and the paroccipital process: this pit is the inner part of the middle ear, which has a wide communication with the pharynx below, and across which runs the *columella auris* from the *fenestra ovalis* to the tympanic membrane on the outside (figs. 1, 6 and 13).

The median *supra-occipital* (figs. 3, 4, 5 and 6) forms the roof of the occipital segment and also that of the auditory capsule on each side. Dorsally, it lies at a lower level behind the parietals and slopes in an antero-posterior direction as well as laterally on each side. Looked

<sup>1</sup> In *Sphenodon*, as in the *Chelonia*, *Ophidia* and *Anser (Aves)*, there is no *fenestra rotunda* and no *membrana tympani secundaria* either.

at from the dorsal surface, it is more or less hexagonal in outline with a notch on its posterior border. The anterior crescentic border of the bone rests against the united parietals in front but there is no close-fitting sutural union between the two bones, the joint being formed of

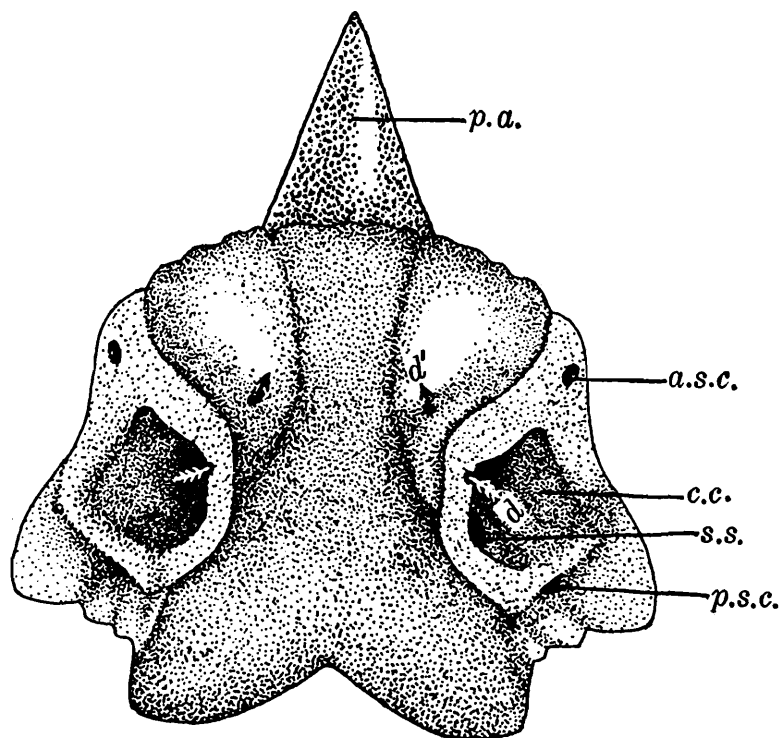


TEXT-FIG. 4. Dorsal view of the skull ( $\times ca. 2$ ).

*a.s.m.f.*, anterior septo-maxillary foramen; *b.o.*, basi-occipital with the basi-occipital cartilage covering its posterior border; *c.*, columella cranii or epipterygoid; *d.m.f.*, dorsal maxillary foramen; *d.p.f.*, dorsal pre-maxillary foramen; *d.s.m.f.*, dorsal septo-maxillary foramen; *ex.o.* ex-occipital; *fr.*, frontal; *int.c.*, intercalary cartilage; *j.*, jugal; *l.*, lacrimal; *mx.*, maxilla; *nas.*, nasal; *n.pmx.*, nasal process of the premaxilla; *o.c.*, place for the cartilaginous olfactory capsule; *o.p.*, orbital process of the post-orbital; *pal.*, palatine; *par.*, parietal; *p.f.*, parietal foramen; *p.fr.*, pre-frontal; *pmx.*, premaxilla; *p.o.*, post-orbital; *p.p.ex.*, paroccipital process of the ex-occipital; *pro.*, pro-otic; *pty.*, pterygoid; *q.*, quadrate; *s.mx.*, septo-maxillary; *s.o.*, supra-occipital; *s.or.*, supra-orbital; *s.or.f.*, supra-orbital fossa; *sq.*, squamosal; *s.t.*, supra-temporal; *s.t.a.*, supra-temporal arcade; *s.t.f.*, supra-temporal fossa; *st.*, stapes or columella auris; *tr.*, transverse; *vo.*, vomer.

fibrous tissue and cartilage, the two bones being movable on each other vertically within a limited range. In the middle line, there is a cartilaginous piece (fig. 5) perfectly cone-shaped in appearance, which projects

from the anterior border of the supra-occipital and fits closely into a deep funnel-shaped depression (*parietal fossa*) into the posterior border of the parietal in the median line (fig. 5). Bradley (2, p. 482) regards this cone-shaped cartilage as corresponding to the *processus ascendens tecti synotici* of the cartilaginous cranium. There is thus a "peg and socket" joint between the supra-occipital and the united parietals which would obviously allow only a limited range of movement between these two bones. This joint is an important feature of the Lacertilian skull and forms an essential factor in the *kinetism*<sup>1</sup> of the skull (*vide infra*). The two antero-lateral borders of the supra-occipital fit against the pro-otics on each side, the postero-lateral borders against the ex-occipitals, while the posterior border with the notch is free and forms the roof of the foramen magnum (fig. 6). Along its mid-dorsal line runs an inconspicuous *occipital ridge* or *crest* and the bone slopes down on each side of this crest to meet the ex-occipital behind and the pro-otic in front. The disarticulated supra-occipital resembles in shape the neural arch of a vertebra with thick lateral walls; its ventral aspect (fig. 5) gives the appearance of a deep gutter with thick and expanded but hollowed walls. Each of these thick walls forms the roof of the auditory capsule and is hollowed out into a central fossa which lodges the dorsal portion of the membranous labyrinth. Deep down on the inner wall of the fossa, there is a rounded aperture leading into a narrow tube which lodges the *sinus*

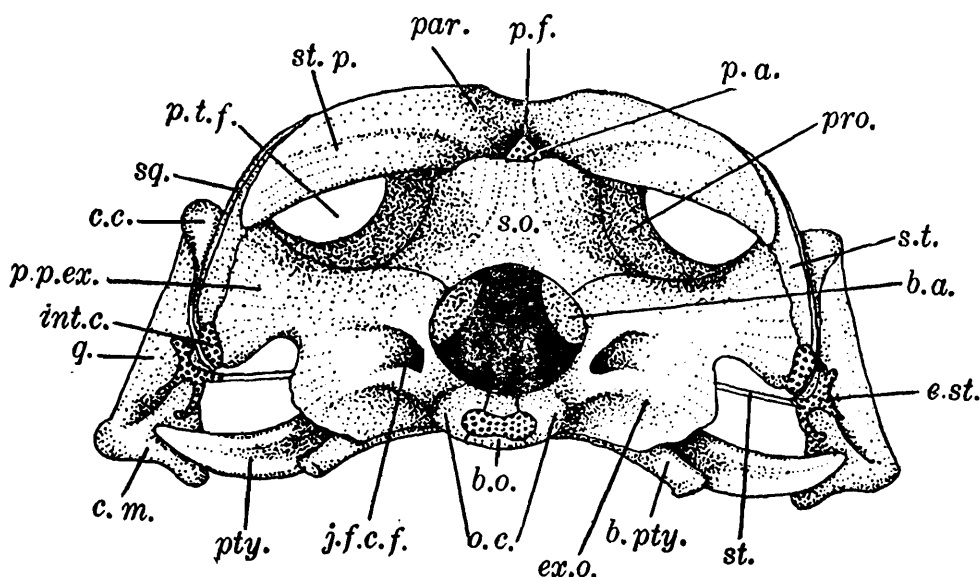


TEXT-FIG. 5. Ventral view of the supra-occipital ( $\times ca. 6$ ).

*a.s.c.*, channel for the anterior semi-circular canal; *c.c.*, the dorsal part of the cavum capsularis; *d-d'*, arrow passing through the aqueductus endolymphaticus which lodges the ductus endolymphaticus; *p.a.*, *processus ascendens* (cartilaginous); *p.s.c.*, channel for the posterior semi-circular canal; *s.s.*, channel for the sinus superior leading into the channel for the anterior semi-circular canal in front and the channel for the posterior semi-circular canal behind.

<sup>1</sup> The fronto-parietal region of the skull is movable upon the occipito-sphenoidal part.

*superior* of the membranous labyrinth; this tube leads into minute hair-like tunnels both anteriorly and posteriorly which can be seen as extremely minute apertures on the outer wall, one lying anteriorly and the other posteriorly to the fossa; these tunnels accommodate the upper parts of the *anterior* and *posterior vertical semi-circular canals* (fig. 5). A third hair-like tunnel pierces the inner wall of the fossa a little above and anterior to the aperture for the sinus superior; it leads into the cranial cavity by a minute aperture (*aqueductus vestibuli*) lying on the antero-lateral surface of the inner wall of the supra-occipital as seen from the ventral side (fig. 5); this tunnel lodges the *ductus endolymphaticus*, which opens into the cranial cavity.



TEXT-FIG. 6. Posterior view of the skull of *Varanus monitor* ( $\times ca. 3$ ).

*b.a.*, bulging of the auditory capsule into the cranial cavity; *b.o.*, basi-occipital with the elliptical basi-occipital cartilage attached to its posterior end; *b.pt.*, basipterygoid process of the basisphenoid; *c.c.*, condylus cephalicus; *c.m.*, condylus mandibularis; *e.st.*, cartilaginous extra-stapes; *ex.o.*, ex-occipital; *int.c.*, intercalary cartilage; *j.f.c.f.*, combined jugular and condylar foramen for the exit of the Xth, XIth and XIIth nerves and the vena cerebialis posterior branch of the internal jugular vein and for the entrance of the occipital branch of the occipito-vertebral artery; *o.c.*, occipital condyle; *p.a.*, processus ascendens cartilage fitting into the parietal fossa; *par.*, parietal; *p.f.*, parietal fossa; *p.p.ex.*, paroccipital process of the ex-occipital; *pro.*, pro-otic; *p.t.f.*, post-temporal fossa; *pty.*, pterygoid; *q.*, quadrate; *s.o.*, supra-occipital; *sq.*, squamosal; *s.t.*, supra-temporal; *st.*, stapes; *st.p.*, supra-temporal process of the parietal.

The supra-occipital forms the roof of the bun-shaped cerebellum disposed in an obliquely dorso-ventral direction and the medulla oblongata (hind-brain). The anterior border and the dorsal surface of the supra-occipital form the place of insertion for the occipito-vertebral muscles (*rectus capitis*, *obliquus capitis* and *spinalis capitis* muscles). These muscles form a thick pad covering the supra-occipital in such a way that, on removal of the integument, the occipital segment appears on the same level with the parietal.

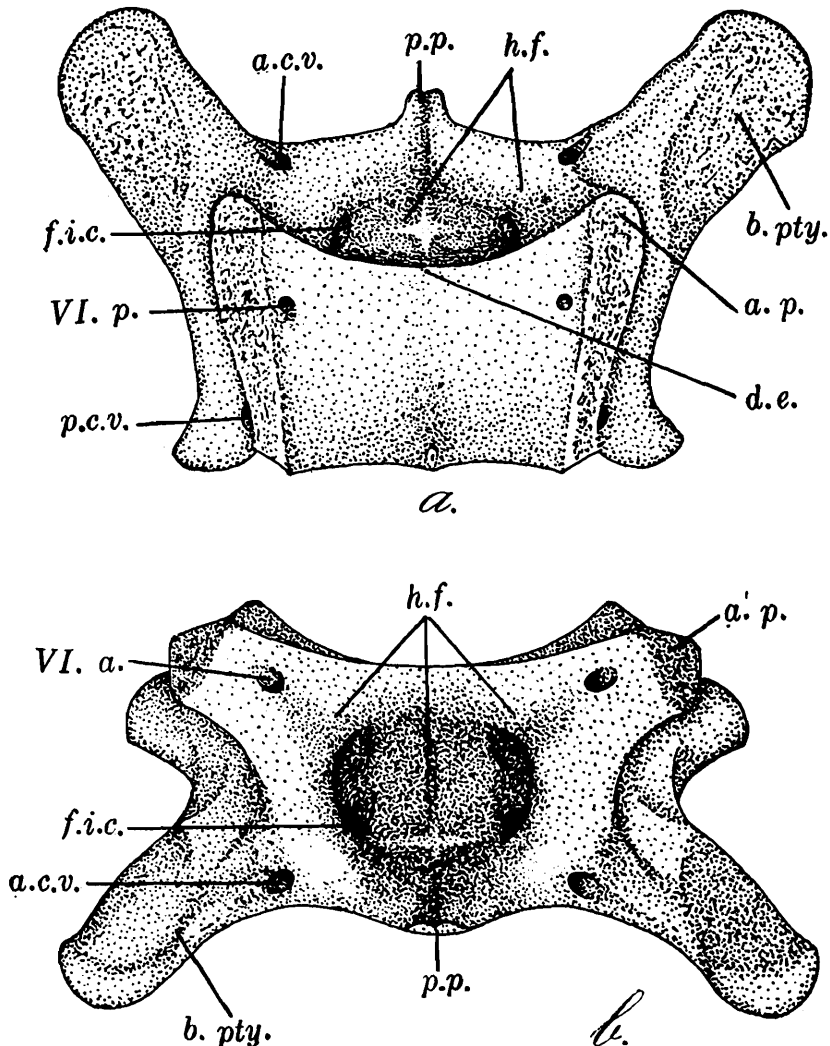
In *Sphenodon*, the external jugular foramen transmits the IXth Xth and XIth nerves and the vena cerebialis posterior branch of the internal jugular, while there is a separate foramen for the XIIth nerve. In *Lacerta*, there are two separate foramina for the XIIth nerve and another for the Xth. The IXth nerve also comes out separately and not from the *fenestra rotunda* as it does in *Varanus*.

In *Lacerta* (9, p. 9), the *processus ascendens* of the supra-occipital is bony and is only tipped with cartilage, but in *Varanus* the process is wholly cartilaginous and fits into the hinder and not on the under surface of the parietal.

(b) *The Parietal Region.*

The *parietal region* consists of the united parietals above and the median basisphenoid below. There are no alisphenoids, the side-walls of the cranium in this region being formed by the pro-otics behind and thick membranous walls in front. The basisphenoid is a chondrocranial ossification but the parietals are dermal bones.

The *basisphenoid* (figs. 1 and 7) is more or less quadrangular in shape and lies immediately in front of the basi-occipital, forming the floor of the cranial cavity beneath the mid-brain and a part of the hind-



TEXT-FIG. 7. Two views of the basisphenoid ( $\times ca. 6$ )

a. dorsal; b. anterior.

a.c.v., anterior opening of canalis vidianus; a.p., alar process; b.pty., basispterygoid process; d.e., dorsum ephippii; f.i.c., foramen caroticum internum; h.f., hypophyseal fossa; p.c.v., posterior opening of canalis vidianus; p.p., parasphenoid process; VI.a., anterior foramen for the abducens nerve; VI.p., posterior foramen for the abducens nerve.

brain. Its posterior border is straight and single, fitting closely and immovably against the basi-occipital, but the anterior border is double,

there being a *dorsal anterior border* (*dorsum ephippi*) and a *ventral anterior border* formed as a result of the presence at the anterior end of a large and deep depression called the *hypophysial fossa* (*sella turcica*), which lodges the *recessus infundibularis* and the *hypophysis* of the diencephalon. The dorsal anterior border is concave and is produced laterally on each side into a very short conical process (fig. 7) corresponding to the *alar process* in *Sphenodon*. The ventral anterior border gives off a short and stumpy median bifid process with which the parasphenoid articulates in front; this median process is therefore called the *parasphenoid process* (*processes trabeculae inferiores* of Siebenrock). On each side of this process, the bone is produced antero-laterally into a thick stout process, the *basipterygoid process*<sup>1</sup>, which is expanded at its extremity and articulates with the pterygoid, there being a cartilaginous meniscus (figs. 1 and 13) at the point of articulation. It should be noted that this articulation is movable like that between the supra-occipital and the parietal and forms another essential factor in the kinesis of the skull. Just as there are two anterior borders, similarly there are two lateral borders on each side, a *dorsal lateral border* and a *ventral lateral border* separated by a longitudinal groove (*sulcus venae jugularis*) between the two; the dorsal border articulates all along its length with the pro-otic, while the ventral border is free.

The dorsal surface of the basisphenoid is concave from side to side and is higher in front than behind; the concavity of the two bones (the basi-occipital and the basisphenoid) together forms a shallow depression into which fits the ventral convex surface of the brain behind the pituitary body. In the anterior third of the dorsal surface lie two small foramina (fig. 7a), one on each side, for the exit of the VIth (*abducens*) nerve<sup>2</sup>. This nerve perforates the bone at the base of each alar process, runs through a very short canal and comes out into the dorsal part of the hypophysial fossa (fig. 7b), wherefrom it runs outwards to innervate the external rectus muscle of the eye. The base of the basipterygoid process of each side is tunnelled through by the *canalis vidianus*<sup>3</sup> (fig. 7a), through which pass the *palatine branch of the internal carotid artery* and the *palatine branch of the facial nerve*. These two structures run close together side by side along the lateral wall of the basisphenoid in the groove between its dorsal and ventro-lateral borders and then pass together through the *canalis vidianus* and even on coming out run close together on the palate. The posterior opening of the *canalis vidianus* lies on the lateral wall of the basisphenoid just in front of its posterior end; the anterior opening of the canal, however, lies at the base of the basipterygoid process, on each side, on the outer side of the median parasphenoid process. About the middle of its course, the *canalis vidianus* passes through the extreme lateral boundary of the

<sup>1</sup> The basipterygoid process of the basisphenoid represents an ossification of a part of the greatly reduced palato-quadrate cartilage (5, p. 428).

<sup>2</sup> Siebenrock (9, pp. 11 and 12) mentions this foramen as *foramen internum* in *Lacerta* and says that it transmits a branch of the internal carotid. According to his description, the position of the *foramen internum* is the same as that of the foramen for the VIth nerve in *Varanus*. I think Siebenrock mistook the nerve for a branch of the internal carotid; at any rate, his statement on this point needs confirmation.

<sup>3</sup> The palatine branch of the facial nerve, as it joins the sympathetic branch from the IXth is called the *vidian nerve* (5, p. 271).

hypophysial fossa. The hypophysial fossa itself is a funnel-like pit, the base of which extends laterally on each side and communicates through an aperture with the canalis vidianus. Through this aperture (foramen caroticum internum, figs. 3, 8, 9 and 11), the cranial branch of the internal carotid enters the sella turcica from the canalis vidianus and becomes completely intra-cranial; it then runs laterally to the hypophysis and mounts upwards to supply the latero-ventral wall of the brain.

The united *parietal* (fig. 4) forms a more or less quadrangular bony plate, narrow in the middle but expanded both anteriorly and posteriorly. It articulates in front with the paired frontals through a more or less straight transverse suture, but is produced behind into two long, stout and laterally compressed processes, the *supra-temporal processes*—*processus parietales* of Siebenrock—(fig. 6), which diverge and run outwards and backwards to articulate behind with the supra-temporal on each side through an obliquely running suture. Laterally, between the supra-occipital and the pro-otic on one side and the parietal on the other, there is always a small area which is unossified and in a dry skull looks like a triangular fissure. It is covered in life with a thick fibrous membrane and provides a loose movable connection between the parietal and the pro-otic, so that the whole of the occipital segment, the basisphenoid and the pro-otic move as one piece on the parietal (Kinetism).

Each of the two concave lateral borders of the parietal is bevelled off all along its length to form a narrow ledge (fig. 4) slanting outwards; these bevelled ledges serve chiefly for the attachment of the adductor mandibulae medius muscles. The *parietal process* (*anterior superior process*) of the *pro-otic* articulates movably with each of these bevelled borders about the middle of its length.

The dorsal surface of the united parietal is evenly flat like that of the frontals, but the ventral surface is slightly concave from side to side, forming a shallow depression into which fits the dorsal surface of the fore-brain and the mid-brain. In the anterior half of the bone, right in the median line, lies the oval *parietal foramen*, into which fits the parietal organ. Between the roots of the supra-temporal processes, the posterior border of the parietal is excavated in the median line to form a deep funnel-like pit, the *fossa parietalis* (fig. 6), which in the entire skull is hidden by the anterior border of the supra-occipital. Into the fossa parietalis is inserted the cone-shaped cartilaginous projection<sup>1</sup> from the anterior border of the supra-occipital, forming a "peg and socket" joint (p. 142).

The basisphenoid of *Varanus* presents important differences from that of *Sphenodon*. The alar processes are very short and there is no median dorsal process of the *dorsum ephippii*. Further, the anterior openings of the canalis vidianus are paired and not median and common as in *Sphenodon*, and the canalis vidianus transmits both the palatine artery and nerve and not the palatine artery alone as it does in

---

<sup>1</sup> The processus ascendens tecti synotici cartilage.



pushed back behind the large eyes into the parietal and occipital regions. The brain is obliquely placed: the olfactory stalks are lodged in the narrow tubular cavity formed by the ventro-lateral extensions of the frontals, the cerebral hemispheres are covered by the frontals above and are supported by cartilage and thick fibrous membrane below, while the optic chiasma is surrounded by the minute orbitosphenoid bones. The *inter-orbital septum* extends forwards from the median parasphenoid process of the basisphenoid, and lies below the narrow cranial cavity between the two large orbits, continuing forwards into the olfactory chamber as the *inter-nasal septum* (fig. 8b). As the cranial cavity is very much reduced between the large eyes and is largely replaced by the inter-orbital septum, the skull is almost completely *tropibasic*.

The *parasphenoid* (figs. 1 and 8b) is a long narrow bone flattened dorso-ventrally and resembling in shape the blade of a bayonet. It underlies the ventral border of the inter-orbital septum in the mid-ventral line just in front of the basisphenoid, articulating behind with the median parasphenoid process of the basisphenoid and terminating in front at a point about half the length of the inter-orbital septum (fig. 8b). Posteriorly, the parasphenoid protects the infundibulum of the diencephalon and even forms part of the hypophysial fossa, while along the greater part of its length it forms the ventral support of the posterior half of the inter-orbital septum. In a freshly prepared skull, the parasphenoid is more or less horizontal in position, being only slightly bent upwards anteriorly; but in a dried skull, as the inter-orbital septum shrivels up, the parasphenoid gets bent upwards, but its anterior end never reaches the frontal as is shown by Reynolds (7) in his diagrams.

The parasphenoid of *Varanus* is very much reduced and corresponds only to the *rostrum parasphenoidei* (*processus cultriformis*) of *Sphenodon*, the main body of the parasphenoid corresponding to the hinder wing-like processes, the middle shield and the transverse processes of the parasphenoid of *Sphenodon* being absent.

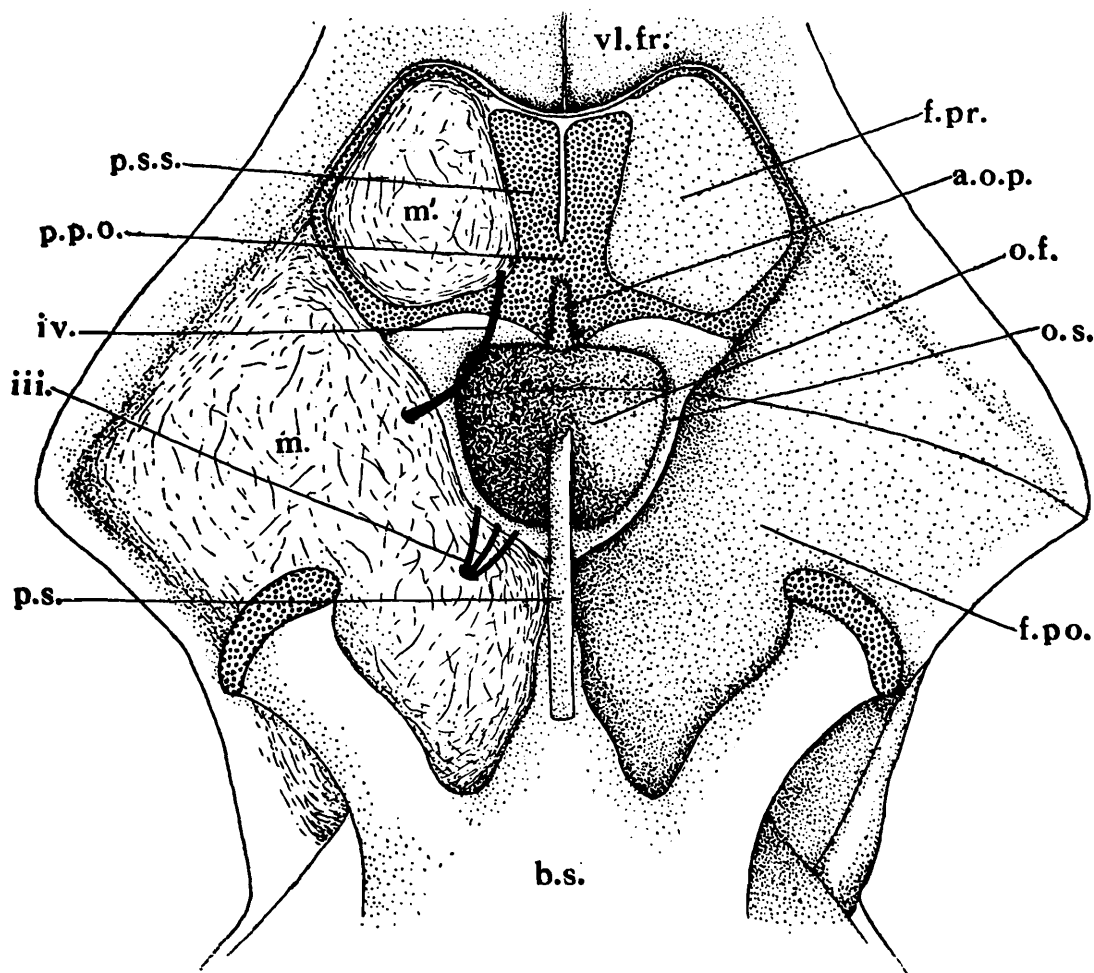
The paired *frontals* (fig. 4) are elongated bones, narrow in front but broad behind. They articulate with each other through a long and straight median suture and with the parietals behind through a more or less straight transverse suture. Anteriorly each frontal presents a shallow concavity and a cleft, into which is wedged in one of the two posterior processes of the united nasals, while along the anterior half of its outer lateral border, there is a triangular depression for articulation with the pre-frontal of its own side. Dorsally, the frontals are evenly flat and lie at the same level with the parietals, but laterally each is inflected downwards and inwards to form a latero-ventral process (fig. 8b), which meets the corresponding process of the other side, enclosing a more or less complete bony canal (*canalis olfactorius*<sup>1</sup>), in which are lodged the elongated olfactory stalks. Ventrally these inflected processes enclose between them the dorsal membranous border of the inter-orbital septum.

The ventro-lateral walls of the cranial cavity (fig. 9) enclosing the fore-brain are formed partly of calcified and hyaline cartilage, partly

<sup>1</sup> In *Lacerta*, the *canalis olfactorius* is mainly membranous.

of a thick fibrous membrane and partly by the paired *orbitosphenoid* bones. The cartilaginous portion is represented by the *planum (septum) supra-septale* or *pila preoptica* and its lateral extensions. The *planum supra-septale* (figs. 1 and 9) rests anteriorly against the ventral part of the posterior border of the *canalis olfactorius* and is divided into two longitudinal strips along the greater part of its length by the insertion of the dorsal border of the *inter-orbital septum*. The posterior part of the cartilage is undivided; it forms the anterior boundary of the *optic fenestra* and gives off an obliquely directed median ventral process, the *anterior optic process* (fig. 9) and two long narrow *lateral processes* which extend upwards and reach the *frontals* above, and then run forwards along their postero-ventral borders (figs. 8b and 9).

The *orbitosphenoids*<sup>1</sup> (figs. 1, 8b and 9) are two minute, curved, and flattened bones which are connected anteriorly with the *pila*



TEXT-FIG. 9. The orbitosphenoids and the connected cartilages and membranes from the ventral side ( $\times ca. 4\frac{1}{2}$ ).

*a.o.p.*, anterior optic process; *b.s.*, basisphenoid; *f.po.*, fenestra postoptica; *f. pr.*, fenestra preoptica; *m.*, membrane covering the fenestra postoptica; *m'*, membrane covering the fenestra preoptica; *o.f.*, optic fenestra; *o.s.*, orbitosphenoid; *p.p.o.*, pila preoptica; *p.s.*, parasphenoid; *p.s.s.*, planum supra-septale; *vl.fr.*, ventro-lateral process of the frontal; *iii.*, the three branches of the oculomotor nerve; *iv.*, trochlear nerve.

<sup>1</sup> Reynolds (7) shows the orbitosphenoids in a longitudinal section hanging vertically downwards from the junction of the parietal and frontal bones in *V. varius*. His diagram does not seem to be correct, as it is extremely unlikely that both could be seen in a longitudinal section. In *Varanus monitor*, they lie in a vertical position, one on each side of the middle line, between the septum supra-septale above and the posterior end of the inter-orbital septum below, as shown in fig. 8.

*preoptica* and posteriorly with the vestigial *pila postoptica*. The orbitosphenoids represent the reduced vestiges of the sphenethmoid ossification of some primitive extinct reptiles (5). Each is a slender bone, broader at its dorsal than at its ventral end and forms the antero-lateral, lateral and posterior boundary of the optic fenestra (fig. 9).

On either side of the planum supraseptale, bounded behind and laterally by its lateral extensions and in front by the frontals, there is a large oval area covered by membrane: this is the *fenestra preoptica* (fig. 12). On either side of the orbitosphenoids, there is a similar *fenestra postoptica*. The fourth nerve (pathetic) leaves the cranial cavity at the inner border of this fenestra, while the three branches of the third nerve come out a little behind the fourth (fig. 9).

The vertical *inter-orbital septum* is chiefly cartilaginous all along its length but a small dorsal part of it lying immediately below the *canalis olfactorius* of the frontals is membranous (fig. 8*b*). The optic fenestra enclosed by the two orbitosphenoids is single when looked at from the dorsal side, but as the inter-orbital septum runs vertically below it, it is seen to be divided into two when looked at from the ventral side, each of the two fenestrae providing an exit for the optic nerve of its own side. In dried skulls, the cartilages and membranes of the region and the minute orbito-sphenoid bones are lost and therefore the orbits are seen to open widely into each other.

In *Lacerta* also, the inter-orbital septum is partly membranous and partly cartilaginous. Siebenrock (9) applies the name inter-orbital septum only to the upper membranous part, while the lower cartilaginous part is distinguished by him as the *pre-sphenoid*.

### III. The Sense-Capsules.

Of the three sense-capsules, the auditory and the olfactory are closely connected with the skull, but the optic capsule is free although it is supported and protected by a number of bones of the skull.

#### (a) *The Auditory Capsules.*

The *auditory capsules* are closely associated with the occipital region of the cranium and are formed on each side by the pro-otic, the opisthotic part of the ex-occipital and the supra-occipital. Each auditory capsule bulges inwards into the cranial cavity as the *auditory bulla* (fig. 6), which is easily seen on each side through the foramen magnum. All the three bones taking part in the formation of the auditory capsules are chondrocranial ossifications.

The ex-occipitals and the supra-occipital have already been described. We shall, therefore, describe the pro-otic only here.

The *pro-otic (otosphenoid)* is an irregularly triradiate bone on each side (figs. 2*a*, 2*b*, 8*a*, 8*b* and 10), forming the anterior and antero-ventral parts of the auditory capsule. One of its radii (the *anterior inferior process*) is flat and stumpy and articulates ventrally with the upper lateral border of the basisphenoid in front and with the tuberculum speno-occipitale behind. Another radius (the *anterior superior*

*process* or the *parietal process*<sup>1</sup>) articulates moveably against the lateral bevelled edge of the parietal internally and against the dorsal end of the epipterygoid externally, while the third conical radius (the *posterior process*) fits against the outer surface of the paroccipital process of the ex-occipital. The central part of the bone where the three radii meet is hollowed out and fits posteriorly against the opisthotic part of the ex-occipital, completing the floor and side-walls of the auditory capsule, the roof of the capsule being formed by the supra-occipital, with the anterior half of which the pro-otic articulates dorsally. The outer surface of the dorsal part of the bone is deeply concave, while the inner surface is strongly convex.

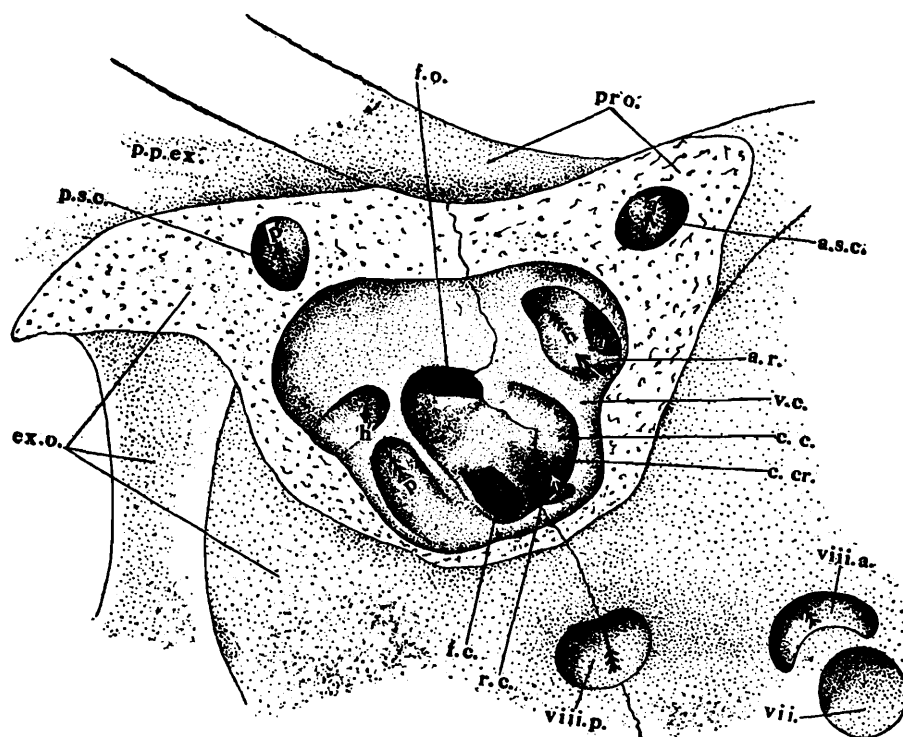
Looked at from the side (fig. 2a), the anterior superior and anterior inferior processes meet at an angle and enclose between them a triangular space covered over in life with a membrane. This membrane is perforated by a large aperture through which the trigeminal nerve (Vth) leaves the cranial cavity. This triangular space corresponds to the "incisura otosphenoida" (Siebenrock) of *Sphenodon* and *Lacerta*. The root of the anterior superior process is perforated dorsally by the *anterior vertical semi-circular canal* of the internal ear, the remaining part of which lies in the corresponding portion of the supra-occipital. The greater part of the *horizontal semi-circular canal* lies within the pro-otic in a canal-like perforation of its outer wall, the remaining part of this canal lying in the opisthotic part of the ex-occipital (fig. 10). The hollow excavation of the central part of the bone extends deep into the anterior superior process forming the anterior ampullary recess and accommodating both the *ampulla anterior* and the *ampulla horizontalis* of the membranous labyrinth (fig. 10).

On the outer surface of the bone close to its ventral border, there is a groove overhung by an elongated crest which extends forwards even on the basisphenoid; the crest is called the *otosphenoidal crest* (fig. 2a), while the groove is named the *sulcus venae jugularis*. In this groove, there are two foramina: the anterior one provides for the exit of the *palatine branch*, while the posterior lets through the *hyomandibular branch* of the facial nerve. Immediately below and behind the foramen for the hyomandibular branch of the 7th nerve lies the *fenestra ovalis* (fig. 2) for the insertion of the inner end of the columella auris. The anterior and posterior facial foramina lead into a common canal within the body of the bone and open internally into the cranial cavity by a common aperture, the *facial foramen* (figs. 2b, and 10), lying immediately behind the "incisura otosphenoida" and below the anterior auditory foramen. The inner surface of the pro-otic bears three foramina: the facial foramen and the anterior and posterior auditory foramina. The facial foramen provides exit for the facial (VII) nerve, while the anterior auditory foramen lets through the anterior division of the auditory nerve. The posterior auditory foramen lies at the junction of the inner wall of the pro-otic with that of the ex-occipital and lets through the posterior division of the auditory nerve.

---

<sup>1</sup> *Ala otosphenoida* of Siebenrock.

The *cavum capsularis* (fig. 10) or the cavity of the auditory capsule lodging the internal ear is a more or less spherical space lined by the



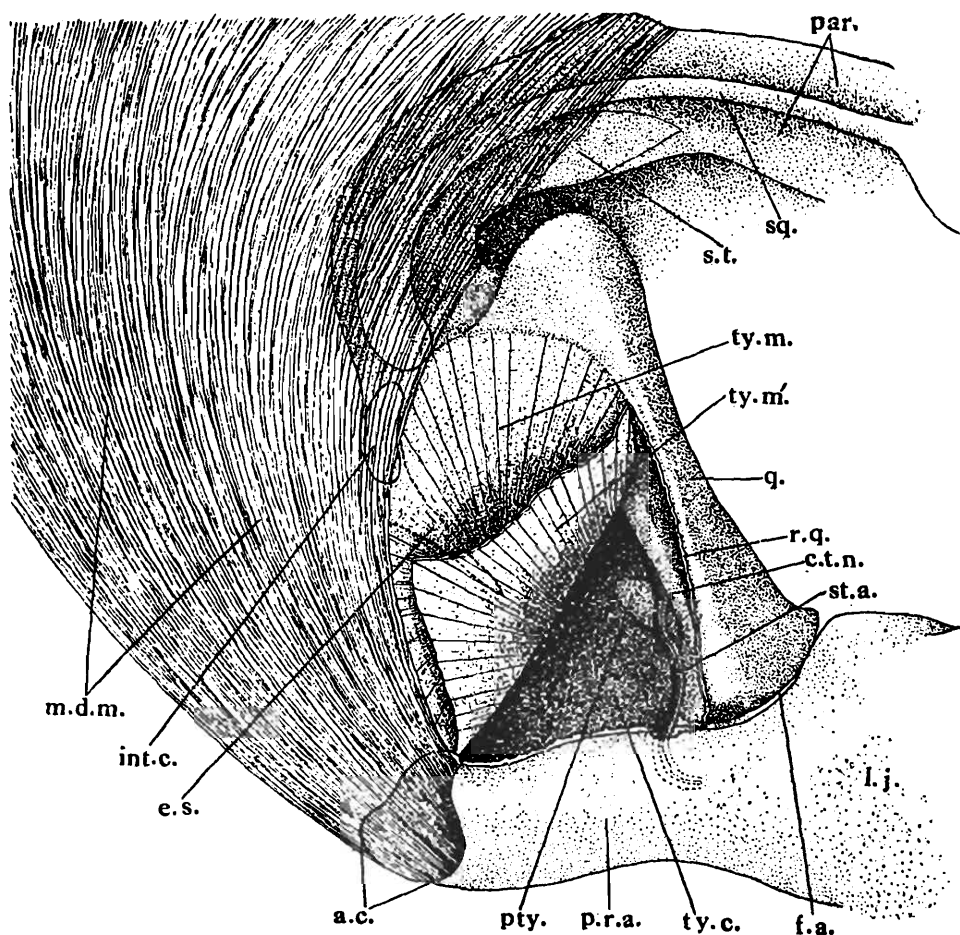
TEXT-FIG. 10. Dorsal view of the *cavum capsularis* after removal of the supra-occipital. The flat upper border with crooked lines and dots represents the place of articulation with the supra-occipital ( $\times ca. 10$ ).

*a-a'*, arrow passing through the channel for the anterior semi-circular canal; *a.r.*, anterior ampullary recess; *a.s.c.*, opening for the anterior vertical semicircular canal; *c.c.*, cochlear cavity; *c.cr.*, cochlear crest; *ex.o.*, ex-occipital; *f.c.*, fenestra cochleae; *f.o.*, fenestra ovalis; *h.h'*, arrow passing through the channel for the horizontal semi-circular canal; *p.p.ex.*, paroccipital process of the ex-occipital; *p.p'*, arrow passing through the channel for the posterior vertical semi-circular canal; *pro.*, pro-otic; *r.c.*, recessus cochlearis; *v.c.*, vestibular cavity; *vii.*, facial foramen; *viii.a.*, foramen through which the *nervus acusticus anterior* leaves the cranial cavity; the arrow represents the course of the nerve, which enters the anterior ampullary recess *a.r.* to supply the anterior part of the membranous labyrinth; *viii.p.*, foramen through which the *nervus acusticus posterior* leaves the cranial cavity; the arrow represents the course of the nerve which enters the inner wall of the vestibular cavity just above the recessus cochlearis.

perilymphatic membrane and enclosed by the ex-occipital, pro-otic and supra-occipital bones. It is divided into an upper large *vestibular cavity* containing the utricle and the saccule, and a lower small egg-shaped *cochlear cavity* lodging the cochlea and the legena, the two cavities being separated by a ridge called the *cochlear crest* (fig. 10). At the anterior end of the vestibular cavity lies the *anterior ampullary recess*, into which are lodged the *ampulla anterior* and *ampulla horizontalis* leading into the anterior vertical and horizontal semi-circular canals, and into which enters the *anterior auditory nerve* through a small aperture on its inner face. Along the posterior wall of the vestibular cavity lie: (1) the *posterior ampullary recess* into which is lodged the *ampulla posterior* leading into the posterior vertical semi-circular canal, and (2) the opening for the posterior end of the horizontal semi-circular canal. Along the inner wall of the vestibular cavity lies the aperture for the posterior auditory nerve. This aperture and the anterior

ampullary recess lie in the pro-otic bone, while the posterior ampullary recess and the posterior aperture for the horizontal canal lie in the ex-occipital.

The cochlear cavity presents a deep, funnel-shaped pit a long its inner wall just below the aperture for the posterior auditory nerve; this is called the *recessus cochlearis* and lodges the cochlear portion of the membranous labyrinth. Immediately behind the recessus cochlearis lies a fissure called the *fenestra cochleae* which leads below into the fenestra rotunda and through which the perilymphatic sac passes into the recessus scalae tympani. Along the outer edge of the cochlear



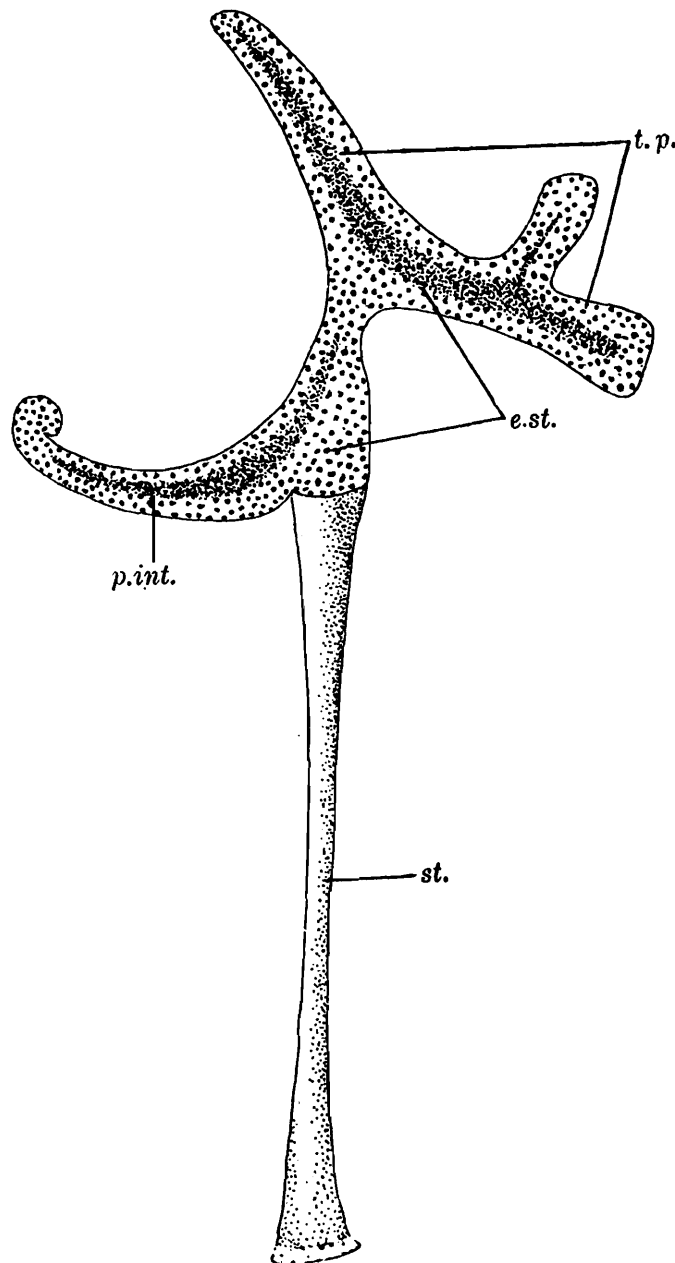
TEXT-FIG. 11. A dissection of the postero-lateral part of the head showing the tympanic membrane and its relations. The lower part of the membrane has been detached and reflected ( $\times ca. 3$ ).

*a.c.*, position of the articular cartilage; *c.t.n.*, chorda tympani nerve; *e.s.*, position of the extra-stapes lying immediately beneath the tympanic membrane; its outline is shown in broken lines; *f.a.*, fovea articularis; *int.c.*, intercalary cartilage; *l.j.*, lower jaw; *m.d.m.*, musculus depressor mandibulae, to which is attached the posterior border of the tympanic membrane; *par.*, parietal; *p.r.a.*, processes retro-articularis, to which is attached the ventral border of the tympanic membrane; the wavy line represents the cut border of the tympanic membrane; *pty.*, posterior end of the pterygoid; *q.*, quadrate; *r.q.*, outer ridge of the quadrate to which is attached the dorsal and anterior border of the tympanic membrane; *sq.*, squamosal; *s.t.*, supra-temporal; *st.a.*, stapedial artery (arteria auricularis); *ty.c.*, tympanic cavity; *ty.m.*, tympanic membrane in position; *ty.m'*, tympanic membrane cut and reflected.

cavity lies another fissure which opens into the fenestra ovalis and through which the inner end of the stapes fits against the perilymphatic

membrane of the internal ear. The recessus cochlearis lies in the pro-otic bone, the fenestra cochleae perforates the ex-occipital, while the fissure leading into the fenestra ovalis lies between the ex-occipital and the pro-otic. Fig. 10 represents the cavum capsularis and the associated chambers and canaliculi in relation to the different parts of the membranous labyrinth.

The *columella auris* (figs. 1 and 12) extends from the fenestra ovalis to the tympanic membrane across the cavity of the middle ear. It consists of two distinct parts: (a) a long proximal bony rod called the *stapes* or *columella*, with a small cartilaginous piece at its inner end embedded in the membrane closing the fenestra ovalis; the outer



TEXT-FIG. 12. The columella auris ( $\times ca. 14$ ).

*e.st.*, extra-stapes; *p.int.*, internal or ventral process; *st.*, stapes; *t.p.*, tympanic process.

end of the stapes reaches the level of the upper end of the quadrate bone where it (the stapes) is connected with the base of the *processus*

*internus* of the extra-columella; and (b) a distal cartilaginous triradiate part called the *extra-stapes* or *extra-columella*, which consists of a thick elongated concave piece or *body* pressed obliquely against the upper half of the tympanic membrane (fig. 11) and a *processus internus* or *ventralis* (*quadrate process*) which is slightly curved and runs downwards and forwards along the posterior surface of the quadrate. A *processus dorsalis* is absent. The forked end of the body of the extra-stapes rests against the quadrate while the other pointed end reaches about the centre of the tympanic membrane (fig. 11). A strong ligament passes from the "intercalary" (a meniscus of cartilage wedged in between the quadrate and the paroccipital process of the ex-occipital ventro-internally) to the outer side of the body of the extra-stapes, between it and the tympanic membrane; another ligament from the intercalary passes directly across the anterior surface of the extra-stapes and is inserted along the anterior surface of the *processus internus* (fig. 13).

The *chorda tympani nerve* (figs. 11 and 13) branches off from the hyo-mandibular division of the VIIth along the posterior wall of the cavity of the middle ear, close to the upper end of the quadrate, and runs forwards and downwards along the ridge on the posterior surface of the quadrate, between it and the *processus internus* of the extra-columella, towards the lower end of the quadrate, where it crosses over to the outer side of the pterygo-quadrate articulation (fig. 13) and then runs downwards to enter into the foramen on the dorsal surface of the post-articular process of the mandible.

We may note here that the anterior and dorsal borders of the tympanic membrane are supported by the outer elongated ridge (tympanic crest) and the upper end of the quadrate and that the ventral border of the tympanic membrane is supported by the post-articular process of the mandible of the lower jaw, while its posterior border is supported by the *musculus depressor mandibulae* (fig. 11).

#### (b) *Bones in Relation with the Optic Capsules.*

The *optic capsule* proper (the eye-ball) remains free from the skull and retains its usual mobility. It is not bony by itself but is protected by a number of bones of the skull, which are described at this place as a matter of convenience.

The *supra-orbitals* (fig. 4) are a pair of triangular bones, each of which is attached by its broad base to the outer upper border of the pre-frontal of its own side, but is free along its other two sides and also at its apex. The bone is more or less flattened and strongly curved backwards, so that its inner border is strongly concave while the outer border is slightly convex. The detached bone strongly resembles a large tooth of a shark. The supra-orbital undoubtedly affords a strong protection to the antero-dorsal part of the eye-ball and forms the anterior and incomplete outer boundary of the *supra-orbital fossa*.

The paired *pre-frontals* (fig. 8a) are capsule-shaped bones, each with an elongated conical process, which forms a sort of handle to the capsule and articulates with the antero-lateral border of each frontal. The capsular body of the bone articulates directly with the lacrymal on the outside and with the maxilla in front, and through a small inter-

vening area of cartilage with the palatine below. The triangular supra-orbital is loosely attached to its antero-lateral border and often gets detached. The posterior surface of the pre-frontal forms the anterior wall of the orbit, while its anterior cup-shaped surface together with the lacrymal forms the hind-wall and part of the lateral wall of the olfactory chamber. The outer border of the pre-frontal with the inner border of the lacrymal encloses a large oval aperture, the *orbito-nasal canal*.

The *lacrymal* (fig. 8a) on each side is a small irregular bone wedged in between the pre-frontal on the inside and the posterior border of the maxilla on the outside. The anterior end of the bone is produced into a small triangular process which articulates with the inner surface of the maxilla and forms part of the lateral wall of the olfactory chamber. Posteriorly also, the bone is produced into a short but broad triangular process which is prominently seen at the anterior border of the orbit, just below the base of the supra-orbital (fig. 8a). The inner surface of the bone is concave and forms the entire outer border of the orbito-nasal canal. The ventral part of the bone articulates with the jugal and the maxillary process of the palatine and is perforated by a small oval foramen, the *lacrymal foramen*, which provides a passage for the *lacrymal canal*.

The *post-orbitals* (post-frontals of Siebenrock) are a pair of elongated bones, each with a clasp-shaped process on the inner side of its anterior half (fig. 4). The elongated posterior bar of the bone articulates with the squamosal behind and forms the anterior half of the supra-temporal arcade. The outer anterior end of the bone is curved downwards and forms a short thick conical process, the *orbital process*, which is connected by means of a cartilaginous bar with the posterior end of the jugal, thus forming the outer posterior boundary of the orbit. The anterior and inner clasp-shaped process has a deeply concave inner border and closely grips within it the antero-lateral border of the parietal and the postero-lateral border of the frontal bone.

There is a single post-orbital on each side unlike the case in some species of *Lacerta* in which there are two on each side, described by Siebenrock (9) as post-frontal 1 and post-frontal 2.

The paired *jugals* (fig. 8a) are slender curved bones forming with the lacrymals the outer ventral boundary of the orbit. Anteriorly each of them is thickened and is triangular in cross-section, but posteriorly it becomes slender and pointed. It articulates anteriorly with the maxilla and the lacrymal, laterally with the transverse, while posteriorly it is connected with the post-orbital through a slender cord of cartilage. Its anterior part articulating with the maxilla is called the *maxillary process*, while its posterior part leading towards the post-orbital is called the *temporal process*. A quadrato-jugal is absent in the skull of the *Lacertilia*. The loss of this bone evidently leads to a greater mobility of the jaws.

All these four bones are dermal in origin (*investing bones*).

The free bony shields (*lamina superciliaris* and *schläfenpanzer* of Siebenrock) covering the orbit from above and also the temporal region in *Lacerta* are absent in *Varanus*. Thus, the *scuta supraocularia* and the *scuta superciliaria* are absent and so are the *scuta temporalia*.

(c) *Bones in Relation with the Olfactory Capsules.*

The *olfactory capsules* are two fairly large oblong structures occupying the greater part of the facial portion of the skull. They lie in front of the cranial cavity, one on each side of the middle line, and are formed almost completely of cartilage partially protected by bones. Each is bounded behind by the pre-frontal and the lacrymal, and laterally by the lacrymal and the maxilla ; the roof is covered over chiefly by the integument of the face and only partially by the united nasals behind, while the floor is formed by the flat rostral portion of the maxilla and the septo-maxillary in front, and the vomer and the vomerine process of the palatine behind. The two capsules are separated from each other and bounded internally by the nasal process of the pre-maxilla and the cartilaginous nasal septum which extends below and behind this bony nasal process, and continues behind into the inter-orbital septum.

Each olfactory capsule is horse-shoe-shaped in outline and consists of two parts : (1) the *vestibule*, corresponding to the outer limb of the  $\cap$ , which begins behind with the external narial aperture and leads forwards right up to the junction of the pre-maxilla and maxilla ; and (2) the *olfactory chamber* corresponding to the inner limb of the  $\cap$  and lying parallel and internal to the vestibule and leading backwards to open into the buccal cavity through the *internal nares* or *choanae*. The vestibule and the olfactory chamber are continuous with each other at the extreme anterior end just behind the pre-maxilla, but are separated from each other along the remaining parts of their lengths by an obliquely vertical cartilaginous partition called the *concha*. The external nares are funnel-shaped ; each is bounded behind by the slightly flattened and gradually ascending anterior border of the maxilla and leads forwards into the vestibule, which extends right up to the pre-maxilla and then turns round on the inner side of the concha to continue into the olfactory chamber. The concha extends forwards and inwards from the posterior border of each external nare along the outer edge of each septo-maxillary, as seen from the dorsal surface.

The united *nasals* (fig. 4) form an elongated, more or less triangular, bone lying immediately anterior to the frontals. The two bones are fused together along the greater part of their length and form a more or less flat plate, but their laterally compressed and conical anterior fourths remain separate, enclosing between them the posterior end of the median nasal process of the pre-maxilla, which extends behind to meet the frontals ventrally beneath the nasals (fig. 11). Posteriorly the nasals present a short median cleft and are produced into two small lateral wing-like processes, each of which closely fits into the concavity and cleft at the anterior end of each frontal. The nasals form a very small part of the roof at the posterior end of each olfactory chamber, the greater part of which is covered by the thick integument of the face. The cartilaginous *inter-nasal septum* is attached to the ventral surface of the frontals and the nasal process of the pre-maxilla in the middle line, the nasals remaining on the dorsal surface of the skull (fig. 11).

The paired *septo-maxillaries* (*turbinals* of Siebenrock) are two small, more or less triangular bones, lying one on each side of the nasal process of the pre-maxilla, between it and the maxilla on the outside (fig. 4).

Dorsally each of these bones is seen to lie just behind the flat rostral portion of the maxilla. A disarticulated bone has the shape of an inverted watch-glass, the hollow being directed ventralwards so as to overlie the anterior part of the vomer and enclose the Jacobson's organ within. The latter communicates with the anterior part of the buccal cavity through a triangular aperture on the roof of the mouth, between the maxilla and the vomer (fig. 1). Along the whole length of its inner border, each septo-maxillary presents a narrow groove, along which runs the *ramus frontalis ophthalmici nerve* (V). At the anterior conical end of the bone this nerve gives off a branch which passes through a *foramen* (the *anterior septo-maxillary foramen*) and runs outwards along the antero-lateral border of the bone and then penetrates inwards to innervate the mucous membrane of the Jacobson's organ.

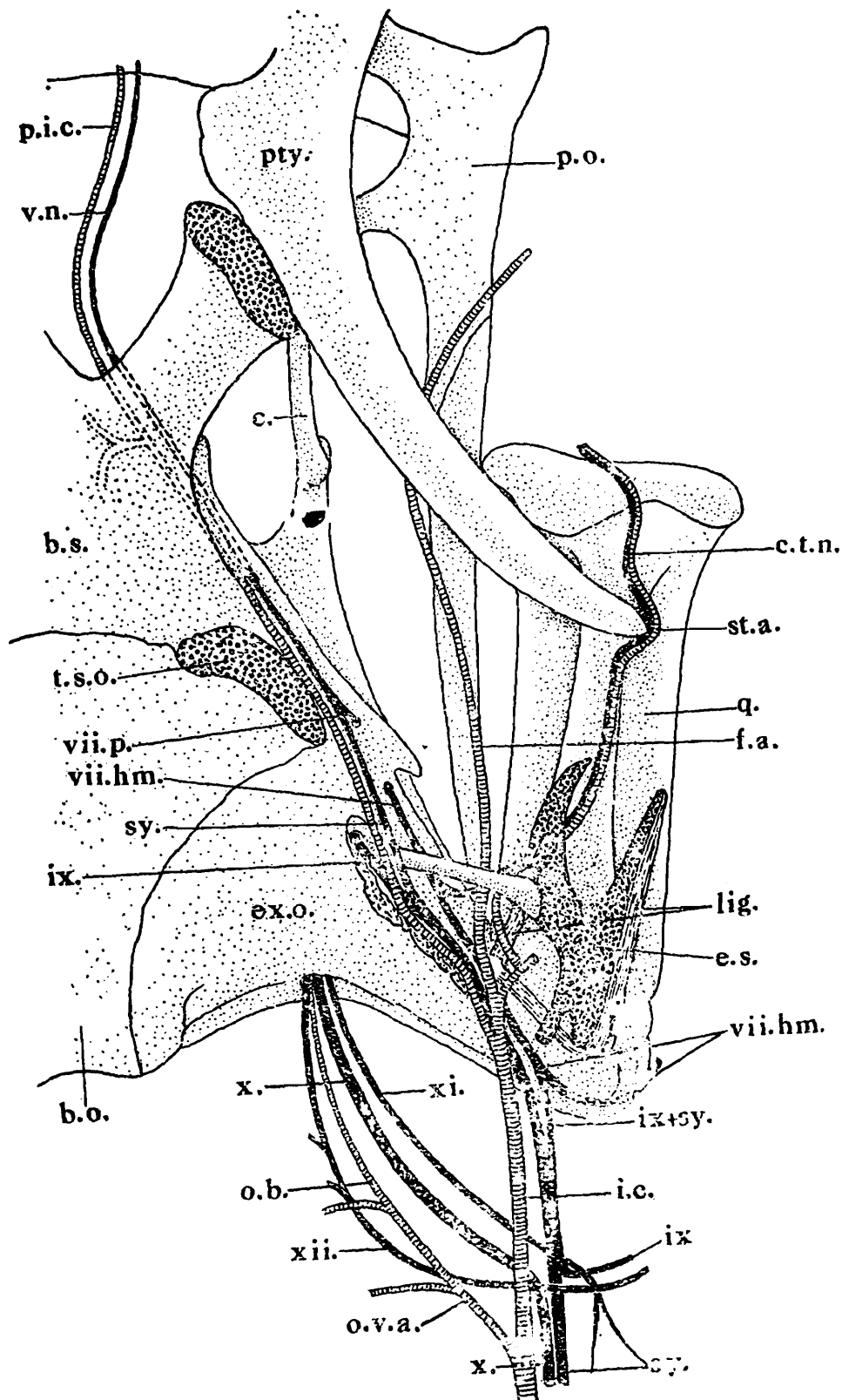
All the bones in relation with the olfactory capsule are dermal investing bones.

#### IV. The Suspensorium.

The *suspensorium* is formed on each side by the stout pillar-like quadrate, the ventral end (*condylus mandibularis*) of which forms the articular surface for the lower jaw, while the dorsal end is supported and strengthened by the squamosal, the supra-temporal and the paroccipital process of the ex-occipital (fig. 8a).

The palatoquadrate cartilage is very much reduced in the Amniota, the only parts remaining being the processus ascendens and the basal process articulating with the basitrabecular process and the quadrate cartilage. The former ossifies as the epipterygoid bone and the basipterygoid process of the basisphenoid and the latter as the quadrate bone (5, p. 440).

The *quadrate* is a stout pillar-like bone forming the posterior boundary of the side-wall of the skull and the anterior and outer boundary of the middle ear. It is disposed in an obliquely dorso-ventral direction, the dorsal end being directed backwards and the ventral end slightly forwards. The upper dorsal end (*condylus cephalicus*) is expanded antero-posteriorly and articulates above with the squamosal, the supra-temporal and the paroccipital process of the ex-occipital (fig. 8a). Between the articular surface of the quadrate and the paroccipital process, there is a small meniscus of cartilage called the "intercalary cartilage" (*supra* p. 155). This cartilage provides for the movement of the quadrate on the paroccipital process (*streptostylism*). In front of the articulation with the squamosal, there is a more or less rounded facet covered with cartilage for the insertion of the adductores mandibulae externus and medius muscles. The lower end is expanded laterally to form the articular surface for the lower jaw. Close to this articular surface, along its internal border, the quadrate bears a facet for articulation with the pterygoid. Along both of its outer and inner borders, the quadrate is produced into thin elongated ridges, to the outer of which (*tympanic crest*) is attached the anterior margin of the tympanic membrane. The anterior and posterior surfaces are broad; the anterior gives attachment to the adductores mandibulae externus and medius muscles, while the whole of the posterior surface forms part of the cavity of the middle ear.



TEXT-FIG. 13. Ventral view of the left half of the posterior part of the skull showing the relations of the nerves and arteries with the bones ( $\times ca. 4\frac{1}{2}$ ).

b.o., basioccipital; b.s., basisphenoid; c., columella cranii; c.t.n., chorda tympani nerve; e.s., extra-stapes; ex.o., ex-occipital; f.a., facial artery; i.c., internal carotid artery; lig., two ligaments, first, between the outer surface of the extra-stapes and the tympanic membrane originating from the intercalary cartilage; the second also originates from the same cartilage and goes towards the *processus ventralis* of the extra-stapes on which it is inserted; o.b., occipital branch of the internal carotid artery; p.i.c., palatine branch of the internal carotid; p.o., post-orbital; pty., pterygoid; q., quadrate; st.a., stapedial artery (arteria auricularis); sy., sympathetic nerve; t.s.o., tuberculum spheno-occipitale; v.n., vidian nerve consisting of the palatine branch of the VIIth nerve and the sympathetic; vii.p., palatine branch of the VIIth nerve; vii.hm., hyomandibular branch; ix., glossopharyngeal; ix+sy., combined ninth and sympathetic nerve; x., vagus nerve; xi., spinal accessory; xii., hypoglossal nerve.

The paired *epipterygoids* (*columella cranii*) are slender rod-shaped bones (figs. 8a and 8b) which are disposed in an obliquely dorso-ventral direction, the ventral end lying distinctly anterior to the dorsal end. The dorsal and ventral ends of the bone are slightly flattened; the dorsal end fits against the parietal process of the pro-otic, while the ventral fits into a depression (*fossa columellae*) on the dorsal surface of the pterygoid at about the middle of its length.

The *squamosal* (fig. 8a) is a thin elongated bone curved posteriorly into a comma-like shape, the head of the comma fitting on to the dorsal end of the quadrate and against the outer surface of the supra-temporal. The anterior end of the bone forming the tail of the comma is directed forwards and fits against the outer surface of the hinder end of the post-orbital, the two bones together (squamosal and post-orbital) forming the superior temporal arcade.

The *supra-temporal* (figs. 4 and 8a) is a small bone resembling in shape the *Kukri* (short sword) of the Gurkha soldier. It is curved like the squamosal and its lower hinder end fits on to the dorsal end of the quadrate. Its anterior blade-like portion is sickle-shaped and covers externally the hinder end of the supra-temporal process of the parietal, while its posterior curved end is wedged in between the squamosal externally and the paroccipital process of the ex-occipital internally.

The quadrate and the epipterygoid are endochondral ossifications of the palatoquadrate cartilage but the squamosal and the supra-temporal are dermal bones

## V. The Palate and the Upper Jaw.

The palate and the upper jaw are formed of the pterygoids, ectopterygoids (transpalatines), palatines and vomers and the pre-maxillae and the maxillae. All these are dermal (investing) bones.

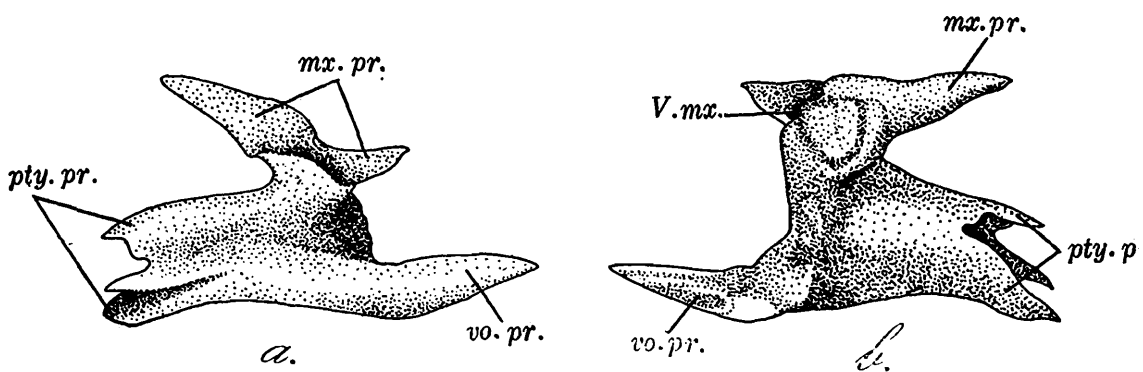
The *pterygoid* (figs. 1 and 8) is an elongated, slightly curved bone, which forms a more or less flat plate in front and a long outwardly directed rod-like process behind. The flat plate is produced in front into an expanded *palatal process* articulating with the palatine, and externally into a conical *transverse process* articulating with the ectopterygoid (transverse). These two processes enclose between them a space which forms the posterior part of the *sub-orbital fossa* (fig. 1). The rod-like *quadrate process* is the longest and rests posteriorly against the inner border of the quadrate, close to its lower end, in such a way that the articulation is movable, the pterygoid sliding on the quadrate. On the dorsal surface, at the junction of the quadrate and palatal processes, lies a slightly elongated but deep pit, the *fossa columellae*, into which fits the lower end of the *epipterygoid* (*columella cranii*); on the inner surface of the pterygoid, about the middle of its length, supported below by a small conical tubercle, lies the articular facet for the basiptyergoid process of the basisphenoid. As in *Sphenodon*, there is a cartilaginous meniscus between the basiptyergoid process of the basisphenoid and the pterygoid. This meniscus is prominent in the adult *Varanus* and Broom holds that it corresponds to the mesopterygoid of Fishes. The pterygoid in *Varanus* does not articulate with the vomer as it does in *Sphenodon*, *Uromastix*, the Crocodilia and some

Chelonia. Unlike the case in *Lacerta*, the pterygoids of *Varanus* bear no teeth.

Between the pterygo-palato-vomerine bar on the outside and the ventral border of the inter-orbital and inter-nasal septum in the middle line, there is an elongated space called the *incisura piriformis* or the *lacuna pterygo-vomerina* of Siebenrock (fig. 1).

The *transverse* (*ectopterygoid* or *transpalatine*) is a small curved bone (fig. 1), the inner and posterior end of which embraces the transverse process of the pterygoid, while the anterior end fits against the maxilla and the maxillary process of the palatine. The internal concave border of the bone forms the outer boundary of the sub-orbital fossa, while its outer and dorsal convex border articulates all along its length with the jugal.

The *palatine* (figs. 1 and 14) is roughly H-shaped in appearance and has an irregular outline, with *three* differently shaped articulating processes : (1) the anterior process is narrow and elongated ; it is directed antero-mesially and articulates with the vomer in front ; it is therefore called the *vomerine process* ; (2) the posterior process is broad



TEXT-FIG. 14. Palatine of the right side ( $\times ca. 3$ ).

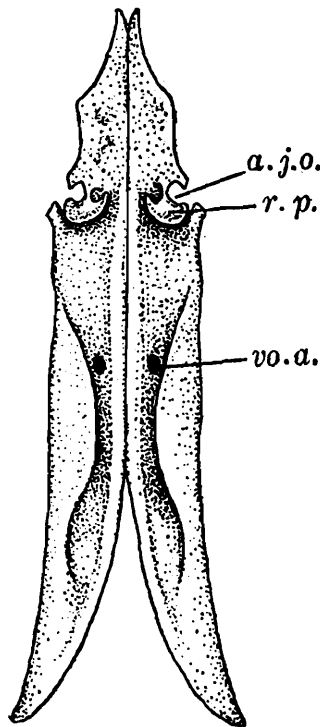
a., ventral view ; b., dorsal view.

mx.pr., maxillary process ; pty.pr., pterygoid process ; V.mx., foramen for the maxillary division of the Vth nerve ; vo.pr., vomerine process.

and is directed backwards and slightly outwards ; it is produced at its distal end into three small conical projections, which articulate immovably with the pterygoid behind ; this process is called the *pterygoid process* ; (3) the third or the outer lateral process is narrow at its origin but is expanded antero-posteriorly at its distal end, which forms an elongated articular surface for the maxilla on the outside ; the pointed posterior end of the process joins the jugal and transverse bones ; this outer process may be called the *maxillary process*. It is perforated by a foramen (*the maxillary or palatine foramen*), through which the *superior alveolar nerve* (maxillary branch of the Vth nerve) along with the *inferior orbital artery* and the *vena maxillaris* passes into the long bony canal (*canalis alveolaris superior*) of the maxilla. On the dorsal surface, the anterior concave border joining the vomerine and maxillary processes is produced into a shallow ridge on which are seated the pre-frontal and lacrymal bones. The palatines bear no teeth.

The upper surface of the palatine with the pterygoid behind forms the floor of the orbit, while the anterior smaller portion of the palatine with the vomer forms the floor of the nasal chamber,

The paired *vomers* (figs. 1 and 15) lie, one on each side of the middle line, in front of the palatines, and together form the median part of the roof of the anterior region of the buccal cavity. Looked at from the dorsal surface (fig. 15), the posterior two-thirds of each vomer appears like an open drain-pipe, the outer wall of which is higher than the inner and is slightly curved inwards. Along this drain-pipe canal of the vomer run the *dorsal palatine artery* and the *ramus frontalis ophthalmici* of the *Vth* nerve and the branch of the olfactory nerve going to the Jacobson's organ. Anteriorly each vomer at first flattens and then becomes pointed at the extreme anterior end, which articulates with and is covered over by the palatal process of the pre-maxilla. At about one-fourth of its length from the anterior end, each bone gives off a very small and slender rod-like process expanding into a small kidney-shaped outgrowth at its end (fig. 15), the process and its outgrowth being so thin and delicate as to be broken off in prepared skulls. In a whole skull this outgrowth projects into the ventral hollow concavity of the septo-maxillary and forms in life a ventral ingrowth into the cavity of the Jacobson's organ. Just behind this process, on each lateral border, there is an articular facet for articulation with the maxilla of each side. Posteriorly each vomer diverges from the middle line and articulates with the palatine of each side, while dorsally the greater part of the vomer is covered over by the septo-maxillary of each side and the nasal process of the premaxilla in the median line.



TEXT-FIG. 15. Dorsal view of the vomers ( $\times ca. 3$ ).

*a.j.o.*, aperture for the Jacobson's organ; *r.p.*, reniform or kidney-shaped process of each vomer which projects upwards into the cavity of the Jacobson's organ; *vo.a.*, vomerine aperture.

On the ventral surface, the anterior part of the vomers bears a low median ridge flanked by two long oblique ridges, one on each side. Enclosed between the posterior ends of these oblique ridges, there are

two minute foramina, the *vomerine apertures* (figs. 1 and 15), one on each side. Through each of these foramina comes out a small vein from the posterior part of the Jacobson's organ and enters the *sinus palatinus medius* lying immediately beneath the mucous membrane of the roof of the mouth at this place. About half an inch in front of these foramina, there are two large triangular apertures, each enclosed between the vomer and maxilla of its own side, just in front of the articular facet of the vomer fitting against the maxilla ; these are the *openings of the Jacobson's organs* (fig. 1) into the buccal cavity.

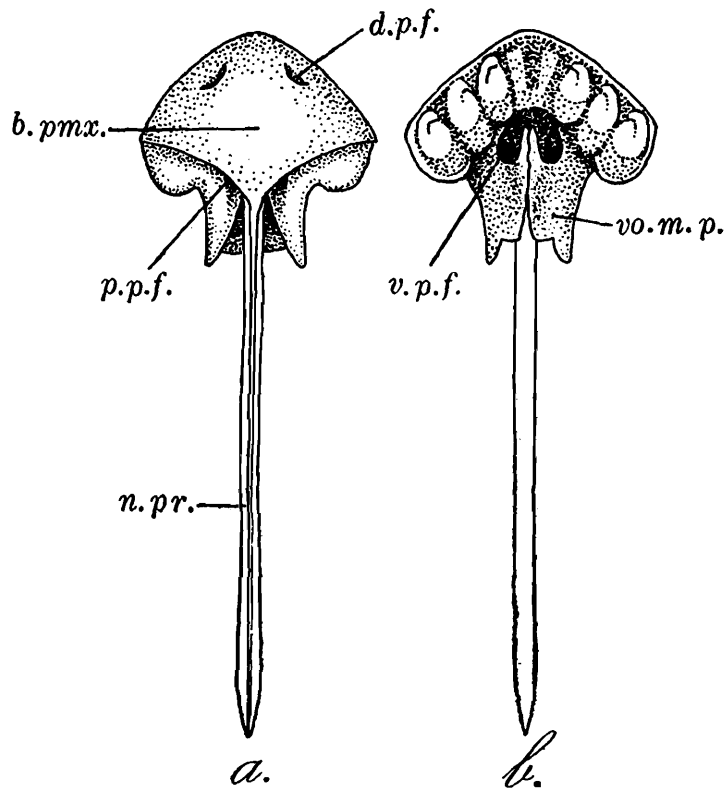
The vomers bear no teeth.

The paired *maxillae* (fig. 8a) are extensive bones, more or less triangular in outline, which form the greater part of the face of the lizard, with narrow alveolar and palatal portions. Each maxilla articulates in front with the pre-maxilla, mesially with the septo-maxillary and the vomer and through a piece of cartilage with the nasal process of the pre-maxilla, and posteriorly with the pre-frontal, the lacrymal, the jugal, the transverse and the maxillary process of the palatine. The anterior part of each maxilla is made up of a narrow vertical facial portion and a flattened nasal or rostral portion lying on each side of and in front of the septo-maxillary ; this nasal portion forms the floor of the vestibule of the olfactory capsule. The posterior part of the maxilla is chiefly facial in position and forms a high lateral wall on the outer side of the hinder part of the olfactory chamber. The anterior concave border of the high lateral wall forms the posterior border of the anterior nares on each side. The alveolar portion of the maxilla is narrow except at its anterior end and at its junction with the vomer, where it forms flat palatal processes.

The alveolar portion of the bone is tunnelled through by the *canalis alveolaris superior*, which lodges the *superior alveolar nerve* and the *arteria maxillaris* (p.) 161. The cutaneous branches of this nerve come out through several (8-10) fine openings which lie in a long row, a little above the base of the outer facial part of the bone. Another aperture on the palatal surface between the first group of two teeth and the other group of six or seven transmits the palatal branch of the superior alveolar nerve.

The *pre-maxillae* (figs. 1, 4, 8a and 16) of the two sides are united to form a single median *pre-maxilla*, which forms a triangular rostral *body* at the anterior end of the skull and gives off posteriorly a long median laterally compressed sabre-shaped process, the *nasal process*. The posterior end of the nasal process is wedged in between the nasals and extends behind to meet the frontals beneath the nasals, while along the greater part of its length, it divides the two septo-maxillaries from each other and supports the cartilaginous inter-nasal septum behind. The median rostral portion (*body*) gives off on the ventral surface a short *vomero-maxillary process* on each side ; these two processes meet in the middle line and form the anteriormost part of the hard palate, articulating behind with the vomers and laterally with the maxilla of each side. At the junction of the two vomero-maxillary processes in the mid-ventral line, each process is produced into a ridge, the two ridges together forming

a double median ridge projecting in front and overhanging the ventral pre-maxillary foramina.



TEXT-FIG. 16. Pre-maxilla ( $\times ca. 3$ ).

a., dorsal view : b., ventral view.

b.pmx., body of the pre-maxilla ; d.p.f., dorsal pre-maxillary foramen ; n.pr., nasal process of the pre-maxilla ; p.p.f., posterior pre-maxillary foramen ; v.p.f., ventral pre-maxillary foramen ; vo.m.p., vomeromaxillary process.

Three pairs of foramina are seen on the united pre-maxillae. A pair of transversely elongated slit-like foramina perforate the dorso-lateral surfaces of the pre-maxillae. These *anterior dorsal pre-maxillary foramina* look like anterior narial apertures and lead behind into the two *posterior pre-maxillary foramina*, lying one on each side of the root of the nasal process on the pre-maxilla. At the extreme anterior end of the hard palatal vomeromaxillary processes, there are a pair a *ventral pre-maxillary foramina* which also lead into the posterior pre-maxillary foramina. The ventral foramina transmit the anterior small branches of the arteria maxillaris, while the anterior and posterior foramina transmit the *ramus frontalis ophthalmici* branch of the Vth nerve.

The united premaxillae generally carry 8 small teeth on the inner side of their margin.

## VI. The Lower Jaw.

The *lower jaw* (fig. 17) consists of two long slightly curved rami, which are united together at their anterior ends through a bony symphysis. Each ramus consists of six bones : the *articular* (+*pre-articular*), the *angular*, the *supra-angular*, the *splénial*, the *coronoid* and the *dentary*. The *articular*, with which is united the pre-articular, forms the *hinder*

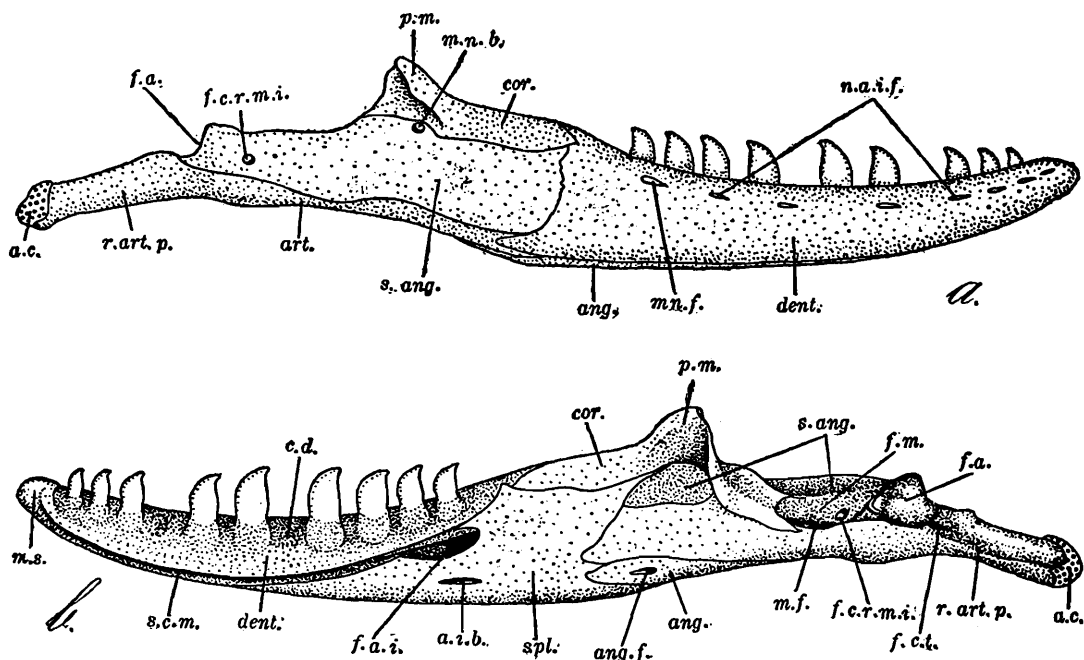
proximal end of the mandible. It is an elongated bone, the posterior part of which is strong and stout, while the anterior part is thin and vertical. The posterior stout part bears on its dorsal surface a transversely concave facet (*fovea articularis*) for articulation with the lower end of the quadrate. The part of the bone behind the articular facet is called the *post-articular process* (*processus retro-articularis*). The outer upper border of this process forms the ventral boundary of the tympanic membrane (fig. 11), while its dorsal surface behind the fovea articularis is depressed to form a shallow *fossa retro-articularis*, at the anterior end of which there is an aperture for the entrance of the *chorda tympani nerve*. The posterior end of the articular is tipped with a piece of cartilage on which is inserted the *musculus depressor mandibulae* (fig. 11). The thin vertical anterior part of the articular fits against the inner surface of the ventral part of the supra-angular. The articular extends over half the length of the mandible on the inner side, and is, in fact, the longest of all the bones of the lower jaw.

Closely fitting against the part of the articular lying in front of the fovea articularis is the *supra-angular*, visible chiefly on the outer surface of the mandible, although partially visible also on the inner and dorsal surfaces. This is a stout laterally compressed bone which expands posteriorly to form a depressed surface, and grips the vertical surface of the articular immediately below and in front of the fovea articularis. About the middle of its length, the supra-angular is produced dorsally into a flat triangular process which fits into the coronoid and is, therefore, called the *coronoid process*.

The supra-angular bears a number of foramina. Close to its posterior end, running through the thickness of the bone from the inner to the outer surface, there is a canal-like perforation into which enters, from the inner surface, the *nervus cutaneus recurrens maxillae inferiores* branch of the mandibular division of the Vth nerve. This nerve comes out on the outer surface almost opposite the leading-in foramen and supplies the skin of this region. Just in front of this foramen, on the inner surface of the mandible, bounded ventrally and internally by the articular, and dorsally and externally by the supra-angular, there is a large elliptical fossa, the *fossa Meckelii*, at the anterior end of which lies the *mandibular foramen*, through this foramen the main trunk of the *mandibular division* of the Vth nerve and the mandibular artery enter the lower jaw, while the mandibular vein comes out of this foramen. The mandibular nerve gives off several branches: one of them comes out through a foramen on the outer surface of the coronoid process of the supra-angular; another branch canalises the supra-angular all along its length, but the main trunk of the nerve runs in a ventral canal formed by the apposition of the articular and the supra-angular as the *nervus alveolaris inferior*.

When the articular and supra-angular are fitted together, there remains an elongated cleft between the anterior thirds of their ventral borders; this cleft is filled up in the complete lower jaw by the *angular*, which is a short and thin splint-like bone, being, in fact, the smallest of the six bones of the mandible. The greater part of the angular is wedged in between the articular and the supra-angular, while a

small anterior part lies in between the dentary on the outside and the splenial on the inside. About the middle of its length, the angular bears a foramen which leads into the *canalis alveolaris inferior*, and transmits the angular branch of the *nervus alveolaris inferior*.



TEXT-FIG. 17. The mandible ( $\times ca. 2$ ).

a. from the outer side; b. from the inner side.

a.c., articular cartilage; a.i.b., foramen for a branch of the *nervus alveolaris inferior*; ang., angular; ang.f., angular foramen; art., articular; c.d., crista dentalis; cor., coronoid; dent., dentary; f.a., fovea articularis; f.a.i., foramen for the main trunk of the *nervus alveolaris inferior*; f.c.r.m., foramen for the cutaneous recurrens maxillae inferiores branch of the mandibular division of the Vth nerve; f.c.t., foramen for the chorda tympani branch of the VIIth nerve; f.m., fossa Meckelii; m.f., mandibular foramen for the entrance of the mandibular division of the Vth nerve and the mandibular artery; m.n.b., foramen for a branch of the mandibular nerve; mn.f., mental foramen; m.s., surface of the mandibular symphysis; n.a.i.f., foramina for the branches of the *nervus alveolaris inferior* (mandibular division of the Vth nerve); p.m., processus messetericus; r.art.p., processus retro-articularis; s.ang., supra-angular; s.c.m., sulcus cartilaginis Meckelii; spl., splenial.

The *dentary* forms the greater part of the distal half of the mandible. Its inner surface is partially covered by the *splenial*, while on its outer surface it is fully exposed and presents a long row of eight foramina, the most posterior of which is called the *mental foramen* for the exit of the *mental branch* of the inferior alveolar nerve. The bone is canalised all along its length by the *nervus alveolaris inferior*, which gives off several branches, each coming out of one of the eight foramina of the row. The upper inner border of the dentary, called the *crista dentalis*, bears nine teeth. Along its ventral and inner border runs an open channel, narrow in front but wide behind, called the *sulcus cartilaginis Meckelii*, into which fits the persistent part of the *Meckel's cartilage*. The anterior end of the dentary is slightly flattened on its inner surface and fits against a similar surface of the dentary of the other side to form the *symphysis mandibularis*. The posterior end of the dentary has a concave border and a deep notch into which fits the anterior end of the supra-angular.

The *splénial* consists of a thin vertical quadrangular part and an elongated horizontal splint-like part. The vertical part partially covers internally a part of each of the articular, supra-angular, coronoid and dentary bones and serves to hold all these bones together, while the lower horizontal part forms the inner surface of the ventral border of the mandible and serves to hold the angular in position. On the inner surface of the mandible, between the anterior border of the splénial and the lower border of the dentary, there is a large elliptical notch, the greater part of which lodges the posterior end of the Meckel's cartilage, while at the bottom of the notch there is a foramen through which the *inferior alveolar nerve* enters the dentary.

The *coronoid* is an elongated triangular bone which is slightly twisted and is seated on the coronoid process of the supra-angular. It articulates posteriorly with the articular and the supra-angular and anteriorly with the splénial and the dentary. Along its ventral border, it presents a shallow groove into which fits the upper border of the coronoid process of the supra-angular. The posterior end of the bone forms the anterior boundary of the mandibular foramen in the fossa Meckelii, while the vertex of the bone in the complete skull projects upwards into the lateral temporal fossa to form the *processus messetericus*. The outer posterior border of the coronoid along with the upper border of the supra-angular serves for the attachment of the adductores mandibulae externus and medius muscles.

Of the six bones of the lower jaw, the articular alone is an endochondral ossification, while the other five are dermal bones.

## VII. Temporal arcades and fossae and other large vacuities.

The temporal region of the skull is strongly built and bears a lateral bridge or arcade called the *superior temporal arcade* (figs. 3 and 8a), formed by the post-orbital and the squamosal; a second arcade, the *inferior temporal arcade*, formed by the jugal and quadrato-jugal in *Sphenodon* and the Crocodilia amongst recent reptiles, is absent in *Varanus*, there being no quadrato-jugal in *Varanus*. We get three fossae in the temporal region: (1) a more or less triangular *superior temporal fossa* (figs. 4 and 10) on the roof of the skull on each side, bounded externally by the superior temporal arcade and internally by the parietal and supra-temporal; (2) a confluent *lateral* and *inferior temporal fossa* bounded above by the superior temporal arcade, below by the pterygoid and behind by the quadrate; and (3) a *post-temporal fossa* (*foramen retro-temporale* of Siebenrock) on the posterior aspect of the skull (fig. 6), which is more or less triangular in outline and is bounded above by the post-temporal process of the parietal and below by the supra and ex-occipitals and the pro-otic. In life, these temporal fossae are filled in by the adductor mandibulae muscles and the extensor muscles of the head.

Lying in front of each superior temporal fossa is the incomplete *supra-orbital fossa* (fig. 3) on each side, bounded by the supra-orbital and pre-frontal in front and the frontal and post-orbital internally and behind. It is incomplete on its outer and hinder aspects, as there

is no bony connection between the supra-orbital and the post-orbital, the two being joined only by a cartilaginous bar.

On the ventral surface of the skull in its posterior region, there is a large quadrangular vacuity on each side, bounded internally by the outer edge of the floor of the cranium and externally by the quadrate and the quadrate process of the pterygoid. In the living condition, the tympanic membrane stretches across the hinder part of this vacuity, which is really the *cavity of the middle ear*. In front of these two vacuities, lying beneath the optic capsules, there are two elongated oval apertures, one on each side, surrounded by the pterygoid, transverse and palatine bones. These are the *sub-orbital fenestrae*. In the middle, there are two large cavities lying one on each side of the parasphenoid and the inter-orbital septum in the mid-ventral line, and bounded externally by the pterygoids and palatines: these (fig. 1) are called the *incisura piriformis* (*inter-ptyergoid fissures*). In front of these fissures there are a pair of large elongated elliptical openings, the posterior portions of which form the *choanae* or the *internal nares* (fig. 1).

### VIII. The Foramina of the Skull.

#### (a) Dorsal Surface (fig. 4).

1. The *dorsal pre-maxillary foramina* are a pair of small slit-like apertures, one on each side of the middle line, on the dorso-lateral surfaces of the body of the united pre-maxillae. In a dry skull they look like a pair of external nostrils. Through these emerge two short terminal branches of the *ramus frontalis ophthalmici* of the deep ophthalmic division of the Vth nerve to supply the skin of the snout.

2. The *posterior pre-maxillary foramina* are a pair of small apertures, one at each angle between the median nasal process of the pre-maxilla and the body of the pre-maxilla. These apertures lead through very short canals within the united pre-maxillae to the dorsal pre-maxillary foramina. The *ramus frontalis ophthalmici* enters the pre-maxilla through each of these two apertures.

3. The *anterior septo-maxillary foramina* are a pair of apertures, at the anterior end of each septo-maxillary. Each of these transmits a lateral twig of the *ramus frontalis ophthalmici* along with a small vein.

4. The *dorsal septo-maxillary foramina* are a pair of small apertures as shown in fig. 4. They also transmit a branch of the *ramus frontalis ophthalmici* of the Vth nerve.

5. The *posterior septo-maxillary foramina* are a pair of small apertures, each at the posterior end of each septo-maxillary. The *ramus frontalis ophthalmici* enters this foramen to run forwards along the inner border of the septo-maxillary all along its length.

6. The *anterior narial openings* are a pair of oval apertures, one on each side on the maxillae. Each is bounded anteriorly by cartilage and posteriorly by the ascending anterior border of the maxilla. These openings lead forwards on each side into the vestibule which turns backwards into the olfactory chamber proper, opening behind into the choanae or internal nares. In a dry skull, therefore, the posterior end alone of the place for the olfactory chamber represents anterior nares proper (fig. 4).

7. The *parietal foramen* is a prominent median aperture lying in the middle line of the united parietals. It lodges the parietal organ.

(b) *Ventral Surface* (fig. 1).

1. The *ventral pre-maxillary foramina* lie on the ventral surface of the pre-maxilla on each side of the anterior end of the median ridge. A branch of the *arteria maxillaris* comes out of each of these foramina to supply the mucous membrane of this region.

2. The *apertures for the Jacobson's organs* are two large triangular apertures, one on each side, between the anterior part of each vomer and the palatal process of the maxilla. The Jacobson's organs communicate through these apertures with the buccal cavity, the apertures on the mucous membrane of the roof of the mouth in a whole specimen being slit-like in appearance.

3. The *anterior maxillary foramina* are a pair of apertures, each situated just on the outside of the aperture for the Jacobson's organ. Through this aperture, the *superior alveolar nerve* and the *arteria maxillaris* leave the alveolar canal of the maxilla and run forwards supplying branches to the mucous membrane of the anterior region of the hard palate.

4. The *vomerine apertures* are a pair of apertures on the vomers lying one on each side of the middle line. A venule from the Jacobson's organ comes out through each of these apertures and enters the *sinus palatinus medius*.

(c) *Lateral Surface* (figs. 2a, 3 and 7a).

1. The *fenestra ovalis* is a small aperture, lying at the antero-lateral end of the ex-occipital and bounded anteriorly by the pro-otic. It lies immediately above the fenestra rotunda being separated from it by a narrow bony ridge. The inner end of the stapes fits into the fenestra ovalis. In dry skulls, the fenestra ovalis is seen to open internally into the cavity of the internal ear but sometimes the inner cartilaginous end of the stapes remains and clogs the fenestra.

2. The *fenestra rotunda* is a large elliptical aperture which lies immediately below the fenestra ovalis and is bounded by the ex-occipital except at its anterior end where it is closed by the *tuberculum spheno-occipitale* cartilage. The aperture leads into a small space the *recessus scalae tympani*, in which lies the *saccus perilymphaticus*, the outer wall of which forms the *secondary tympanic membrane* closing the fenestra rotunda. On the posterior wall of this fenestra runs the *glossopharyngeal nerve* (IXth) which leaves the fenestra at its posterior end.

3. The *posterior facial foramen* is a very small aperture lying in front of the fenestra ovalis at a slightly higher level. It perforates the pro-otic bone and is overhung by the backwardly directed conical process of the pro-otic (*otosphenoidal crest*). The *hyomandibular division of the facial* (VIIth) nerve leaves the skull through this foramen.

4. The *anterior facial foramen* is also a small aperture lying in front of the posterior facial foramen and perforating the pro-otic bone. Through it the *palatine branch of the facial nerve* leaves the skull.

5. The *canalis vidianus (ductus caroticus)* is a short canal which perforates the basisphenoid bone on each side. Its posterior opening lies in front of the anterior facial foramen at a slightly lower level. Through it the *palatine division of the facial nerve* and the *internal carotid artery* perforate the basisphenoid bone to run forwards. During their passage through the *canalis vidianus*, the internal carotid gives off an *intra-cranial branch* which enters the cranial cavity through the hypophysial fossa, while the palatine branch of the internal carotid and the palatine branch of the facial come out through the anterior opening of the vidian canal to run forwards on the roof of the mouth. The palatine branch of the seventh nerve receives a *sympathetic branch from the ninth nerve* (fig. 13) and is, therefore, called the *vidian nerve*, which gives the name *canalis vidianus* to the passage through the basisphenoid.

6. The *optic fenestrae* (figs. 2a, 8a and 9) are two large oval apertures, one on each side, for the exit of the optic nerves. The two minute orbito-sphenoids enclose the optic chiasma between them, but as the inter-orbital septum lies in the middle line immediately below these bones, the common optic fenestra above is seen to be divided into two fenestrae ventro-laterally, each providing an exit for the *optic nerve* of its own side. Each optic fenestra is thus bounded by the orbito-sphenoid externally and the inter-orbital septum internally.

7. The *orbito-nasal canal* is a large oval aperture bounded internally by the pre-frontal and externally by the lacrymal. It lies at the extreme anterior angle of the orbit and is hidden from the lateral surface by the outer conical process of the lacrymal. Through this aperture, the orbit is placed in communication with the nasal chamber.

8. The *lacrymal foramen* is a small aperture perforating the ventral part of the lacrymal bone and lying below the orbito-nasal canal.

9. The *maxillo-palatine foramen* lies below the lacrymal foramen and perforates the outer maxillary process of the palatine bone. Through this aperture, the *maxillary division of the trigeminal nerve* enters the upper jaw and continues forwards into the bony canal of the maxilla as the *superior alveolar nerve*, giving off branches all along its length to the skin on the outside of the maxilla through a row of minute apertures all along the outer surface of the lower border of the maxilla.

#### (d) *Posterior Surface* (fig. 6).

1. The *foramen magnum* is the large median aperture, almost circular in outline, at the posterior end of the skull. It is bounded by the four occipital bones and forms an important landmark where the medulla oblongata of the brain passes out into the spinal cord.

2. The *foramen lacerum posterius + hypoglossal foramen* is an obliquely oval aperture on each side of the foramen magnum perforating the ex-occipital. It transmits the *pneumogastric* or *vagus* (X),

*spinal accessory* (XI) and *hypoglossal* (XII) nerves and the *vena cerebialis posterior branch* of the *internal jugular vein* and the *occipital branch* of the *internal carotid artery*.

(e) *Longitudinal Section* (figs. 2b, 8b, 10 and 13).

1. The *hypoglossal foramen* is a small rounded foramen situated on the ex-occipital a little in front of its posterior border. It lets through the *hypoglossal nerve* and opens externally into the jugular foramen or foramen lacerum posterius.

2. The *foramen for the spinal accessory nerve* is a very small foramen lying just above the hypoglossal foramen. This foramen, like the hypoglossal, opens into the jugular foramen and transmits the *spinal accessory nerve*.

3. The *jugular foramen* is a large dorso-ventrally elongated aperture situated just in front of the hypoglossal and spinal accessory foramina. The *vagus nerve* and the *vena cerebialis posterior branch of the internal jugular vein* leave the cranial cavity and the *occipital branch of the occipito-vertebral artery* enters through this foramen. The hypoglossal and spinal accessory foramina open into the jugular foramen and consequently the foramen on the posterior surface of the skull is a combined foramen lacerum posterius and hypoglossal foramen (*vide supra*).

4. The *foramen perilymphaticus* or *glossopharyngeal foramen* is a fairly large oval foramen at the junction of the pro-otic, opisthotic part of the ex-occipital and the basi-occipital. Through it, the *glossopharyngeal nerve* leaves the cranial cavity, while the *ductus perilymphaticus* enters the cranial cavity.

5. The *foramen acusticum posterius* lies about a quarter of an inch above the foramen perilymphaticus at the junction of the pro-otic and opisthotic bones. It transmits the *ramus acusticus posterior* division of the auditory nerve.

6. The *foramen acusticum anterius* is a small foramen on the inner wall of the pro-otic lying anterior to and at the same level with the *foramen acusticum posterius*. This foramen transmits the *ramus acusticus anterior* division of the auditory nerve.

7. The *facial foramen* is a small aperture lying below and slightly anterior to the *foramen acusticum anterius*. The *facial nerve* (VII) leaves the cranial cavity through this foramen and divides within the bone into two branches which emerge separately on the outside of the skull through the anterior and posterior facial foramina.

8. The *foramen for the abducens nerve* lies on the dorsal surface of the anterior part of the basisphenoid bone. This nerve perforates the base of each alar process by a very short canal and comes out through a *foramen* in the dorsal part of the hypophysial fossa.

9. The *hypophysial fossa* appears in a longitudinal section as a triangular pit, in the dorsal part of which opens the foramen for the abducens nerve, while laterally there is a large *foramen leading into the*

*canalis vidianus* through which the intra-cranial branch of the internal carotid enters the hypophysial fossa and in which is lodged one of the two lateral diverticula of the recessus infundibularis.

### 3. STREPTOSTYLISM AND KINETISM.

Stannius applied the term *streptostylic* to describe those skulls in which the quadrate was freely movable. The Lacertilian skull shows a typical streptostylic condition in that "the bony quadrate is isolated from the epipterygoid (*columella cranii*) and is only connected somewhat loosely to the pterygoid below and the parotic process above by ligament" (5, p. 433). In *Varanus*, the inner border of the lower end of the quadrate is movably articulated with the pterygoid, while dorsally the quadrate is joined to the squamosal and supra-temporal above and the paroccipital process of the ex-occipital behind in such a manner as to render movement possible. Further, the lower end of the quadrate (*condylus mandibularis*) articulates movably with the mandible. The quadrate, therefore, is movable at all its joints with the other bones and consequently the skull is truly *streptostylic*.

In addition to streptostylism, the skull of *Varanus*, like that of other Lacertilia, shows "a certain degree of looseness and consequent power of motion between the dermal roofing bones (parietals and frontals) and the posterior brain-case." This phenomenon has been termed *kinetism* of the skull by Versluys *et al* (6). We have already seen that the occipital bones (supra-occipital, ex-occipitals and the basi-occipital) are immovably articulated with the basi-sphenoid and the pro-otic. These six bones form a compact rigid structure which moves as one piece and is termed, for convenience, the *occipital segment* (posterior brain-case). The remaining part of the skull consisting of the quadrate, squamosal, supra-temporal, parietal and frontal on the one hand, and the pterygoid, palatine, transverse, maxilla, and pre-maxilla, on the other, together constitutes the *maxillary segment*. These two segments move on each other at various places.

The junction between the supra-occipital and the parietal is formed of fibrous tissue and thus forms a loose vertically movable joint, the movement being limited only by the cone-shaped processus ascendens tecti synotici cartilage which fits closely into the parietal fossa. Similarly, the anterior superior process of the pro-otic is connected loosely with the lateral bevelled border of the parietal. The basipterygoid processes of the basisphenoid are movable on the pterygoids, as the articulation through the cartilaginous meniscus forms a synovial joint. Lastly, the paroccipital process of the ex-occipital is movably articulated with the quadrate and the supra-temporal through the intercalary cartilage. It must, further, be noticed that in front of the "occipital segment" the lateral walls and floor of the cranium, as well as the inter-orbital septum are composed only of cartilage and membrane; these structures are therefore not rigid and would permit of a slight movement.

It is thus clear that there are *four* places (not *three* as stated by Edgeworth, (4, p. 62) at which the occipital segment is movable

on the maxillary segment. The movement is brought about by the action of the protractor pterygoidei, pterygo-sphenoidalis posterior and pterygo-parietalis muscles (5, p. 434) and consists, as pointed out by Bradley (2, p. 484), of a movement of elevation and depression of the maxillary segment on the occipital segment which itself remains fixed. The kinesis, therefore, is very marked in *Varanus* and such a skull is termed *metakinetic*.

#### 4. SUMMARY.

1. The skull of *Varanus* is well ossified, although there are important cartilaginous structures, chief of which are the olfactory capsules, the planum supra-septale and its lateral extensions, the tuberculum sphenoccipitale and the intercalary cartilage.

2. The muscles inserted on the basi- and ex-occipitals and also on the tuberculum sphenoccipitale are described. Similarly, the origin and insertion of the adductor mandibulae and depressor mandibulae muscles have been included.

3. All the foramina of the skull have been listed, and the nerves and blood-vessels entering or coming out of these foramina have been identified and described.

The *foramen internum* of Siebenrock has been identified and it has been shown that it transmits the VIth nerve and not a branch of the internal carotid artery, as he believed.

4. The different bones have been compared with those of *Lacerta* and *Sphenodon* and the differences noted. The orbito-sphenoids and their exact relationship with contiguous cartilages have been described and sketched, these having been incorrectly represented by Reynolds.

5. The diagrams of previous authors have been critically examined and corrected and new standard diagrams of the skull have been provided.

6. The streptostylism and metakinesis of the skull have been described.

#### 5. LIST OF REFERENCES.

1. Boulenger, G. A.—*Reptilia and Batrachia in the Fauna of British India* (London: 1890).
2. Bradley, O. Charnock—The muscles of mastication and the movements of the skull in Lacertilia. *Zool. Jahrb. Anat. Abth.* XVIII, 1903.
3. Bütschli, Otto—*Vorlesungen über vergleichende Anatomie*, Lieferung 1, (Berlin: 1910).
4. Edgeworth, F. H.—*The Cranial Muscles of Vertebrates* (Cambridge: 1935).
5. Goodrich, E. S.—*Studies on the Structure and Development of Vertebrates* (London: 1930).
6. Ihle, Kampen, Nierstrasz und Versluys—*Vergleichende Anatomie der Wirbeltiere* (Berlin: 1927).
7. Reynolds, S. H.—*The Vertebrate Skeleton* (Cambridge: 1913).

8. Schimkewitsch, W.—*Lehrbuch der vergleichenden Anatomie der Wirbeltiere*, (Stuttgart: 1921).
9. Siebenrock, F.—Skelet der Lacerta. *Sitz. AK.wiss. Wien*, CIII, 1894.
10. Smith, Malcolm A.—Reptilia and Amphibia, II, in the *Fauna of British India*, (London: 1935).
11. Thomson, J. A.—*Outlines of Zoology* (Oxford: 1929).
12. Wettstein, Otto von.—Rhynchocephalia in Kükenthal and Krumbach, *Handbuch der Zoologie* (Berlin und Leipzig: 1932).

# INDIAN EARTHWORMS. I. THE GENUS *PHERETIMA*.

By G. E. GATES, *Judson College, Rangoon.*

## CONTENTS.

|                                                                                                                     | PAGE. |
|---------------------------------------------------------------------------------------------------------------------|-------|
| Introduction                                                                                                        | 175   |
| Distribution                                                                                                        | 176   |
| I. <i>P. alexandri</i> , <i>anomala</i> , <i>campanulata</i> , <i>houletti</i> , <i>planata</i> and <i>posthuma</i> | 178   |
| II. <i>P. diffringens</i> , <i>hawayana</i> , <i>morrisi</i> and <i>robusta</i>                                     | 183   |
| III. <i>P. elongata</i> , <i>bicincta</i> and <i>taprobanae</i>                                                     | 185   |
| Habits                                                                                                              | 187   |
| Systematics                                                                                                         | 187   |
| <i>Genus Pheretima</i> —                                                                                            |       |
| Diagnosis and notes on certain characteristics and variations                                                       | 187   |
| Descriptive and diagnostic terms and conventions                                                                    | 188   |
| Miscellaneous notes                                                                                                 | 191   |
| Key to Indian species                                                                                               | 191   |
| Abnormal forms                                                                                                      | 192   |
| Key to abnormal forms                                                                                               | 192   |
| <i>Pheretima alexandri</i> (Beddard) 1900                                                                           | 192   |
| <i>Pheretima anomala</i> Michaelsen 1907                                                                            | 193   |
| <i>Pheretima bicincta</i> (E. Perrier) 1875                                                                         | 195   |
| <i>Pheretima campanulata</i> (Rosa) 1890                                                                            | 197   |
| <i>Pheretima diffringens</i> (Baird) 1869                                                                           | 198   |
| <i>Pheretima elongata</i> (E. Perrier) 1872                                                                         | 201   |
| <i>Pheretima hawayana</i> (Rosa) 1891                                                                               | 202   |
| <i>Pheretima houletti</i> (E. Perrier) 1872                                                                         | 203   |
| <i>Pheretima morrisi</i> (Beddard) 1892                                                                             | 205   |
| <i>Pheretima planata</i> Gates 1926                                                                                 | 207   |
| <i>Pheretima posthuma</i> (L. Vaillant) 1868                                                                        | 207   |
| <i>Pheretima robusta</i> (E. Perrier) 1872                                                                          | 209   |
| <i>Pheretima taprobanae</i> (Beddard) 1892                                                                          | 209   |
| Appendix to the genus <i>Pheretima</i>                                                                              | 210   |
| References                                                                                                          | 211   |

## INTRODUCTION.

Since 1872 more than a score of species have been erected for Indian forms or listed or reported from India. After examination of most of the material (Bourne's specimens apparently have not been preserved and a few other specimens of less importance have not been available for examination), it is now possible by the exclusion of mistaken records, elimination of forms probably belonging to other genera and the reduction of several names to synonyms to bring the number of species to 12, to which one hitherto unrecognized species must be added. All these 13 species now can be defined adequately, though the extent of variation of certain important characteristics of three of the species still remains to be determined. Barring accidental importation by man or

otherwise it is probable that no further species of *Pheretima* will be added to the Indian fauna, at least so far as the area south of the Himalayas and west of Assam and Chittagong is concerned (but see p. 186).

In this paper India is regarded as comprising political India, except that Nepal is included and Burma, the Andaman and Nicobar Islands are excluded. The inclusion of Ceylon would necessitate no additions to the list of species. Moving the eastern boundary of India into Burma nearly to the Irrawaddy in the north and nearly to the Shan Plateau in the south would require the addition of only one species, *P. peguana*.

The author's thanks are extended to Dr. B. Prashad for the loan of a considerable number of specimens from the collections of the Indian Museum as well as of books from the library of the Zoological Survey of India, and to the college geographer, Mr. L. W. Trueblood, for assistance in placing localities and determination of elevations.

#### DISTRIBUTION.

Michaelsen in his 1909 and 1910 lists characterized almost all of the Indian species of *Pheretima* as peregrine or of doubtful status, with suggestions that the dubious names are synonyms of peregrine species. A single species is regarded as "probably endemic" (*anomala*, 1909, p. 119) but in the list in the same paper the term endemic is preceded by an interrogation mark and followed by "aus botanisch Garten!"

The term "peregrine" was introduced by Michaelsen in 1903 to characterize species widely spread through their own inherent powers of migration or as a result of accidental transference by man. "Ich bezeichnete deshalb Arten mit einer derartig weiten Verbreitung überland, einerlei ob Verschleppung durch den Menschen oder Ausbreitung auf natürlichen Wege vorliegt, als 'Weitwanderer' und vereinigte sie unter der Bezeichnung 'peregrine Formen' mit den sicher Verschleppten". (1903, p. 17). "Das hauptsächlichste Merkmal für Verschleppungsfälle bei Regenwürmern ist eine sehr weite, und zumal auch eine sprungweise Verbreitung übersee, sowie auch das sporadische Auftreten weit entfernt von dem Gebiet, das als das Hauptquartier der betreffenden Gattung anzusehen ist". (p. 16). Endemic is explained as follows: "Eine Art, die lediglich in einem eng begrenzten Gebiet vorkommt, ist als endemisch in demselben anzusehen". (p. 17). Michaelsen recognized that the very numerous gaps in our knowledge of the distribution of earthworms necessitated some further indication of endemism and accordingly adds "Eine Anzahl nahe verwandte Arten, die lediglich in einem eng begrenzten Gebiet vorgefunden wurden, sind als endemisch in demselben anzusehen". (p. 17).

Stephenson (1923) refrained from using the terms peregrine and endemic in his lists but indicated by difference in type those species which are considered to be of zoogeographical value or with no such value. No clue is given as to how "zoogeographical value" was determined though peregrine forms are said to be of no importance. "Semi-peregrine forms" however are italicized. Only five species of *Pheretima* are regarded as having zoogeographical value. Of these, *burliarensis* is probably not a *Pheretima*, at all, *travancorensis* and *trivandran* are merely synonyms of *houletti*, a widely spread form of "no zoogeographical value", while *alexandri* is the same as Stephenson's *lignicola*, a species also considered to be of no zoogeographical importance. This leaves only *anomala* which is known now to be distributed widely throughout Burma and also present in Siam. Presumably all of the Indian species of *Pheretima* would be considered by Michaelsen as peregrine, or at least as "etwas peregrine", or by Stephenson as of no zoogeographical value.

It is true that a number of the Indian<sup>1</sup> species of *Pheretima* have been carried far and wide and have been able to establish themselves in a number of localities far removed from their original habitat. Beddard in 1900 characterizes the distribution of *P. heterochaeta*, now known as *diffringens*, as "everywhere, including Europe" Gates, in a paper on "The genus *Pheretima* in North America", now in the press, recognizes 13 American<sup>1</sup> species of which 8 are also Indian. It is likewise true that several species of *Pheretima* are more or less widely distributed throughout India. But the common occurrence of certain species in those (relatively few) localities from which collections have been made and the wide accidental transference have been so over-emphasized that important and almost obvious aspects of distribution have been overlooked. Such statements as "being a well-known peregrine form, the occurrence is of no importance from a zoogeographical point of view" (Stephenson, 1915, p. 37) and "It is scarcely necessary any longer to particularize concerning the distribution of this almost ubiquitous worm, at any rate in those provinces where it has already been found" (Stephenson, 1917, p. 385) are especially unfortunate as they may have been responsible for a failure to record the presence of certain species in important localities.

Beddard's characterization of the distribution of *heterochaeta* is obviously to be taken as an epigram rather than literally. There are many regions to which the species might have been carried and within which it might have become established but from which *P. diffringens* is quite unknown. Expressions such as "one of the commonest worms in India" (Stephenson, 1923, p. 302), "almost ubiquitous", "Throughout India" (1923, p. 304) and "universally found" (1923, p. 311) have certainly led to misconceptions. To mention but one of these, Bahl (1936, p. 8) says that "*Pheretima posthuma* is found *nearly all over* India, Burma and Ceylon" (*italics mine*). This statement is incorrect or at least conveys an altogether erroneous impression for the species is quite unknown from large sections of Burma, including some sections which have been fairly thoroughly investigated, and in the districts in which it has been found, is restricted (largely, though not entirely) to a fairly limited habitat. Furthermore, no record can be found of the occurrence of the species in Ceylon. The statement is also too optimistic so far as India is concerned as a glance at the distribution on p. 182 will show.

Before proceeding to a discussion of the individual distribution of Indian species of *Pheretima* it is again necessary to emphasize certain aspects of our knowledge of Indian earthworms. Systematic collection and study of earthworms has been carried out hitherto only in the Punjab and in Travancore (Aiyer, 1929). Accordingly it is still true "that India is so large and diversified that all that has been done is really not much more than the taking of a few samples here and there" (Stephenson, 1915, p. 17). Therefore, in spite of the memoirs on Indian earthworms that have been published since 1909, any discussion of distribution must still be characterized by considerable caution, as "we

---

<sup>1</sup> The term Indian or American as used in this paragraph implies only that the species is known from India or America.

are still far from a complete acquaintance with the distribution of Indian earthworms, and. . . any conclusions based on the absence of any forms from this or that region are liable to be upset at any time" (Stephenson, 1915, p. 37).

During the past 13 years considerable work has been done on the earthworms of Burma. This work, though still far from complete, has been extensive enough to warrant certain conclusions though based on absence of forms from especial areas. Such conclusions, if found to be applicable in India, are less likely to be upset even though our knowledge of Indian distribution be fragmentary. The consideration of each of the Indian species is prefaced therefore by a statement of the Burmese distribution and, when possible, by some indication as to the Siamese, Indo-Chinese, Chinese or Malayan distribution. However, it should be noted that very little is known of the earthworms of Siam and not a great deal more of the worms of the Malay Peninsula or French Indo-China.

## I.

*P. alexandri*. This species is widely distributed in central and eastern Burma, having been found in 27 of the 40 districts or political divisions (the Northern and Southern Shan States and Karenni each counted as a district). The worm is equally common on the plains and in the hills, and on the Shan Plateau has been found up to an elevation of 4,000+feet. There is no reason to suspect that the species is lacking in those few districts of central and eastern Burma where collections have not yet been made or where it has not yet been found. At present the species appears to be absent from the Arakan Division and the Chin Hills district of western Burma, but it has been collected at Chiengrai, Chiengmai, Mu'ang Pong (Ban Muang) on the Me Yom, in Upper Siam, Bangkok, Kosichang (on the Gulf of Siam) in Lower Siam, and is also known from Yunnan (Lawng Neu in Mong Lem State) and the Andaman Islands.

A line drawn on a map from Mergui through Siam just east of Bangkok to Chiengmai and then through Mong Lem State into Myitkyina district and from there south to the Chindwin and along the eastern side of the Arakan Yomas to the Bay of Bengal will enclose an area that is compact and which lacks just those physical barriers such as the snow-covered mountain ranges, deserts, or salt seas which are usually regarded as effective in restricting the migration of earthworms. Although compact, the area is not homogeneous with respect to climatic, physiographic and edaphic factors but this seems to be of no particular importance in view of the ability of the species to maintain itself in a variety of habitats in both plains and hills. Since accidental transference is not necessary to explain the distribution of the species within the region just outlined, it is possible to regard this area as the natural range of the species and to conclude that the species originated at some point therein. Though this region is compact Michaelsen might not regard it as an "eng begrenzten Gebiet" But how far from its point of origin can a species migrate within a compact region and still be considered endemic?

The presence of *alexandri* in Bombay as well as on the Andaman Islands, for the present at least, must be regarded as due to accidental transportation.

When a species is found in an isolated locality far from its natural range, such a discontinuous distribution can be explained by assuming that the species has been carried by some external agent to the isolated locality or else that the species has become extinct in the intervening area. Extinction can be disregarded so far as the genus *Pheretima* and south-eastern Asia are concerned.

Earthworms are known to have been carried unintentionally by man, for quite considerable distances. Similar accidental transportation by birds, cattle or other non-human agencies have been postulated but not demonstrated. (I have been told of the finding of cocoons of *Pontodrilus bermudensis* on feet of birds but can find no record of this.) It is possible, if not probable, that most instances of accidental carriage mentioned in this paper are to be attributed to man, but whether this be true or not, the agent or agents involved in the transport to 'foreign' regions are not of importance in the present discussion.

If *alexandri* is really absent from western Burma the Calcutta record also will have to be regarded as due to accidental carriage.

The other Indian locality, Dibrugarh in Assam, is less than 200 miles from the nearest Burmese locality. The earthworm fauna of the intervening region, unlike that between Burma and Calcutta, is unknown. There is however no reason to assume that *alexandri* has been unable to push through the intervening region or that it is lacking therein. Dibrugarh is the northernmost record and it should be noted that *alexandri* has never been found in the Himalayas especially at those higher elevations at which *diffringens* has been obtained.

*P. anomala*. This species is widely spread throughout the province of Burma and has been found in 29 of the 40 political districts. It is known from the Arakan division and the Chin Hills district in which *alexandri* has not yet been found and is common both in the plains and on the Shan Plateau where it has been found up to an elevation of 4,000+feet. There is no reason to suspect that the species is lacking in the 9 central and 2 peripheral districts which have not yet been investigated or in which it has not yet been secured. The species has been collected in Siam (Chiengrai) and in the Chinese province of Yunnan (Mong Mong State) but is unknown from the Malay Peninsula and the Andaman Islands.

A line drawn on the map to mark off the *anomala* range passes from a point southeast of Mergui north to Chiengrai, through Mong Mong (Yunnan) and Pang Long (Burma) States into Myitkyina district and then in a southerly direction west of the Chindwin river and the Arakan Yomas to Akyab. The area thus demarcated is compact and approximately of the same size as the *alexandri* area. Within this area *anomala* seems to adapt itself equally well to the varied habitats offered by the hills, the Plateau, the monsoon tropics and the semi-arid central zone. (This distribution is especially impressive in view of the constantly occurring high percentage of abnormal forms.)

The three Indian localities of *anomala* are at some distance from the natural range of the species as indicated above, the two easternmost localities about 300 miles (Calcutta) or 400 miles (Darjiling district) from the western boundary of the area in Burma. The other Indian locality (Dehra Dun) is about 700 miles west from Darjiling district. In the intervening region between Burma and the Indian localities the

physical features (such as snow-covered mountains, etc.) that prevent earthworm migration are lacking. In view of the ability of the species to maintain itself in a variety of habitats and to perpetuate itself in spite of the large percentage of abnormal and sexually non-functional individuals, there is no reason to conclude that the species has been unable to penetrate into Bengal to Calcutta and to Darjiling district by its own activity, providing only that sufficient time for such migration has been available. On this latter topic no information whatever is available. At present the three Indian records appear to be the result of accidental transference and especially the Dehra Dun record. It should be noted however that the western border of the *anomala* area is close to the political boundary of India and probably will have to be moved in the future into India.

Dehra Dun and Pashok (Darjiling district) are the northernmost records. Unfortunately the elevations at which the worms were secured are unknown. Although known from lower elevations in the southern Himalayas, *P. anomala*, like *alexandri*, has not been found at those higher elevations at which *diffringens* has been obtained.

*P. campanulata*. This species is widely spread throughout the province of Burma and has been found in 24 of the political districts. It has been obtained, like *anomala*, from the Arakan division and the Chin Hills district where *alexandri* is unknown, and is common both in the plains and hills and on the Plateau where it has been found up to an elevation of 4,000+feet. The species is known from the Chinese province of Yunnan (Ang Lawng Mt., and Mong Ma, Mong Lem State) and has been found at Mu'ang Pong (Ban Maung) on the Upper Me Yom in Siam (unpublished Ms.), in the Malay Peninsula (Kuala Lumpur) as well as on the Andaman Islands.

*P. campanulata* is closely related to two other Burmese species. One of these, *P. meridiana*, has been found as yet only in eastern and northern Burma (except for one record from the Bahamas, obviously the result of accidental transportation), but the other, *P. houletti*, is even more widely distributed than *campanulata*.

The *campanulata* range is slightly larger than that of *anomala* due to the fact that the line begins at Victoria Point at the southernmost extremity of Burma and passes north through Siam further east than in the case of *anomala*. If "eng" and "Anzahl" are not too strictly interpreted—*campanulata* appears to possess both of Michaelsen's qualifications for endemism. The species seems to be equally adapted to the varied habitats of the plains and hills except for that of the semi-arid zone of Central Burma in which it has not yet been found.

The only Indian localities (both in Darjiling district) are about as far from the northern border of the *campanulata* area as Kuala Lumpur is from the southern border. The Indian and Malay Peninsula as well as the Andaman Islands records, at present, appear to be the result of accidental transference. As in the case of *anomala* the western border of the *campanulata* area is close to the political boundary of India and probably will have to be moved over into India. The elevations at which the Darjiling district worms were secured unfortunately are unknown.

*P. houlleti*. This species is widely spread throughout the province of Burma, having been collected in 33 of the 40 districts. It is found on the plains and hills, and on the plateau up to an elevation of 5,000+ feet and most probably is present in the 7 districts which have not yet been investigated. It is known from several localities in Siam (Bawti, Not Theinko, Bangkok in the south; Chiangmai and Muang Pong in the north), the Malay Peninsula (Kuala Lumpur, Aring in Kelantan, Singapore) and the Andaman Islands. Michaelsen (1900, p. 273) includes Cochin China in the list of localities but I have been unable to trace this record. The species is not known from China (previous records are the result of erroneous suppression of valid species) except for one record from Yunnan just across the Burmese border (Mong Lem State).

In India the species is widely spread and here also has been found in hills and plains and about equally in both. In the hills the species has been found up to an elevation of 4,500 feet but seems to be quite rare or lacking in most parts of the Himalayas, especially at those, higher elevations from which *diffringens* has been obtained. Rawalpindi is the northernmost locality, Dehra Dun and Bhim Tal the next.

Beyond the mainland of Asia the species has been reported from Sumatra (twice), Java (twice), the Philippine Islands (twice), Fiji Islands, Ceylon, Madagascar, Gross Comoro and French Guiana. None of these records can be accepted until verified because of a long confusion of *houlleti* with at least three other species. In view of the ability of the species to maintain itself successfully in a wide range of habitats varying from the equatorial rain forest to the monsoon plains and semi-desert lowland regions as well as the hills, its wide distribution throughout India and southeastern Asia, it is very curious that the species has not been transported as widely as *diffringens*.

*P. houlleti* is close to two other Burmese species, *P. campanulata* (Burmese-Siamese), and *P. meridiana* (eastern and northern Burma). The species is considered to have originated somewhere in the Burmese-Siamese region but just how much of its Indian distribution, if any, is to be attributed to accidental transportation is not clear. The Ceylon and Andaman Islands records are regarded as due to accidental carriage.

*P. planata*. This species is rather widely spread in Burma, having been found in 22 of the 40 districts. Within the semi-arid region of Central Burma it has been found but once (Pyinmana) and is known from only three localities on the Shan Plateau (Namkham, Lashio, Karen Hills of Toungoo district) where it has been found at elevations of 2,000+ to 3,000+ feet. Although widely spread it is not common, usually being found only after careful search and then not in numbers. It is not known from Siam and China but has been found once in the Malay Peninsula (Kuala Lumpur) and apparently is rather common on the Andaman Islands. *P. planata* is close to a trans-Salween species, *P. immerita*, known only from Kengtung, Mang Lun and Pang Long States, an area quite definitely to be characterized as "eng begrenzten"

The only Indian record is Katlicherra (South Cachar in Assam) which is perhaps 150 miles from the nearest Burmese locality (Upper Chindwin district). Very little is known of the earthworm fauna of the

intervening region but there is no reason to suppose that *planata* is lacking therein. A line drawn from the northern portion of Mergui district north through Burma to Lashio, Namkham, and Myitkyina and then through Cachar to Akyab marks off the range of the species as now known and encloses an area somewhat smaller than that of *anomala* (but west of the *immarita* area). *P. planata* appears, at present to be primarily a Burmese species that has been accidentally transported to the Malay Peninsula and the Andaman Islands. However, it is possible if not probable that the species will be found to be fairly widely spread in Assam and Siam and perhaps also throughout the Malay Peninsula.

*P. posthuma*. This species is rather widely spread through the province of Burma, having been collected in 29 of the 40 districts, but is restricted to the plains and low country. Even here it is found most commonly and in greatest numbers in the sandy soil along the banks of rivers and streams. Two records from the Shan Plateau are erroneous. If found in the higher hills and on the Plateau, the localities probably will be along banks of streams. The species is known from the Andaman Islands and has been recorded once from the Malay Peninsula (no specific locality) by Beddard but the record has never been confirmed and Stephenson was unable to find Beddard's specimens in the British Museum. The species has been collected at several localities in Upper Siam (Chiangmai 1,000 ft., Ban Sa-iep and Mu'ang Pong) as well as in lower Siam (Bangkok) but is unknown from China.

According to Stephenson (1923, p. 311) *P. posthuma* is "universally found in North India" but though it has been collected from a number of localities it has never been reported from the higher mountain elevations at which *diffringens* has been found. The northernmost localities are in the Punjab. Furthermore, the species has been found hitherto only once south of a line from Baroda to Calcutta and then at Bombay. Of the Indian localities, almost all are in the plains or lowlands. Five times only has the species been reported from places with an elevation greater than a thousand feet (Hoshiarpur, 1,000+feet; Kalka, 2,000-3,000 ft.; Ajmere and Udaipur, 1,500-2,000; Dehra Dun, 2,000-3,000; and even here the elevations at which the worms were secured may be unknown). Eighteen of the Indian localities are shown even on our small maps as being on the banks of rivers.

Morphologically as well as physiologically (adaptation to the sandy river-bank habitat) *P. posthuma* is rather peculiar and unlike all other Burmese species of *Pheretima*. For this reason a Burmese origin for the species at first seems to be rather doubtful. However, the more important of the morphological peculiarities have to do with the commissural blood vessels of segments x and xi and these characteristics also distinguish the species from all other *Pheretimas*, at least so far as is known at present. The Burmese distribution though extensive is much less so than that of *Pontoscolex corethrurus* which is certainly an introduced species but not so restricted as to habitat. For the present *P. posthuma* may be regarded, though doubtfully, as of Burmese or Burmese-Siamese origin and with a south-eastern Asiatic mainland distribution that does not require the assumption of accidental transference at least by man,

## II.

*P. diffringens*. In Burma this species has been found on the Shan Plateau (Namkhai, Namkham, Lashio, Maymyo, Mogok, Taungyi, Htamsang, Kalaw, Manchio and Thandaung) and outside the plateau only once, at Bhamo. It has been found at elevations of 2,000+ to 4,000+ feet and only once below 2,000 feet, and then at Bhamo (under 500 feet but north of the tropic of Cancer). The species is known from several provinces of China (Yunnan, Szechuan, Kiangsu, Kiangsi, Chekiang, Anhwei and Fukien) and is close to Chinese, Korean and Japanese species which are not at present clearly distinguished and which may have to be suppressed. Unknown from Siam, French Indo-China, the Malay Peninsula or the Andaman Islands.

In spite of the fact that Stephenson gives the distribution of the species as "Throughout India" (1923, p. 304), *diffringens* has been found hitherto only in a region north of a slightly curved line drawn from Lahore south-east to Rangamati, and in South India where it is known only from the Bababudan, Nilgiri and Palni Hills. *P. diffringens* has been found in the eastern and western Himalayas and Assam at elevations of 3,000-7,000 feet, in the North-west Frontier Province at elevations of 1,000-2,000 feet, and in South India at elevations of 4,500-7,500+ feet.<sup>1</sup> At lower elevations the species is known only from the Punjab (600+ feet), Siliguri, Teesta Bridge (500-700 ft.) and Rangamati in Bengal, Kobo and Sadiya in Assam. The Kangra district localities (Punjab) are at the edge of hills north-east of Lahore, Siliguri and Teesta Bridge are close to the Himalayas as are Kobo and Sadiya while Rangamati is close to the hills of the Chittagong Hill Tracts. Rangamati is the only plains record south of the tropic of Cancer (the Rangamati worms may of course have been obtained at some nameless locality in hills near Rangamati), all of the other plains and lower hills records quite to the north of that tropic.

*P. diffringens* is widely spread as a result of accidental transportation, probably much more widely spread than any other species of *Pheretima*. Much of this accidental carriage is certainly due to man,—note the records from botanical gardens and hot houses in Europe, America and elsewhere. It is extremely unlikely that this species has been carried by man, in India for example, only to temperate zone localities or only to those high hills in the tropics with a cool climate. We must assume therefore, that in tropical lowland localities to which the species has been transported, it has been unable to maintain itself though able to adapt itself to a variety of habitats in the temperate zone and higher hills of the tropics. These considerations together with the wide Chinese distribution seem to indicate that the worm is a temperate zone form and that it has originated somewhere in the Chinese region. Penetration into Burma and at least into the eastern portion

---

<sup>1</sup> The elevations at which *P. diffringens* has been secured in South India are as follows:—Kodaikanal, 7,000, 6,850, 6,900, 6,850-7,000 ft.; Kotagiri, 5,700; Fern Hill, 7,500; Bababudan Hills (Kadur district in Mysore), 4,500; Naduvatam, 6,000; Coonoor, ca. 5,000; Benhope, exact elevation not known but nearest railway station, Hillgrove, is ca. 3,000 ft. The writer is indebted to Dr. S. L. Hora for much of this information.

of north India accordingly is to be regarded as due to natural migration of the species, while accidental transportation must be invoked to explain its presence in South India. Whether the presence of *diffringens* in north India way into the North-West Frontier Province can be regarded as brought about without accidental transportation is not yet clear.

*P. hawayana*. In Burma this species has been found on the Shan Plateau and only on the northern portion (Namkham, Kawngmu, Kutkai, Lashio and Mogok, all north of 22° latitude). It has been found only at elevations of 2,000 to 3,000+feet. The species is known from several provinces of China (Yunnan, Szechuan, Fukien and Chekiang) and may have been described from Japan under another name. Stephenson has recorded the species from the Malay Peninsula (Kuala Lumpur and Singapore), records which cannot be accepted until verified because of a failure to distinguish between *hawayana* and *morrisi*.

In spite of the fact that Stephenson calls this species "one of the commonest worms in India" (1923, p. 302), it is known at present only from a few localities; Lahore (Punjab), Ramnee (Western Himalayas), Kurseong (Eastern Himalayas) and Shillong (Assam). All of these localities are north of 25° latitude and the westernmost are north of 30°. All Indian records are from elevations of 3,000 to 5,000+feet. The Ceylon records are also from the hills.

With a distribution like that of *diffringens* and an apparently similar temperature restriction (barrier) it is probable that *hawayana* likewise originated in China. Presumably it has penetrated into Burma and at least the eastern portion of north India by its own activity.

*P. morrisi*. This species is more widely spread in Burma than *hawayana*, having been found not only on the Shan Plateau (Namkham, Kutkai, Hsenwi, Lashio, Mogok, Maymyo, Taungyi, Htamsang, Pang Long, Mang Lun, Mong Yai and Kengtung States) but also in Myingyan (Mt. Popa only), Bhamo and Myitkyina districts. It has been found only at elevations of 2,000 to 4,000 feet, except at Myitkyina and Bhamo (under 500 feet but north of the tropic of Cancer). The species is known from four provinces of China (Szechuan, Fukien, Chekiang and Yunnan). It has been collected once in Siam (Chiengmai, 1,000 feet) but is unknown from the Malay Peninsula and French Indo-China. (A record of *P. hawayana* from the Malay Peninsula by Stephenson may actually be for *morrisi* which is known from Penang.)

In India *morrisi* has been found chiefly at elevations of 2,000 to 6,500 feet. It has been obtained at only three localities south of the Lahore-Rangamati line; Brindaban, Udaipur (2,460 feet) in Rajputana, and Bombay. Only three records are from lowlands; Lahore (600+feet), Brindaban (500-feet), and Bombay.

With a distribution like that of *diffringens* and *hawayana* and an apparently similar temperature barrier, it is possible that *morrisi* likewise originated in China and like the other two species has penetrated into northern Burma and at least the eastern portion of north India by its own activity. Its presence on Mt. Popa in Burma and those localities in India south of the Lahore-Rangamati line is regarded as due to accidental transportation.

*P. robusta.* In Burma this species has been found only in the northern portion of the Shan Plateau (Namkham, Kutkai, Lashio, Hsipaw and Pang Long States) where it has been found at elevations of 2,000+ to 4,000+ft. The species is probably widely distributed in China and has been recorded from the provinces of Yunnan, Szechuan, Fukien, Kiangsu, Kiangsi, Chekiang and Hupei.

Outside the Asiatic mainland the species has been reported from Madagascar, Mauritius, the West Indies and the Philippines. None of these records have ever been confirmed and some of them must be regarded as very dubious.

The only Indian record is that of *P. himalayana* from Darjiling at an elevation of 7,000 feet.

At present it is necessary to regard *P. robusta* as having originated somewhere in China and also as a temperate zone form, that has been able to penetrate into Burma and India as a result of its own activity.

### III.

*P. elongata.* This species is rather widely distributed in Burma having been collected in 20 of the political districts. It has been found both in the plains (monsoon and semi-arid) and hills and in the latter to a height of 3,000 feet but has been obtained from only four localities north of the tropic of Cancer; Mawlaik, Indaw Lake, Bhamo and Myitkyina. Although fairly widely spread it is not common and when found is usually not obtained in any considerable numbers unless the soil is "black". It has been collected in Siam (Bangkok and Chien-gmai) and the Andaman Islands but is unknown from the Malay Peninsula, French Indo-China and China.

In India the species is almost confined to the tropical portion as it has been found only once north of the tropic of Cancer, and then at Karachi.

*P. elongata* has been transported widely throughout the tropics and presumably by man. Only in Burma and at Karachi has the species been found outside of the tropics and then not far to the north. It is unlikely that a species so widely spread by external agencies has been carried only into tropical regions. Restriction to the tropics with the correlated inability to maintain itself in cooler regions to which it must have been carried seems to require a tropical origin for the species. Morphologically *elongata* can be included in Michaelsen's subgenus *Polypheretima* from the southern portion of the Malay Peninsula, Borneo, Celebes and New Guinea and in fact is so close to one of the Borneo species, *P. stelleri*, that the two cannot be adequately distinguished, at least at present. Should the original home of *elongata* be in Borneo, the Burmese and Indian records are to be considered the result of artificial transference. Even though the home of the species should prove to be in the Malay Peninsula the (present) Indian distribution will still have to be explained as the result of accidental transportation.

*P. bicincta* and *P. taprobanae*. Neither of these species has been found in Burma and at present there is little of importance to be said with regard to the distribution of these worms. *P. bicincta* has been recorded only twice from the "*Pheretima* domain"; once from the Philippines and once from Java. Its presence in India is obviously the

result of accidental transportation. *P. taprobanae* is quite unknown from the "*Pheretima* domain", and also must have been carried into India accidentally. All localities at which these two species have been found are within the tropics. Like *elongata*, *bicincta* and *taprobanae* appear to have had a tropical origin and to be able to maintain themselves only in that portion of the world.

*To summarize.*—Of the thirteen Indian species of *Pheretima*, three quite obviously are present in India as the result of accidental transportation. The original homes of these species are unknown but one is to be sought for in Borneo and the probability is that all three are tropical if not primarily equatorial. Four species are regarded as originally Chinese, e.g., *diffringens*, *hawayana*, *morrisi* and *robusta*. Of the remaining species, *alexandri*, *anomala*, *campanulata* and *planata* (possibly also *houletti* and *posthuma*) are regarded as primarily Burmese or Burmese-Siamese. Each species in the last two groups (Chinese and Burmese) is in India, or will eventually be shown to be, as a result of its own activity rather than as the result of accidental carriage. Immigration of Chinese species from the north-east (and north?) and of Burmese species from the east explains the heavy concentration of *Pheretima* localities in that portion of India north of a line from Baroda to Calcutta. Some species however have been carried accidentally to isolated localities which may be at considerable distances from regions to which the species have penetrated naturally.

South-eastern Asia—India-Burma-Siam-French-Indo-China—lacks the physical features such as deserts, snow-covered mountain ranges and salt seas that are usually regarded as effective barriers to earth-worm migrations. This region does have a wide variety of climatic, edaphic and physiographic habitats. One species, *P. posthuma*, is restricted largely to one peculiar habitat, the sandy soil of river banks. Another species, *P. campanulata*, at present, seems to be unable to exist in the semi-arid region of central Burma. Other species however are able to adjust themselves to and maintain themselves in a wide variety of the habitats available. Within the region the only effective barrier to migration seems therefore to be that of temperature. But temperature cannot be invoked to explain the boundaries of natural areas of certain species, or why a particular species is lacking in a contiguous region of suitable habitats. Of those factors which are of most importance in explanation of this problem, factors such as speed of travel and time available for migration since origin of the species, we have no knowledge whatever.

On a previous page a prophecy has been hazarded that few further species of *Pheretima* will be found in India, barring of course importations of an accidental nature. If found, further species will be collected in the Himalayas to the north and in Assam and Chittagong on the east. Of the Chinese species perhaps the most likely to be found is *P. californica* which may be anticipated in the hills and mountains to the north. Of the Burmese species the most likely immigrants to be found in Assam are *austrina*, *choprai*, *exigua*, *birmanica*, *peguana* and some of the *doliaria* group. In Bengal (Chittagong) the most likely immigrant is *P. peguana*. Burmese species are not to be expected in the Himalayas,

at least at the higher elevations at which *diffringens* and other Chinese species are obtained.

#### HABITS.

In an attempt to "determine the significance" of the enteronephric excretory organs of earthworms, Bahl (1934) has discussed the "Habits of *Pheretima* as compared with those of *Eutyphoeus*" Nowhere in the text of the paper is there any indication of the number or names of the species studied, though two names, *P. posthuma* and *E. waltoni*, are mentioned in labels of figures. Failure to observe an elementary precaution in scientific work has resulted in statements such as "the castings of *Pheretima* always consist of solid rounded pellets" (*italics mine*). Actually, *P. posthuma* is the only species of the genus that is known to produce pellet-like castings. The castings of all other species of *Pheretima*, so far as is known, are of the tower-like type that Bahl imputes only to *Eutyphoeus*. Furthermore, *P. posthuma* is the only species of the genus that is restricted to the river-bank habitat.

#### SYSTEMATICS.

##### Genus : **Pheretima** Kinberg.

- 1867. *Amyntas* (Type, *A. aeruginosus*, non Wollaston 1865), + *Nitocoris* (Type *N. gracilis*, non H. & A. Adams 1854.) + *Pheretima* (With two species, *P. montana* and *P. californica*.) + *Rhodopis* (Type, *R. javanica*, non Reichenbach 1854.) + *Perichaeta*, Kinberg, *Ofv. Ak. Forh.* XXIII, pp. 101, 102.
- 1883. *Megascolex* (maximum part) + *Perichaeta* (minimum part) Beddard, *Ann. Mag. Nat. Hist.* (5), XII, p. 214.
- 1884. *Perichaeta* (part), Beddard, *Ann. Mag. Nat. Hist.* (5), XIII, p. 401.
- 1888. *Perichaeta* (maximum part) + *Megascolex* (minimum part), Rosa, *Ann. Mus. Genova*, XXVI, p. 155.
- 1889. *Megascolex* (part), Vaillant, *Hist. Nat. Annel.* III, (1), p.
- 1890. *Perichaeta* subgenus *Perichaeta*, Beddard, *Proc. Zool. Soc. London*, 1890, p. 56.
- 1895. *Perichaeta* (part, excluding *Lampito* and probably also *P. viridis* Schmarida 1861) + *Megascolex* (part, including *M. margaritaceus*, *M. iris* and *M. pictus*), Beddard, *Monog.* pp. 388 and 370.
- 1899. *Amyntas*, Michaelsen, *Mitt. Mus. Hamburg*, XVI, p. 3.
- 1900. *Pheretima* (part, excluding *P. burliarensis* and *P. lawsoni*), Michaelsen, *Das Tierreich*, X, p. 234.
- 1900. *Amyntas*, Beddard, *Proc. Zool. Soc. London*, 1900, p. 613.
- 1907. *Pheretima*, Michaelsen, in Michaelsen and Hartmeyer, *Fauna Sudwestaustraliens*, I, p. 164. (*P. montana* designated type species.)
- 1922. *Promegascolex*, Cognetti, *Boll. Mus. Zool. Torino*, XXXVII, (744), p. 3. (Type, *P. mekongianus*.)
- 1923. *Pheretima* (part), Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 288, (excluding *P. burliarensis*.)
- 1928. *Pheretima*, Michaelsen, *Ark. Zool.*, XX, A, (3), p. 4.
- 1930. *Megascolex* (part, including only *M. mekongianus*) + *Pheretima*, Stephenson, *The Oligochaeta*, pp. 837 and 838.
- 1934. *Pheretima*, Michaelsen, *Quart. J. Mic. Sci.* LXXVII, p. 12. (*P. californica* designated as type species in place of *P. montana*.)

**Diagnosis.** Setae perichaetine. One gizzard in viii<sup>1</sup>. Excretory organs exonephric and enteronephric micronephridia. Testes and male funnels in testis sacs. Prostates racemose.

---

<sup>1</sup> Although the gizzard is in viii, in all species in which septum 8/9 is present, one or more of septa 8/9-10/11 may be lacking or rudimentary so that the gizzard has the appearance of extending posteriorly.

A large proportion of the species of *Pheretima* are characterized as follows. The setae begin on ii on which segment there is a complete setal circle. The clitellum is annular, extending from 13/14 to 16/17; with development of the clitellar glandularity the setae of the clitellar segments drop out and are not replaced, the intersegmental furrows between xiv and xv, and xv and xvi disappear and the dorsal pores on 14/15 and 15/16 are occluded. Ventral reproductive apertures; the spermathecal and male pores symmetrically paired, a single female pore. Septa 8/9-9/10 lacking, rudimentary or not normal. The intestine begins in xv or xvi close to 15/16. The last pair of hearts is in xiii, all hearts of ix-xiii opening into the ventral blood vessel. Seminal vesicles are paired in xi and xii, the vesicles of xi excluded from the testis sac or sacs. Spermathecal diverticulum passing into the duct just at, close to or within the parietes. Only constant specific deviation from any of these characteristics requires especial mention in the diagnoses.

Within a species there may be variation with regard to certain characteristics. Thus the single female pore may be replaced by paired female pores. One or more of the anteriormost dorsal pores may fail to develop. An occasional specimen may have an unusually large or an unusually small number of setae on one or more segments. Normally paired testis sacs may be replaced by unpaired testis sacs and *vice versa*. A genital marking may be lacking or extra genital markings may be present. One or more of the spermathecae, ovaries, prostates, etc., may be lacking or one or more extra spermathecae, prostates, ovaries, etc., may be present. When the specific norm or pattern is known it is scarcely necessary to include such variations in a diagnosis of the species. Unfortunately, in several forms, as *P. taprobanae* and *bicincta*, only a very few specimens have been studied and hence little is known as to the variation of important structures or characteristics. Even in some of the older species, as *P. elongata* (E. Perrier) 1872, the specific norm is as yet scarcely obvious in all its details. In certain species, abnormal individuals may be much more common than normal individuals. Some of these species are known, even today, only from the aberrant specimens, though none of these species are Indian. Even though abnormal individuals are more common than normal worms, a diagnosis must of course describe only the normal forms. A correct definition based on normal individuals has only recently been possible for one Indian species, *P. anomala* (*vide* p. 193).

*Descriptive and diagnostic terms and conventions.* Intersegmental furrow is used in a definitely restricted sense so as to refer only to the slight line constituting the boundary externally between two successive segments. By this limitation of meaning a much more definite characterization of the location of the spermathecal pores is possible. The intersegmental furrow as now defined must be distinguished from the deep circular groove often present between adjacent metameres on strongly contracted specimens. The intersegmental furrow lies at the bottom of such a groove. Actually the intersegmental furrow, as now defined, is not a furrow at all but a new term is perhaps unnecessary.

Important information with regard to setal numbers is shown by a setal formula such as the following: vi/13-17, xvii/20-27, xviii/10-15, xix/20-27, 56-64/xx. The first portion of this formula shows that on segment vi there are 13-17 setae ventrally between two longitudinal lines passing across the spermathecal apertures parallel to the midventral line. These setae are called spermathecal setae. Ventral setae on xviii between the male pores are called male setae. The formula indicates that the number varies from 10 to 15. Similarly there are 20-27 male setae on xvii and xix but in this case the figures show the number of setae between longitudinal lines passing across the male pores parallel to the midventral line when the pores are superficial or across the centres of the apertures of the invaginations if the male pores are invaginate. If the spermathecal pores are large or invaginate the spermathecal pore lines also pass across the centres of the apertures. The portions of a formula with segmental numbers (in Roman numerals) as denominators indicate the total number of setae on the segments mentioned, thus 56-64/xx shows that the number of setae in the circle on xx varies from 56 to 64. It is sometimes necessary to refer to a definite seta or inter-setal interval and in such references italicized small letters are used, thus *a* refers to the first seta on either side of the midventral line, *b* to the second, *c* to third, etc. Dorsally the first seta on either side of the mid-dorsal line is called *z*, the second *y*, the third *x*, etc. A male pore may be located as in line with seta *b* while a dorsal spermathecal pore may be in line with *y*. The setal nomenclature is most useful however in connection with indication of location of genital markings. Thus a genital marking may be said to be in *ab* which does not necessarily mean that the marking is actually between *a* and *b* but in the space between two lines passing across setae *a* and *b* parallel to the midventral line, the exact location of the marking indicated by qualifying terms such as pre- or postsetal or intersegmental.

Superficial and invaginate, in connection with the genital markings scarcely require explanation. An invagination containing a genital pore may be restricted to the body wall or conspicuously protuberant into the coelomic cavity, in the latter case, if associated with the male genital terminalia, a pouch formed by the invagination is called a copulatory chamber.

Spermathecal apertures may be minute as in *diffringens* or large as in *indica*, minute pores may be superficial or invaginate, a large pore, apparently always, superficial. A large primary spermathecal aperture (superficial) must not be confused with the secondary spermathecal aperture of an invagination containing the primary spermathecal pore.

Genital markings are special areas that develop in the epidermis of certain segments of an anterior portion of the body towards sexual maturity. Like the male and spermathecal pores the markings may be either superficial or invaginate. If invaginate the markings are usually within copulatory chambers of male or spermathecal pore invaginations but may be located, as in *P. anomala*, in special invaginations that are eversible. The markings are usually associated with definite, glandular masses which may be sessile on or within the body-

wall, or stalked and either buried in the muscular layers or protuberant into the coelomic cavity.

Length, diameter, and number of segments are usually mentioned in specific descriptions and diagnoses. There has however been considerable carelessness in connection with these characteristics. It should be obvious that segmental enumerations and measurements of juvenile, immature, autotomized, regenerating or regenerated specimens have no particular value so far as specific characterization is concerned. Measurements for the sake of uniformity should be made on preserved, contracted specimens. (The best method of killing worms for taxonomic study is to merely drop the specimen into commercial methylated spirit. Worms may be hardened in 10 per cent. formalin and then preserved in formalin or alcohol.) The diameter may be measured at the region of greatest thickness, usually in or near the clitellar region.

Simple, as applied to intestinal caeca, is used to characterize an anteriorly directed, more or less finger-shaped evagination of the gut that has but one main axis. The term is used even though there may be several short, secondary outgrowths from the dorsal or ventral margins of the caecum.

A seminal vesicle is an outgrowth from a septum, first appearing, at least in many species, as an ovoidal vesicle or ampulla attached by a ventral stalk to the posterior face of a septum, either 10/11 or 11/12. With further development the stalk broadens out into a softish, ventral lamina with which the smaller dorsal ampulla may become fused so as to be no longer recognizable, or the dorsal ampulla may be definitely constricted off from the ventral lamina and of a distinct texture and shade. Seminal vesicles may be free or (in segment xi only) included within the testis sac or sacs. "Included" in association with testis sacs in the specific diagnoses has reference only to the anterior pair of seminal vesicles. Exclusion of these vesicles, as a negative characteristic, is not mentioned in the diagnoses.

Testis sacs are thin-walled, membraneous sacs enclosing the testes and male funnels. The testis sacs may be paired or unpaired. If paired each sac contains only one testis and one male funnel. If unpaired, each sac contains the two testes and two male funnels of a segment. Paired sacs may be ventral and suboesophageal or vertical, *i.e.*, extending dorsally at the sides of the gut. The seminal vesicles of xi may be included within paired, vertical sacs but are never included within paired or unpaired suboesophageal sacs. Unpaired sacs may be ventral and suboesophageal or U-shaped, horseshoe-shaped, annular or cylindrical. When the sacs are U-shaped or horseshoe-shaped the limbs of the sac extend dorsally or ventrally at the sides of the gut. An annular sac surrounds the gut completely and is formed by the dorsal or ventral union of the limbs of a U-shaped or horseshoe-shaped sac. A cylindrical sac is formed by a sheet of tissue in form of a cylinder passing anteroposteriorly between two successive septa in such a way as to enclose practically all of the organs of a segment. If the testis sac of xi is cylindrical the seminal vesicles of that segment are always

included therein. If the sac is U-shaped the vesicles may or may not be included.

*Miscellaneous notes.*—Identification internally of certain anterior segments has occasionally, from Bourne to Bahl, proved troublesome, as a result of the loss of certain septa and the dislocation or delicacy of some of those present. The female pores in *Pheretima* are always (except on very rare, abnormal specimens) on xiv and the ovaries are always one segment in front, in xiii. Having determined that the specimen is normal by reason of the location of the female pores on xiv, the ovaries can then be located in the opened specimen and from the ovarian segment which is readily identified the anterior segmentation can be worked out, checking lost septa against segmental commissures of the circulatory system (hearts) or in case of loss of hearts against segmental nerves or the setal circles which are visible on the coelomic face of the parietes. Spermathecae can be used as indicators only after it has been determined whether the ducts pass into the parietes anteriorly or posteriorly. Failure to observe this simple precaution has resulted in mistaken enumeration of the first post-gizzard septum in *P. posthuma*.

The worm should be dissected through a mid-dorsal incision. This mode of dissection most often enables determination of important characteristics without damage to structures that may require to be kept intact for future reference.

#### Key to Indian species of *Pheretima*.

For the sake of greater convenience this key has been based so far as is possible on external characteristics.

- |                                                                                                      |                        |
|------------------------------------------------------------------------------------------------------|------------------------|
| 1. a. Multithecal                                                                                    | <i>P. elongata.</i>    |
| b. Not multithecal                                                                                   | 2.                     |
| 2. a. Bithecal                                                                                       | <i>P. taprobanae.</i>  |
| b. Quadrithecal to decithecal                                                                        | 3.                     |
| 3. a. Quadrithecal                                                                                   | 4.                     |
| b. Sexthecal to decithecal                                                                           | 6.                     |
| 4. a. Male pores superficial                                                                         | 5.                     |
| b. Male pores invaginate, in copulatory chambers                                                     | <i>P. planata.</i>     |
| 5. a. Spermathecal pores on 5/6-6/7                                                                  | <i>P. morrissi.</i>    |
| b. Spermathecal pores on 7/8-8/9                                                                     | <i>P. robusta.</i>     |
| 6. a. Sexthecal                                                                                      | 7.                     |
| b. Octothecal to decithecal                                                                          | 10.                    |
| 7. a. Spermathecal pores on 5/6-7/8                                                                  | 8.                     |
| b. Spermathecal pores on 6/7-8/9                                                                     | 9.                     |
| 8. a. Male pores on xx, genital markings invaginate                                                  | <i>P. anomala.</i>     |
| b. Male pores on xviii, genital markings superficial.                                                | <i>P. hawayana.</i>    |
| 9. a. First dorsal pore on or anterior to 10/11, one stalked gland to each spermathecal invagination | <i>P. houlleti.</i>    |
| b. First dorsal pore on or posterior to 11/12, two stalked glands to each spermathecal invagination  | <i>P. campanulata.</i> |
| 10. a. Octothecal                                                                                    | 11.                    |
| b. Decithecal                                                                                        | <i>P. bicincta.</i>    |

- |                                                                                                         |                        |
|---------------------------------------------------------------------------------------------------------|------------------------|
| 11. a. Spermathecal pores segmental, male pores invaginate, genital markings in the setal circles       | <i>P. posthuma.</i>    |
| b. Spermathecal pores intersegmental, male pores superficial, genital markings not in the setal circles | 12.                    |
| 12. a. Preclitellar genital markings present, seminal vesicles excluded                                 | <i>P. diffringens.</i> |
| b. Preclitellar genital markings lacking, seminal vesicles included                                     | <i>P. alexandri.</i>   |

#### ABNORMAL FORMS.

Abnormal forms, in particular localities or in certain species, may be as common as or even much more common than normal forms. One unacquainted with the normal forms and having only abnormal individuals may have considerable difficulty in identification. A key is therefore given to assist in placing the more commonly found abnormal forms.

- |                                                                        |                        |
|------------------------------------------------------------------------|------------------------|
| 1. a. Athecal                                                          | 2.                     |
| b. Thecal                                                              | 9.                     |
| 2. a. Male pores present                                               | 3.                     |
| b. Male pores lacking                                                  | 7.                     |
| 3. a. Male pores superficial                                           | <i>P. alexandri.</i>   |
| b. Male pores invaginate                                               | 4.                     |
| 4. a. Male pores in parietal invaginations                             | 5.                     |
| b. Male pores in copulatory chambers                                   | 6.                     |
| 5. a. Male pores on xviii, genital markings superficial.               | <i>P. elongata.</i>    |
| b. Male pores on xx, genital markings invaginate                       | <i>P. anomala.</i>     |
| 6. a. First dorsal pore on 11/12 or posteriorly                        | <i>P. campanulata.</i> |
| b. First dorsal pore on 10/11 or anteriorly                            | <i>P. houlleti.</i>    |
| 7. a. First dorsal pore on 12/13, seminal vesicles included            | <i>P. alexandri.</i>   |
| b. First dorsal pore on 11/12 or anteriorly, seminal vesicles excluded | 8.                     |
| 8. a. First dorsal pore on 11/12                                       | <i>P. campanulata.</i> |
| b. First dorsal pore on 10/11 or anteriorly                            | <i>P. houlleti.</i>    |
| 9. a. Spermathecal pores superficial, occasionally in groups of 2-4    | <i>P. elongata.</i>    |
| b. Spermathecal pores invaginate, never grouped                        | 10.                    |
| 10. a. Male pores lacking                                              | <i>P. anomala.</i>     |
| b. Male pores present                                                  | 11.                    |
| 11. a. Male pores on xix-xxi                                           | <i>P. anomala.</i>     |
| b. Male pores on xviii                                                 | 4.                     |

#### ***Pheretima alexandri* (Beddard.).**

1900. *Amyntas alexandri*, Beddard, *Proc. Zool. Soc. London*, 1900, p. 998. (Type locality, Calcutta. Type in the British Museum.)
1903. *Pheretima Alexandri*, Michaelsen, *Geogr. Verbr. Berlin*, p. 94.
1909. *Pheretima alexandri*, Michaelsen, *Mem. Ind. Mus.* I, p. 109.
1910. *Pheretima Alexandri*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), p. 11.
1914. *Pheretima lignicola*, Stephenson, *Rec. Ind. Mus.* VIII, p. 399. (Type locality, Dibrugarh, Assam. Type in the Indian Museum.)
1915. *Pheretima lignicola*, Stephenson, *Mem. Ind. Mus.* VI, p. 99.
1920. *Pheretima lignicola*, Stephenson, *Mem. Ind. Mus.* VII, p. 223.
1922. *Pheretima suctoria*, Stephenson, *Rec. Ind. Mus.* XXIV, p. 434.
1923. *Pheretima alexandri* + *P. lignicola* + *P. suctoria* (part. excluding Andaman Island forms), Stephenson, *Oligochaeta*, in *F. B. I. Series*, pp. 291, 305 and 311.

1924. *Pheretima lignicola* + *P. sutoria* var. *mullani*, *Rec. Ind. Mus.* XXVI, p. 340.  
 1925. *Pheretima sutoria* var. *mullani*, Stephenson, *Proc. Zool. Soc. London*, 1925, p. 893.  
 1931. *Pheretima alexandri*, Stephenson, *Rec. Ind. Mus.* XXXIII, p. 182. (Re-description of the type.) Also Gates, *Rec. Ind. Mus.* XXXIII, p. 363.

*Diagnosis.*—Octothecal, spermathecal pores minute and superficial, four pairs, on 5/6-8/9. Male pores minute and superficial. Just anterior and posterior to each male pore a small, greyish, translucent area, usually rather crescent-shaped and with the concave side of the area facing the male pore, the translucent areas and the male pore slightly depressed and surrounded by a narrow, slightly protuberant, U-shaped ridge, the limbs of the U directed midventrally. Setae: vi/6-12, vii/8-14, viii/10-16, xvii/13-21, xviii/10-18, xix/14-21, 13-20/ii, 18-24/iii, 40-50/viii, 50-60/xii, 61-71/xx. First dorsal pore on 12/13. Length 105-200 mm. Diameter 4-8 mm. Segments 90-133.

Intestinal caeca simple. Testis sacs paired, ventral in x, vertical in xi; seminal vesicles included. Spermathecal duct bulbous, muscular, lumen in ental portion of the duct large and communicating with the narrowed lumen in the ectal portion through a minute pore on the bluntly rounded tip of a rather conical papilla; diverticulum with slender but muscular stalk and a looped, elongately tubular seminal chamber.

*Distribution.*—Bombay, Calcutta and Dibrugarh in Assam. Outside of India; Burma, China (Yunnan), Siam and the Andaman Islands.

### ***Pheretima anomala* Michaelsen.**

1907. *Pheretima anomala*, Michaelsen, *Mitt. Mus. Hamburg*, XXIV, p. 167. (Type locality, Calcutta. Types in the Indian and Hamburg Museums).  
 1909. *Pheretima anomala*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 189.  
 1910. *Pheretima anomala*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), p. 11.  
 1923. *Pheretima anomala*, Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 294.  
 1933. *Pheretima anomala*, Gates, *Rec. Ind. Mus.* XXXV, p. 496.

*Material examined.*—From the Indian Museum.—1 macerated, clitellate specimen labelled, "On the hill sides near Pashok Bungalow. Dr. S. L. Hora.", 33 acitellate and 19 clitellate specimens labelled, "Forest Rest House, Lachhiwala, Dehra Dun District. 29. ix-3. x. 35. Dr. S. L. Hora.", and 1 clitellate specimen labelled, "Dehra Dun. 12. x. 35. Dr. S. L. Hora.". All of the Dehra Dun specimens are softened.

The Dehra Dun specimen and all except two of the Lachhiwala specimens are athecal (= *forma typica* of Stephenson, 1929). Each of the two exceptional specimens, one clitellate and one acitellate, has a single spermathecal pore, on 5/6, on the right side. The spermathecae are normal but there is no spermatozoal iridescence in the seminal chambers.

*Diagnosis.*—Sexthecal, spermathecal pores minute and invaginate, each pore at the centre of a vertically placed, elliptical marking on the anterior wall of an invagination with a transversely slit-like aperture; three pairs, on 5/6-7/8. Male pores minute and invaginate, each pore at the centre of a transversely elliptical tubercle on the roof of a slight parietal invagination in the setal circle of xx. Genital markings internal, each marking on the roof of a slight parietal invagination

with a transversely slit-like aperture; three pairs, in the setal circles of xvii-xix. Setae present ventrally on xvi: vi/17-22, vii/17-23, xix/16-18, xx/15-21, 60-68/iii, 90-96/viii, 87-95/xii, 81-90/xiii, 6-26/xvi, 61-70/xx. First dorsal pore on 12/13. Length 80-180 mm. Diameter 4-5½ mm. Segments 119-30.

Intestinal caeca simple. Testis sacs unpaired and ventral. Spermathecal diverticulum with short stalk, looped middle portion in which the lumen is gradually widened and a slenderly club-shaped seminal chamber. Genital marking glands mushroom-shaped, the duct muscular, shortly spindle-shaped and coelomic.

Very few or none of the specimens in a series of *P. anomala* from any particular locality are actually characterized as above. Most of the specimens are quite markedly different. The variations diverge in two different directions with a large proportion of the variant forms attaining the extreme of divergence in one direction or the other. One extreme (= *forma typica* of Stephenson, 1929) is distinguished from the forms defined above as follows: genital markings on xxi-xxiv, testes and male funnels in (iv) v-ix (xii), no seminal vesicles, no normal testis sacs, no spermathecae, genital marking glands in xxi-xxiv. Intermediates between this extreme and the form defined above have one or more seminal vesicles, more or less normal testis sacs, one or more spermathecae and lack one or more of the genital markings and their glands posterior to xx as well as some of the supernumerary testes and male funnels. The variation in this direction tends towards a reduction or elimination of certain secondary female organs, the spermathecae, and increase in the number of certain male organs, the gonads, deferent duct funnels and copulatory glands. Without spermathecae a worm cannot receive spermatozoa in a copulatory act and such an individual is regarded by Stephenson as a secondarily evolved, dioecious male. There is, however, no evidence (*vide* Gates 1932 and 1933) to show that spermatozoa are ever produced in completely pseudo-masculinized individuals for the testes are always flat discs in an undischarged, juvenile condition. Furthermore, seminal vesicles, the organs in which the spermatozoa mature, are lacking. Although the pseudo-masculinized individuals do not produce mature spermatozoa, they do have, and apparently always, normal ovaries and a functional oviducal apparatus as well as a clitellum for the secretion of a cocoon. Since spermatozoa are not produced the worms cannot function as males even though the male deferent apparatus is present and normal. Although the clitellum is normally developed and ovaries and the oviducal apparatus appear to be functional the worms apparently do not function as females since they cannot receive spermatozoa from another worm during a copulatory act. In these circumstances the pseudo-masculinized individuals can only be regarded as abnormal. Gates (1933, pp. 508-510) has suggested that the pseudo-masculinization is caused by protozoan parasites present in juvenile individuals prior to initiation of development of the secondary reproductive organs. The definition above is accordingly of normal individuals with a full hermaphroditic complement of reproductive structures.

The other extreme of divergence from normality (= *forma insolita* of Stephenson, 1929) is represented by worms characterized as follows:—

male pores, prostates, prostatic ducts, genital markings and their glands lacking. Intermediate forms between this extreme and the normal worms have one or more prostates and one or more genital markings and mushroom-shaped glands. The deviation from normal in this direction consists of a reduction or elimination of the male copulatory organs. Without male pores a worm cannot transfer spermatozoa in a copulatory act and such an individual is regarded by Stephenson as a secondarily evolved, dioecious female. These pseudo-feminized individuals always have normal seminal vesicles, normal testis sacs with discharged testes and matured spermatozoa and are merely prevented from functioning as males by a failure of the male genital terminalia to develop. A similar condition is occasionally found as an abnormality in other Indian species of *Pheretima* (*P. alexandri* and *P. campanulata*) and there is at present no reason for regarding the absence of the male genital terminalia in *P. anomala* as other than an abnormality in spite of the frequency of its occurrence. Gates (1933, pp. 508-510) has suggested that the pseudo-feminization is caused by protozoan parasites present in juvenile individuals prior to the initiation of development of the secondary reproductive organs, the parasites different from those which cause the pseudo-masculinization. Pseudo-feminized individuals can, theoretically, receive spermatozoa in a copulatory act and deposit cocoons containing fertile eggs.

Only completely or almost completely pseudo-masculinized individuals of *P. anomala* have been found hitherto in India.

*Distribution*.—Pashok (Darjiling district), Eastern Himalayas ; Dehra Dun and Lachhiwala (Dehra Dun district), Western Himalayas ; Calcutta in Bengal. Outside of India : Burma, Siam (Chiengrai), and China (Mong Mong in Yunnan).

### ***Pheretima bicincta* (Perrier).**

1875. *Perichaeta bicincta*, E. Perrier, *C. R. Ac. Sci. Paris*, LXXXI, p. 1044. (Types in the Paris Museum. Type locality unknown but supposed to be on Luzon or Mindonoro, Philippine Islands.)

1909. *Pheretima violacea*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 188.

1910. *Pheretima bicincta*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), pp. 11 and 84.

1916. *Pheretima bicincta*, Stephenson, *Rec. Ind. Mus.* XII, p. 335.

1923. *Pheretima bicincta*, Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 294.

1929. *Pheretima bicincta*, Aiyer, *Rec. Ind. Mus.* XXXI, p. 15.

*Material examined*.—From the Indian Museum : 3 clitellate specimens labelled, "*Pheretima bicincta* = *Pheretima violacea* (Bedd.). Hyderabad, Deccan. Col. D. C. Phillot. ZEV 2829/7."

*External characteristics*.—Pigmentation is no longer reconizable.

The setae begin on ii, on which segment there is a complete circle, and are small, closely and regularly spaced. The setal formulae are shown below :—

| v  | vi | vii | viii | xvii | xviii | xix | iii | viii | xii | xx  |
|----|----|-----|------|------|-------|-----|-----|------|-----|-----|
| 10 | 7* | 10  | 9    | 9    | 7     | 10  | 33  | 43   | 44  |     |
| 7* | 9  | 10  | 11   | 10   | 8     | 11  | 35  | 45   | 46  | ..  |
| 6* | 7  | 9   | 10   | 8    | 6     | 9   | 31  | 42   | 43  | 42† |

\* Gaps in setal line in which setal pits or traces of setal pits are visible,

† Including setal pits as setae,

The clitellum is yellowish or reddish brown, annular, extending from 13/14 to just in front of the setae of xvi, not protuberant (level or constricted); intersegmental furrows and dorsal pores lacking, setae present.

There is a pair of female pores (3).

The male pores are minute and superficial, each pore at the tip of a very tiny, rather conical or almost thread-like protuberance from the centre of a small, indistinctly delimited, shortly elliptical, transversely placed, male pore area that scarcely reaches to a presetal or postsetal secondary furrow.

Genital markings are not visible on these specimens, even after removal of the cuticle, nor with brilliant illumination and under the highest magnification of the binocular. Although the markings are not visible, glands are present internally and after noting these glands the sites of the genital markings were re-examined. On the postsetal portion of xviii, in a region just median to the male pore line, on each side, a number of minute pores are just barely visible, but the areas on which these pores are situated do not appear to be different from the surrounding epidermis.

*Internal anatomy.*—Septum 9/10 is present and muscular (2); 8/9 lacking (2).

The intestine begins in xv (2). The intestinal wall of one specimen is softened and in this worm the caeca were not seen. In the other specimen the caeca are short, anteriorly directed, confined to xxii, two slight incisions of the dorsal margin, 2-3 slight incisions of the ventral margin.

The last pair of hearts is in xii (2). There is a pair of hearts belonging to ix (2). The hearts of x and xi are included within the testis sacs.

The testis sacs are unpaired and horseshoe-shaped, the midventral termini of the sacs separated by a slight space in which is the ventral blood vessel. The dorsal blood vessel, in at least the posterior portions of x and xi, is included within the testis sac. The sac may be constricted in such a way as to form an anteriorly directed mid-dorsal lobe. The ventral ends of the anterior testis sac may be continued anteriorly on the ventral parietes parallel to the nerve cord for a short distance. The anterior vesicles are small and are included within the posterior testis sac. The vesicles of xii are rather small, acinous, vertically placed bodies that reach up into contact with the dorsal blood vessel. The prostates are in xvii-xix. The duct is short, with muscular sheen, bent into a U-shaped loop, the ectal limb much thicker than the ental limb, but narrowed as it passes into the parietes.

The spermathecae are small, the ampulla only slightly wider than the duct, shortly ovoidal, ellipsoidal or heart-shaped, and distinguished from the duct by a translucent appearance. The duct, including the portion within the parietes, is a trifle longer than the ampulla. The diverticulum which passes into the anterior face of the duct at the parietes is shorter than the combined lengths of duct and ampulla and comprises an ellipsoidal seminal chamber that is translucent or transparent and a stalk of about the same length as the chamber.

The genital marking glands are acinous masses, sessile on the parietes, the masses circular or nearly so in outline.

*Diagnosis.*—Decithecate, spermathecal pores minute and superficial, 5 pairs, on 4/5-8/9. Male pores minute and superficial, each on a transversely placed marking which may be included within a genital marking. Genital markings paired, on xviii. Setal circles present on all clitellar segments; v/9-10, vi/7-11, vii/9-11, viii/9-12, xvii/8-11, xviii/4-8, xix/9-11, 31-35/iii, 42-45/viii, 43-46/xii, 42/xx. First dorsal pore on 12/13. Clitellum terminates anterior to the setae of xvi. Length 50-80 mm. Diameter 2-3 mm. Segments 78.

Septum 9/10 present and muscular. Intestinal caeca simple but with margins incised, in xxii. Last hearts in xii. Testis sacs unpaired and horseshoe-shaped; anterior seminal vesicles included. Spermathecal diverticulum shorter than combined lengths of duct and ampulla, passing into the anterior face of the duct at the parietes, comprising an ovoidal to ellipsoidal seminal chamber and a stalk that may be as long as or longer than the chamber. Genital marking glands sessile on the parietes.

*Distribution.*—Trivandrum, Travancore; Hyderabad, Deccan. Outside of India known from the Philippines, Java, Penang, Trinidad, Grenada and St. Thomas. The species has been recorded only twice from the *Pheretima* domain; once from Java—3 specimens from Malan, and once from the Philippines, 371 (?) specimens from some locality on Luzon or Mindonoro. The original home of the species is to be looked for either in the Philippines or in the region between those islands and Java.

### ***Pheretima campanulata* (Rosa).**

1890. *Perichaeta campanulata*, Rosa, *Ann. Mus. Genova*, XXX, p. 115. (Type locality, Palon, Burma. Types in the Genoa Museum.)

1923. *Pheretima houlleti* (part), Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 304. (Excluding synonymy and distribution of forms with only one stalked gland to the spermathecal pore invagination and also forms with no copulatory chambers.)

1931. *Pheretima campanulata* var. *penetratis*, Gates, *Rec. Ind. Mus.* XXXIII, p. 435.

*Material examined.*—From the Indian Museum: 1 clitellate specimen labelled, "On the hillside near Pashok bungalow. S. L. Hora".

*Diagnosis.*—Sexthecal, spermathecal pores minute and invaginate, each pore on a tiny conical protrusion into an invagination with transversely slit-like lumen and aperture; three pairs, on 6/7-8/9. Male pores minute and invaginate, each pore on a penial body with a trilobed tip within a spheroidal copulatory chamber, a genital marking on each of the two lateral lobes of the penial body. Genital markings tiny, circular, greyish, translucent areas, sharply demarcated by slight circumferential furrows, on the margins of segments near 6/7-8/9 or on the intersegmental furrows, median to the secondary spermathecal apertures, and in addition internally; one marking on the anterior wall and one on the posterior wall of each spermathecal invagination, a group of 3-5 markings within each copulatory chamber in addition to markings at the base and at the tip of the penial body. Setal circles present on all clitellar segments, clitellar setae with bifid tips, 1-2 penial

setae within the wall of each copulatory chamber : vii/11-15, viii/14-19, xvii/18-22, xviii/9-17, xix/17-21, 20-25/iii, 33-43/viii, 44-52/xii, 50-61/xx. First dorsal pore on 11/12. Length 107-200 mm. Diameter 4-7 mm. Segments 107-136.

Intestinal caeca simple. Testis sacs unpaired and ventral. Lumen in ental part of the spermathecal duct large and communicating with the narrowed lumen of the ectal portion of the duct through a tiny, slit-like pore on the bluntly rounded, dorsal face of a conical papilla ; diverticulum comprising a short, slender stalk and an elongate seminal chamber, the latter slightly widened entally and looped, often in an approximation to zigzag. One or more stalked glands on the posterior face of each copulatory chamber, three or more on the anterior face ; one stalked gland to the anterior face and one to the posterior face of each spermathecal invagination. Genital marking glands stalked and coelomic.

*Distribution*.—Kalimpong and Pashok, Darjiling district, Eastern Himalayas. Outside of India ; Burma, China (Yunnan), Siam, Malay Peninsula (Kuala Lumpur), Andaman Islands.

### ***Pheretima diffringens* (Baird).**

1869. *Megascolex diffringens*, Baird, *Proc. Zool. Soc. London*, 1869, p. 40. (Type locality, Plas Machynlleth, Montgomeryshire, North Wales. Types in the British Museum.)
1887. *Perichaeta mirabilis*, Bourne, *Proc. Zool. Soc. London*, 1886, p. 668, (Type locality, Naduvattam, Nilgiris, S. I. No types.)
1900. *Pheretima mirabilis*, Michaelsen, *Das Tierreich*, X, p. 284.
1900. *Amyntas heterochaetus* (part), Beddard, *Proc. Zool. Soc. London*, 1900, p. 622.
1909. *Pheretima heterochaeta*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 189.
1910. *Pheretima heterochaeta*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX, (5), pp. 11 and 83.
1914. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* VIII, p. 399 and X, p. 343.
1915. *Pheretima heterochaeta*, Stephenson, *Mem. Ind. Mus.* VI, p. 99.
1916. *Pheretima heterochaeta*, Prashad, *J. Bombay Nat. Hist. Soc.* XXIV, p. 503.
1916. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* XII, p. 334.
1917. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* XIII, p. 385.
1917. *Pheretima heterochaeta*, Stephenson, *Quart. J. Mic. Sci.* LXII, p. 265. (Pharyngeal gland cells.)
1918. *Pheretima heterochaeta*, Thapar, *Rec. Ind. Mus.* XV, pp. 71 and 73. (Lymph glands.)
1919. *Pheretima heterochaeta*, Bahl, *Quart. J. Mic. Sci.* LXIV, p. 104 (Nephridia), and p. 111 (Septa).
1920. *Pheretima heterochaeta*, Stephenson, *Mem. Ind. Mus.* VII, p. 222.
1921. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* XXII, p. 760.
1922. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* XXIV, p. 433.
1923. *Pheretima heterochaeta* (part, excluding synonymy and distribution of forms with copulatory chambers), Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 302.
1924. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* XXVI, p. 339.
1924. *Pheretima heterochaeta*, Stephenson, *Proc. Roy. Soc. London*, B. XCVII, pp. 179, 188, 198, and 201. (Blood glands.)
1925. *Pheretima heterochaeta*, Stephenson, *Rec. Ind. Mus.* XXVII, p. 59.
1925. *Pheretima heterochaeta*, Stephenson, *Proc. Zool. Soc. London*, 1925, p. 893.
1931. *Pheretima heterochaeta*, Gates, *Rec. Ind. Mus.* XXXIII, pp. 387 and 437.
1934. *Pheretima mirabilis*, Gates, *Rec. Ind. Mus.* XXXVI, p. 260,

*Material examined.*—From the Indian Museum.—92 clitellate specimens labelled, "Dumpep, Khasi Hills, Assam. Dr. S. L. Hora", 49 clitellate specimens labelled, "Teesta Bridge<sup>1</sup> Teesta Valley. Dr. S. L. Hora", 1 acitellate and 7 clitellate specimens labelled, "Kalimpong, E. Himalayas. Dr. S. L. Hora", 1 clitellate, macerated specimen labelled, "Dharamshala Cantonment, Kangra Dt., Punjab. Dr. S. L. Hora", 9 clitellate specimens labelled, "Dhobijhora, Kurseong, Darjeeling. Md. Sharif", 2 clitellate specimens labelled, "Kotla, Kangra Dt., Punjab. Dr. S. L. Hora", 13 acitellate, macerated specimens labelled, "Kangra, Punjab. Dr. S. L. Hora", 4 clitellate specimens labelled, "Palampur, Kangra Dt., Punjab. Dr. S. L. Hora", 1 clitellate specimen labelled, "Kodaikanal, Palni Hills, S. India. Dr. S. L. Hora", 41 clitellate specimens labelled, "Benhope, Nilgiris. Dr. S. L. Hora", 5 clitellate specimens labelled, "Fern Hill, Nilgiris. Dr. S. L. Hora". From the Madras Museum.—27 clitellate specimens labelled, "From a pit containing decomposing cow dung and vegetable matter, Coonoor, Nilgiris. Major K. R. K. Iyenger, I. M. S.", 1 acitellate and 21 clitellate specimens labelled, "From garden soil, Coonoor, Nilgiris. Major K. R. K. Iyenger, I. M. S.". From the Fisheries Reserve Officer.—3 clitellate specimens labelled, "Fern Hill. 6-8. x 35.". From Prof. K. N. Sharma.—13 acitellate and 55 clitellate specimens labelled, "Near Katmandu, Nepal."

*External characteristics.*—The setal numbers of five Nepal specimens are shown below:—

| iii | vi | viii | xii | xx |
|-----|----|------|-----|----|
| 26  | 33 | 40   | 43  | 51 |
| 25  | 32 | 37   | 45  | 49 |
| 24  | 32 | 35   | 41  | 43 |
| 27  | 28 | 36   | 42  | 49 |
| 28  | 32 | 35   | 41  | 50 |

The clitellum, on nearly all of the mature Nepal specimens, extends slightly anterior to 13/14 and slightly posterior to 16/17, intersegmental furrows 13/14 and 16/17 not visible but the sites of the occluded dorsal pores of those two furrows visible.

The first dorsal pore is on 11/12 (all Nepal specimens) except that two worms have a definitely pore-like marking on 10/11.

On the Nepal worms there are no postsetal or postclitellar genital markings. The presetal genital markings are paired, on some or all of vii-ix. Each marking is approximately in *cd*.

Of the Madras specimens, 19 have paired presetal genital markings on vii-ix, while 14 have similar markings on vii-viii only. Other worms lack some or all of these markings. The markings are usually slightly nearer to the setae than to the intersegmental furrow and are either in *c*, *cd*, or *d*. A number of the Madras specimens have paired, postsetal genital markings on vi-viii, immediately in front of the spermathecal pores.

Nearly all of the Dumpep specimens have three pairs of postsetal genital markings, one marking immediately in front of each spermathecal pore on 6/7-8/9. One specimen has in addition postsetal markings on v. Nearly all of these worms have two pairs of presetal markings on vii-viii while one specimen also has presetal markings on ix.

<sup>1</sup> Teesta Bridge, according to Dr. S. L. Hora, is about 33 miles from Siliguri Ry. station and at an elevation of 500-700 feet,

*Internal anatomy.*—There is a pair of hearts belonging to ix in 5 specimens, a single heart belonging to ix, on the right side in 16 specimens, on the left side in 19 specimens. There are no hearts belonging to x in 26 specimens; a single heart belonging to x, on the left side in 6 specimens, on the right side in 7 specimens. One worm has a pair of hearts belonging to x (Nepal specimens).

The seminal chamber of the spermathecal diverticulum is about twice as long as thick, the chamber about three times as thick as the stalk and one-half to one-third as long as the stalk.

*Abnormality.*—Two of the Teesta Valley specimens are abnormal. One worm varies from normal as follows:—The right male pore is on xx, on the left side an additional male pore on xvii. The clitellum extends on the right side to 17/18. The other worm varies from normal as follows.—Spermathecal pores on 7/8-12/13. Female pores on xvii, xviii and xix. Male pores on the left side on xxiii and xxiv, on the right side on xxiv. The clitellum extends from a posterior portion of xvii on to xxii. Presetal genital markings on the left side of viii and the right side of ix; postsetal markings on the right side of viii and the right and left sides of ix. (There are no spiral, metameric abnormalities.) The gizzard is in xi-xiii, septa 10/11-12/13 lacking. The intestine begins in xvi, the right intestinal caecum extending through xl-xxxviii, the left through xxxix-xxxvii. Testis sacs in xiii and xiv. Seminal vesicles in xiv and xv. No prostates. Paired ovaries and oviducal funnels in xvi, xvii and xviii. The single heart of xii on the right side, of xiii on the left side, the last hearts in xvi.

*Diagnosis.*—Octothecal, spermathecal pores minute and superficial, four pairs, on 5/6-8/9. Male pores minute and superficial, each pore at the centre of a transversely placed, disc-shaped porophore. Genital markings small, circular to shortly elliptical tubercles, paired; presetal on vi-ix, in *cd* or (and) about in *bc*, postsetal on v-viii and just in front of the spermathecal pores. Setae: vi/6-11, vii/8-14, viii/10-16, xvii/13-18, xviii/9-16, xix/12-17, 21-28/iii, 26-36/vi, 35-42/viii, 39-45/xii, 42-52/xx. First dorsal pore on 11/12. Length 45-170 mm. Diameter 3-6 mm. Segments 90-113.

Intestinal caeca simple. Hearts of x lacking. Testis sacs unpaired and ventral. Spermathecal diverticulum with long stalk and shorter, thicker, ovoidal, simple seminal chamber. Genital marking glands stalked and coelomic.

*Distribution.*—Peshawar, Mardan, Northwestern Frontier; Lahore, Dharamsala Cantonment, Kotla, Kangra, Palampur, Punjab; Simla, Naini Tal, Western Himalayas; Nepal, Darjiling, Kurseong, Kalimpong, Teesta Bridge, Singla, Ghum, Sureil, Pashok, Darjiling district, Gangtok (Sikkim), Kobo (Abor country), Eastern Himalayas; Cherrapunji, Sadiya, Myntaung Valley, Shillong, Imphal (Manipur), Dimpur, Assam; Siliguri, Rangamati (Chittagong Hill Tracts), Bengal; Kodaikanal, Tiger Shola (Palni Hills), Naduvattam, Benhope, Kotagiri, Fern Hill, Coonoor (Nilgiri Hills), Bababudan Hills (Mysore), South India.

Outside of India: Ceylon, Burma (Shan Plateau and Bhamo district only), China (Provinces of Yunnan, Szechuan, Chekiang, Kiangsi, Kiangsu, Anhwei, Fukien, as well as Hongkong), Java, Sumatra, New

Caledonia, Australia, Hawaiian Islands, Transvaal, Natal, Madagascar, Anjouan, Cape Verde, St. Helena, Sardinia, Azores, Poland,\* Scotland,\* Wales,\* Italy, Portugal, France, United States, Mexico, Costa Rica, San Domingo, Colombia, Peru.

***Pheretima elongata* (Perrier).**

1872. *Perichaeta elongata*, E. Perrier, *N. Arch. Mus. Paris*, VIII, p. 124. (Type locality, Peru ! Type in the Paris Museum.)  
 1909. *Pheretima biserialis*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 187.  
 1910. *Pheretima elongata*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), pp. 11 and 84.  
 1920. *Pheretima elongata*, Stephenson, *Mem. Ind. Mus.* VII, p. 222.  
 1922. *Pheretima elongata*, Michaelsen, *Mitt. Mus. Hamburg*, XXXVIII, p. 68.  
 1922. *Pheretima elongata*, Stephenson, *Rec. Ind. Mus.* XXIV, p. 433.  
 1923. *Pheretima elongata*, Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 298.  
 1924. *Pheretima elongata*, Stephenson, *Rec. Ind. Mus.* XXVI, p. 433.  
 1926. *Pheretima elongata*, Stephenson, *Rec. Ind. Mus.* XXVIII, p. 256.

**Diagnosis.**—Multithec, spermathecal pores minute and superficial, in paired groups of 2-4, on or near to 5/6-6/7. Male pores minute and invaginate, each pore on a disc-shaped porophore on the median wall of a parietal invagination with a crescentic aperture. Genital markings transversely elliptical, presetal, widely paired, on xix-xxiv. Setae: xvii/12-17, xviii/10-15, xix/12-15, 50-66/iii, 67-104/viii, 54-80/xii, 55-75/xx. First dorsal pore on 12/13. Length 85-300 mm. Diameter  $3\frac{1}{2}$ -6 mm. Segments 169-241.

Testis sacs unpaired and annular; seminal vesicles as well as hearts of x and xi included. Spermathecal diverticulum with stalk longer than the ovoidal to ellipsoidal seminal chamber. Genital marking glands sessile on the parietes.

**Remarks.**—*P. elongata* is usually athecal. Absence of spermathecae, as in *P. anomala*, is regarded as an abnormality. Thecal specimens do not have a symmetrically paired arrangement of the spermathecae, the latter either asymmetrical or in groups. A grouped arrangement of the spermathecae characterizes a subgenus of *Pheretima* recently erected by Michaelsen (1934, p. 15). The subgenus *Polypheretima* is further distinguished only by the absence of intestinal caeca. *P. elongata* which is acaecal and when thecal often with a multithec arrangement of the spermathecae, may possibly have originated in Michaelsen's *Polypheretima* region, an area including the southern portion of the Malay Peninsula, Borneo, Celebes and New Guinea. Actually *P. elongata* is close to *P. stelleri* (Michaelsen), 1891. This species cannot at present be adequately characterized and is possibly a conglomerate of two or more species.

**Distribution.**—Poona, Bombay, Manmad and Karachi in Bombay Presidency; Palia, Indore and Ujjain in Central India; Namkhana (Sunderbans) and Calcutta in Bengal; Hyderabad, Deccan; Mockoli, Bhaganamola, Manakoti (Curg), Shimoga (Mysore), Singanallur (Coimbatour district) in South India. Outside of India: Ceylon, Burma, Andaman Islands, Siam, Sumatra, Java, Celebes, Philippines, New Caledonia, Sumba, Salibaboe, Kei, Flores and Hawaiian Islands, Madagascar, Porto Rico, Hayti, Cuba, Panama, Peru, Venezuela, British and Dutch Guiana.

---

\* Only in greenhouses.

***Pheretima hawayana* (Rosa).**

1891. *Perichaeta hawayana*, Rosa, *Ann. Hofmus. Wien*, VI, p. 396. (Type locality, Hawaii. Type in the Vienna Museum.)
1909. *Pheretima hawayana f. typica*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 187.
1910. *Pheretima hawayana f. typica*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), pp. 11 and 83.
1914. *Pheretima hawayana* (part), Stephenson, *Rec. Ind. Mus.* X, p. 343. (Excluding quadrithecal forms.) Although none of these specimens have been preserved in the Indian Museum, individuals with enlarged setae on iv-viii or v-vii must be referred to *hawayana*.
1916. *Pheretima hawayana typica* (part) + *P. h. barbadensis* (part), Prashad, *J. Bombay Nat. Hist. Soc.* XXIV, pp. 499 and 501. (Excluding quadrithecal forms.)
1916. *Pheretima hawayana f. typica*, Stephenson, *Rec. Ind. Mus.* XII, p. 334.
1923. *Pheretima hawayana* (part), Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 300. (Excluding synonymy and distribution of quadrithecal forms.)
1925. *Pheretima hawayana*, Stephenson, *Rec. Ind. Mus.* XXVII, p. 59.
1934. *Pheretima hawayana*, Gates, *Rec. Ind. Mus.* XXXVI, p. 259.

*Material examined*.—From the Indian Museum: 5 clitellate specimens labelled, "*Pheretima hawayana* (Rosa). Under stones in thicket of trees, Kurseong, E. Himalayas. Sta. 13. 5,000 feet. 9. iii. 24. Dr. B. N. Chopra. W 1221/1.", 1 clitellate anterior fragment and 1 aclitellate specimen labelled, "*Pheretima hawayana forma typica*. Kurseong, E. Himalayas. 4,500 feet. 26. iii. 10. Dr. F. H. Gravely. ZEV 6540/7.", 1 clitellate specimen labelled, "*Pheretima hawayana forma typica*. Kurseong, E. Himalayas. E. Bergtheil, Esq. ZEV 2826/7.", 3 clitellate specimens labelled, "*Pheretima hawayana forma typica*. Kurseong, E. Himalayas. 5,000 feet, 13-16. vii. 07. Mus. Coll. (R. Hodgart). ZEV 4154/7.", 1 clitellate specimen labelled, "*Pheretima hawayana forma typica*. Ramnee, Garwhal Dist. U. P. 20-10-07. Mus. Coll. (R. Hodgart). ZEV 4188/7.", 3 clitellate specimens labelled, "*Pheretima hawayana forma typica*. Tengyueh, Yunnan. J. Coggin Brown. ZEV 4892/7.", and 1 clitellate specimen labelled, "*Pheretima hawayana forma typica*. Pattipola (Hill Country) Ceylon. Dr. N. Annandale. ZEV 5085/7.". The Yunnan tube contains, in addition to the *P. hawayana*, 1 macerated and 1 well preserved specimen of *P. californica* Kinberg 1867.

One of Dr. Chopra's specimens from Kurseong has twelve postsetal genital markings on xviii, in two groups of six each. One of Hodgart's specimens from Kurseong has eight postsetal genital markings on xviii.

*Diagnosis*.—Sexthecal, spermathecal pores minute and superficial, three pairs, on 5/6-7/8. Male pores minute and superficial, each pore at the centre of a small, transversely elliptical, disc-shaped porophore. Genital markings small, paired tubercles; postsetal on vii-viii and slightly median to the spermathecal pore lines; on xviii, in or just behind the setal circle and just median to the male pore lines. Setae present ventrally on xvi: vi/4-8, vii/10-15, xvii/15-20, xviii/10-15, xix/16-20, 17-21/iii, 36-40/viii, 44-49/xii, 48-56/xx. First dorsal pore on 10/11. Length 60-112. Diameter 3-4 mm. Segments 71-91.

Intestinal caeca simple, with a few short lobes on the ventral margin. Testis sacs unpaired and ventral. Spermathecal diverticulum with stalk longer than the seminal chamber and with irregular lumen, seminal chamber slenderly club-shaped. Genital marking glands stalked and coelomic.

*Distribution*.—Kurseong in the Eastern Himalayas, Shillong in Assam, Ramnee in the United Provinces, Lahore in the Punjab. Stephenson (1923, p. 302) includes Rangamati in the distribution of the species but no record of this can be found. Outside of India: Ceylon

(Pattipola), Burma (Namkham, Kawngmu, Kutkai, Lashio and Mogok, all on the Shan Plateau), China (Provinces of Chekiang, Szechuan, Yunnan, Fukien, also Hongkong), Borneo, Samoa, Hawaiian and Fiji Islands, Bermuda, Barbados, United States (southern), Brazil, Uruguay and Chile.

### ***Pheretima houlleti* (Perrier).**

1872. *Perichaeta houlleti*, E. Perrier, *N. Arch. Mus. Paris*, VIII, p. 99. (Type locality, Calcutta. Types in the Paris Museum.)
1889. *Megascolex Houlleti*, Vaillant, *Hist. Nat. Annel.* III, (1), p. 75.
1895. *Perichaeta houlleti* (part), Beddard, *Monog.*, p. 424. (Excluding *P. campanulata*.)
1898. *Perichaeta crescentica*, Fedarb, *Proc. Zool. Soc. London*, 1898, p. 447. (Type locality, Dehra Dun. Types probably in the British Museum. *Vide* note below.)
1898. *Perichaeta travancorensis*, Fedarb, *J. Bombay Nat. Hist. Soc.* XI, p. 435. (Type locality, Travancore. Types in the British Museum. The types were obtained by the Museum on the purchase of Beddard's collection. It is probable that specimens labelled *crescentica* and obtained in the same way and from the type locality of this species are actually the types.)
1900. *Pheretima crescentica* + *P. houlleti* (part, excluding at least *campanulata*, *guillelmi* and possibly also *udekemi*) + *P. travancorensis*, Michaelsen, *Das Tierreich*, X, pp. 262, 273 and 310.
1900. *Amyntas houlleti* (part, excluding at least *campanulata* and *guillelmi*) + *A. travancorensis*, Beddard, *Proc. Zool. Soc. London*, 1900, pp. 613 and 614.
1903. *Pheretima Houlleti* (part, excluding distribution of *campanulata* and Bahama forms) + *P. travancorensis*, Michaelsen, *Geogr. Verbr.* pp. 97 and 100.
1909. *Pheretima houlleti* (part, excluding the distribution of *campanulata*) + *P. travancorensis* + *P. houlleti*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 187.
1910. *Pheretima houlleti* (part, excluding the distribution of *campanulata*, *guillelmi* and *meridiana*) + *P. travancorensis* + *P. houlleti*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), pp. 11, 13 and 83.
1911. *Pheretima travancorensis*, Cognetti, *Ann. Mag. Nat. Hist.* (8), VII, p. 494.
1916. *Pheretima houlleti*, Stephenson, *Rec. Ind. Mus.* XII, p. 334.
1916. *Pheretima trivandran*a, Stephenson, *Rec. Ind. Mus.* XII, p. 335. (Type locality, Trivandrum, Travancore. Type in the Indian Museum).
1917. *Pheretima houlleti*, Stephenson, *Rec. Ind. Mus.* XIII, p. 385.
1922. *Pheretima houlleti*, Michaelsen, *Mitt. Mus. Hamburg*, XXXVIII, p. 68.
1922. *Pheretima houlleti*, Stephenson, *Rec. Ind. Mus.* XXIV, p. 434.
1923. *Pheretima houlleti* (part, excluding *campanulata* and the distribution of *guillelmi* and *meridiana*) + *P. travancorensis* + *P. trivandran*a, Stephenson, *Oligochaeta*, in *F. B. I. Series*, pp. 304, 313 and 314.
1924. *Pheretima houlleti*, Stephenson, *Rec. Ind. Mus.* XXVI, p. 340.
1929. *Pheretima travancorensis* + *P. trivandran*a, Aiyer, *Rec. Ind. Mus.* XXXI, p. 15.
1934. *Pheretima houlleti*, Gates, *Rec. Ind. Mus.* XXXVI, p. 259.

*Material examined*.—From the Indian Museum : 12 clitellate specimens labelled, "*Pheretima houlleti* (E. Perr.) Bhim Tal, Kumaon ; 4,500 ft. alt., N. A., 19-28. ix. 06. ZEV 2825/7.", 4 clitellate specimens of which two are dissected, labelled, "*Pheretima houlleti* (E. Perr.). Raniganj, Burdwan dist., Bengal. L. L. Fermor. ZEV 2824/7.", 1 dissected, clitellate specimen labelled, "*Pheretima houlleti* (E. Perr.). Mangalore, Malabar. G. Matthai. ZEV 4143/7.", 2 dissected, clitellate specimens labelled, "*Pheretima houlleti* (E. Perr.). Trichur (Cochin State) Malabar, Madras Pres. July 1909. G. Matthai. ZEV 3504/7.", 1 a clitellate, dissected specimen labelled, "*Pheretima houlleti* (E. Perrier). Trivandrum, Travancore. Trivandrum Museum. "Type". ZEV 7233/7.", 1 clitellate, dissected specimen labelled, "*Pheretima houlleti*. Rawal Pindi, Punjab. Dec. 1915. Ragunath Sahai. Lt. Col. J. Stephenson, I.M.S. W 41/1.", 1 dissected, clitellate specimen labelled, "*Pheretima houlleti* (E. Perr.) Bombay. J. P. Mullan. W 1165/1.", 1 clitellate, macerated, dissected

specimen labelled, "*Pheretima houlleti* (E. Perr.). Compound of the Forest Research Institute, Dehra Dun. 20. viii. 21. W 686/1.", 2 clitellate, dissected specimens labelled, "*Pheretima houlleti* (E. Perr.). Khasi Hills, Sta. 5, Under stones and in muddy pools around Dak bungalow at Cherrapunji, Assam. 28. x. 1921. S. L. Hora. W 685/1.", 1 clitellate, dissected specimen labelled, "*Pheretima houlleti* (E. Perr.). Matheran. x. 21. J. P. Mullan. W 1164/1.", and 2 clitellate, dissected specimens labelled, "*Pheretima houlleti* (E. Perr.). Gorge below Chota tank, Buldana, Berar. 2190 ft. Sta. 7, 17, ii. 23. H. S. Rao. W 1128/1.". From the British Museum: 1 a clitellate and 3 clitellate dissected specimens labelled, "*Pheretima travancorensis* (type) 1904. 10. 5. 167/8. coll. Beddard."

*Remarks.*—The types of *P. travancorensis* are quite obviously referable to *houlleti*.

With the exceptions noted below, all of the Indian Museum material can be referred, without question, to *houlleti*. One lot of specimens from Bombay (Stephenson) and others from Malabar (Chevagan bei Calicut), Trivandrum, Coorg and Mysore (Michaelsen) have not been available for examination. There is, however, no evidence to indicate that any of these specimens might be anything but *houlleti*.

The Mangalore specimen is peculiar in that some of the spermathecal pore invaginations have the posterior stalked gland characteristic of *campanulata* and *meridiana*. The left spermathecal invagination of vii has two anterior stalked glands. The penial body is slenderly conical, genital markings apparently lacking thereon or nearby, the shape much more like that of *houlleti* than that of either *campanulata* or *meridiana*. The first dorsal pore is definitely on 8/9. The size is well within the *houlleti* limits. In spite of the presence of the posterior stalked glands the other characteristics just mentioned necessitate identification as *houlleti*. The presence of posterior stalked glands on the spermathecal invagination is accordingly regarded as an abnormality, associated with an abnormal doubling of the anterior glands. The doubling of the anterior glands has been observed previously but the presence of posterior glands on the spermathecal pore invagination has not hitherto been noted in *P. houlleti*.

One specimen labelled, "*Pheretima houlleti* (E. Perr.) Bansda, Surat. October 1922. J. P. Mullan. W 1166/1.", is macerated and lacks at least a portion of the anterior end. Identification in the present condition is not feasible, but paired, rather thread-like segmental structures are almost certainly meganephridia. It is highly improbable that Stephenson mistook a meganephric worm for *P. houlleti*, which is purely micronephric. Presumably labels or specimens have been accidentally changed. Hence the Surat record has not been questioned.

*Diagnosis.*—Sexthecal, spermathecal pores minute and invaginate, each pore on the roof or lateral wall near the roof of an invagination with transversely slit-like lumen and aperture; three pairs, on 6/7-8/9. Male pores minute and invaginate, each pore on a slenderly conical to shortly columnar penis on the roof of a spheroidal copulatory chamber. Genital markings tiny, circular, greyish translucent areas sharply demarcated by slight circumferential furrows, internal only; one marking on the anterior wall of each spermathecal pore invagination, one marking on the median wall of each copulatory chamber, one to three markings on or near the base of each penis. Seta *a* and some of the ventral setae of the preclitellar segments enlarged, modified and ornamented;

setae present on all clitellar segments and with bifid or trifid tips : vii/11-17, viii/16-25, xvii/12-16, xviii/5-12, xix/12-15, 24-31/iii, 37-51/viii, 46-54/xii, 51-61/xx. First dorsal pore on 7/8-10/11. Length 55-110 mm. Diameter 3-4½ mm. Segments 90-116.

Intestinal caeca simple. Testis sacs unpaired and ventral. Lumen in ental part of the spermathecal duct wide and communicating with the narrowed lumen of the ectal portion of the duct through a tiny, slit-like aperture at the centre of a low, disc-shaped papilla of circular outline; diverticulum with short, straight stalk and wider, elongate seminal chamber, the latter looped in part or in whole, often in an approximation to zigzag. One or more stalked glands to the anterior face of each copulatory chamber, one stalked gland on the posterior face; one stalked gland to the anterior face of each spermathecal invagination.

*Distribution.*—Rawalpindi, Punjab; Dehra Dun, Bhim Tal, Allahabad, United Provinces; Calcutta, Raniganj (Burdwan district), Bengal; Cherrapunji, Assam; Bombay, Matheran, Bansda (Surat), Bombay Presidency; Buldana (Berar), Central Provinces; Mangalore, Trivandrum (Travancore), Trichur (Cochin), Chevagun (near Calicut), Merkara (Coorg), Shimoga, Bangalore (Mysore), Salem, South India. Outside of India: Ceylon (Panadhure), Burma (widely spread), Andaman Islands, Siam, Malay Peninsula. *P. houlleti* has been recorded from other places but in view of the confusion of at least three species with *houlleti* the records require confirmation. There is no valid record of the occurrence of the species in China, outside of the province of Yunnan.

### ***Pheretima morrisi* (Beddard).**

- 1892. *Perichaeta morrisi*, Beddard, *Proc. Zool. Soc. London*, 1892, p. 166. (Type locality, Penang. Types in the British Museum.) According to Beddard the types are from Penang, but the label in the tube of types states that the worms are from Hongkong.)
- 1898. *Perichaeta cupulifera*, Fedarb, *Proc. Zool. Soc. London*, 1898, p. 445. (Type locality, Dehra Dun. Types, if still in existence, in the British Museum.)
- 1900. *Pheretima barbadensis* (part, excluding sexthecal forms) + *P. morrisi*, Michaelsen, *Das Tierreich*, X, pp. 254 and 287.
- 1900. *Amyntas hawayanus* (part), Beddard, *Proc. Zool. Soc. London*, 1900, p. 645. (Excluding sexthecal forms.)
- 1903. *Pheretima hawayana* (part), Michaelsen, *Geogr. Verbr.*, p. 96. (Excluding sexthecal forms.)
- 1909. *Pheretima hawayana barbadensis*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 187.
- 1910. *Pheretima hawayana barbadensis*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), p. 11.
- 1914. *Pheretima hawayana* (part), Stephenson, *Rec. Ind. Mus.* X, p. 343. (Excluding sexthecal forms with enlarged setae on iv-viii or v-vii.)
- 1916. *Pheretima hawayana typica* (part) + *P. h. barbadensis* (part), Prashad, *J. Bombay Nat. Hist. Soc.* XXIV, pp. 499 and 501. (Excluding sexthecal forms.)
- 1917. *Pheretima hawayana*, Stephenson, *Rec. Ind. Mus.* XIII, p. 386.
- 1920. *Pheretima hawayana*, Stephenson, *Mem. Ind. Mus.* VII, p. 222. (All of Stephenson's specimens of *hawayana* from Bombay that have been preserved in the Indian Museum are referable to *morrisi*.)
- 1921. *Pheretima hawayana*, Stephenson, *Rec. Ind. Mus.* XXII, p. 760.
- 1922. *Pheretima hawayana*, Stephenson, *Rec. Ind. Mus.* XXIV, p. 433.
- 1923. *Pheretima hawayana* (part), Stepehnson, *Oligochaeta*, in *F. B. I. Series*, p. 300. (Excluding sexthecal forms.)
- 1924. *Pheretima hawayana*, Stephenson, *Rec. Ind. Mus.* XXVI, p. 339. (*Vide* note under Stephenson, 1920.)

1926. *Pheretima hawayana*, Stephenson, *Rec. Ind. Mus.* XXVIII, p. 256. (Vide note under Stephenson, 1920.)

*Material examined*.—From the Indian Museum: 10 clitellate or partially clitellate specimens labelled, "*Pheretima hawayana* (Rosa). Lahore, Punjab. Lt.-Col. J. Stephenson. W 49/1.", 1 a clitellate specimen labelled, "*Pheretima hawayana* (Rosa). Nepal Valley, E. Himalayas. 4,500-6,500 feet. Lt.-Col. J. Manners-Smith. W 74/1.", 7 clitellate specimens labelled, "*Pheretima hawayana* (Rosa). Brindaban, Muttra Dist. U. P. 15. vii. 17. Dr. B. Prashad. W 233/1.", 5 clitellate specimens labelled, "*Pheretima hawayana* (Rosa). Udaipur, Rajputana. March 1918. Lt.-Col. J. Stephenson. W 234/1.", 4 clitellate macerated specimens labelled, "*Pheretima hawayana* (Rosa). Compound of Forest Res. Inst. Dehra Dun. 20. viii. 21. W 682/1.", 4 clitellate specimens labelled, "*Pheretima hawayana* (Rosa). Imphal Residency Garden, Manipur. 2. iii. 20. Manipur Survey. W 566/1.", 1 a clitellate and 1 clitellate specimens labelled, "*Pheretima hawayana* (Rosa). Bombay. Prof. J. P. Mullan. W 1163/1.", 13 clitellate, macerated specimens labelled, "*Pheretima hawayana* subsp. *barbadensis*. Lahore, Punjab. Major J. Stephenson. ZEV 2827/7.", and 1 a clitellate and 6 clitellate specimens labelled, "Kalimpong, E. Himalayas. June 1934. S. L. Hora."

One of Stephenson's specimens from Lahore has a transverse, pre-setal row of 8 markings on xviii, a transverse row of 7 pre-setal markings on xix, in addition to the usual pair of markings just median to each male porophore. Other specimens from Lahore have several pre-setal genital markings on each of segments xviii and xix in addition to the markings close to the male porophores. Four of the Kalimpong specimens have a pre-setal row of markings on xvii, of 5 markings (3 specimens) or of 6 markings (1 specimen). One of these specimens has in addition 5 pre-setal markings on xix. One of Mullan's specimens from Bombay has an extra male pore on xvii on the left side and just median thereto a pair of markings, one pre-setal and one post-setal. Associated with the extra male porophore is a well-developed prostate and prostatic duct. On one of the Manipur Survey specimens the median pre-setal marking on vii is replaced by a pair of markings in contact at the midventral line.

*Diagnosis*.—Quadrithecal, spermathecal pores minute and superficial, two pairs, on 5/6-6/7. Male pores minute and superficial, each pore on a tiny, transversely elliptical, disc-shaped porophore. Genital markings small, transversely elliptical to circular tubercles; two just median to each male porophore with one pre-setal and one post-setal; pre-setal and median on v-viii; pre-setal and just median to the spermathecal pore lines on vii-viii; pre-setal and median to the male pore lines on xviii-xix, post-setal and median to the male pore lines on xvii-xviii. Setae present ventrally on xvi: vi/16-28, xvii/16-23, xviii/10-17, xix/16-23, 23-29/iii, 46-51/viii, 48-56/xii, 4-22/xvi, 46-59/xx. First dorsal pore on 10/11. Length 40-150 mm. Diameter  $2\frac{1}{2}$ -6 mm. Segments 87-95.

Intestinal caeca simple, with a few short lobes on the ventral margins. Testis sacs paired and ventral. Spermathecal diverticulum with short stalk-lumen narrow and irregular, a middle portion with high and thick transverse ridges, seminal chamber slenderly club-shaped. Genital marking glands stalked and coelomic.

*Distribution*.—Lahore, Punjab; Dehra Dun, Bindraban near Muttra, United Provinces; Nepal Valley, and Kalimpong, Eastern Himalayas; Imphal, Manipur; Udaipur, Rajputana; Bombay. Outside of India: Burma (widely distributed on the Shan Plateau and also known from

Myitkyina and Bhamo district and from Mt. Popa in Myingyan district), China (provinces of Yunnan, Szechuan, Fukien and Chekiang, also Hongkong), Siam (Chiengmai), Penang, Sumatra, Hawaiian Islands, Cape Verde, St. Helena, Barbados, United States (southern), Brazil and Chile.

### ***Pheretima planata* Gates.**

1926. *Pheretima planata*, Gates, *Ann. Mag. Nat. Hist.* (9), XVII, p. 411. (Type locality, Rangoon.)

1926. *Pheretima planata*, Stephenson, *Rec. Ind. Mus.* XXVIII, p. 256.

**Diagnosis.**—Quadrithecal, spermathecal pores minute and superficial, two pairs, on the anterior margins of vii and viii close to 6/7 and 7/8. Male pores minute and invaginate, each pore on the roof of a copulatory chamber with a transversely slit-like aperture. Genital markings tiny, circular, translucent areas; external markings on the posterior margins of vii and viii and the anterior margin of viii, 1-4 markings just median to each spermathecal pore; internal markings 8-12, on the roof and walls of the copulatory chamber. Setae; vii/35-42, xvii/17-22, xviii/9-14, xix/16-20, 60-67/iii, 75-87/viii, 63-78/xii, 56-65/xx. First dorsal pore on 11/12. Length 64-170 mm. Diameter 4-7 mm. Segments 115-142.

Intestinal caeca simple. Testis sacs paired; of x, ventral; of xi, vertical; seminal vesicles included. Spermathecal diverticulum longer than combined lengths of duct and ampulla, comprising a short stalk, a thicker middle portion with thick wall within which are numerous small, spheroidal to ovoidal chambers opening into the central lumen, and a terminal, elongately ellipsoidal seminal chamber. Genital marking glands stalked and coelomic.

**Distribution.**—Katlicherra in South Cachar, Assam. Outside of India found in Burma, Andaman Islands and the Malay Peninsula (Kuala Lumpur).

### ***Pheretima posthuma* (Vaillant).**

1868. *Perichaeta posthuma*, L. Vaillant, *Ann. Sci. Nat.* (5), X, p. 228. (Type locality, Java! Types in the Paris Museum.)

1883. *Megascolex affinis*, Beddard, *Ann. Mag. Nat. Hist.* (5), XII, p. 214.

1889. *Megascolex posthuma*, Vaillant, *Hist. Nat. Annel.* III, (1) p. 72.

1895. *Perichaeta posthuma*, Beddard, *Monog.* p. 424.

1900. *Pheretima posthuma*, Michaelsen, *Das Tierreich*, X, p. 295.

1900. *Amyntas posthumus*, Beddard, *Proc. Zool. Soc. London*, 1900, p. 641.

1901. *Amyntas posthumus*, Beddard, *Proc. Zool. Soc. London*, 1901, p. 196.

1902. *Pheretima posthuma*, Beddard and Fedarb, *Proc. Zool. Soc. London*, 1902, p. 164. (Coelomic pouches.)

1903. *Pheretima posthuma*, Michaelsen, *Geogr. Verbr.* p. 98.

1909. *Pheretima posthuma*, Michaelsen, *Mem. Ind. Mus.* I, pp. 110 and 189.

1910. *Pheretima posthuma*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX (5), p. 12.

1911. *Pheretima posthuma*, Lloyd, *Introduction to Biology for Students in India*, p. 68.

1911. *Pheretima posthuma*, Lloyd and Powell, *J. Bombay Nat. Hist. Soc.* XXI, pp. 289 and 291.

1913. *Pheretima posthuma*, Stephenson, *Trans. Roy. Soc. Edinburgh*, XLIX, p. 764. (Circulatory System.)

1914. *Pheretima posthuma*, Stephenson, *Rec. Ind. Mus.* X, pp. 323 and 342.

1915. *Pheretima posthuma*, Stephenson, *Mem. Ind. Mus.* VI, pp. 37 and 99.

1916. *Pheretima posthuma*, Prashad, *J. Bombay Nat. Hist. Soc.* XXIV, p. 502.

1916. *Pheretima posthuma*, Prashad, "The Anatomy of an Indian Earthworm, *Pheretima posthuma*.", Lahore, p. 1.  
 1916. *Pheretima posthuma*, Stephenson, *Rec. Ind. Mus.* XII, p. 334.  
 1917. *Pheretima posthuma*, Stephenson, *Quart. J. Mic. Sci.* LXII, p. 261. (Pharyngeal gland cells.)  
 1917. *Pheretima posthuma*, Stephenson, *Rec. Ind. Mus.* XIII, p. 385.  
 1918. *Pheretima posthuma*, Thapar, *Rec. Ind. Mus.* XV, pp. 71 and 74. (Lymph glands and coelomic organs.)  
 1919. *Pheretima posthuma*, Bahl, *Quart. J. Mic. Sci.* LXIV, pp. 76 and 109. (Nephridia and septa.)  
 1920. *Pheretima posthuma*, Stephenson, *Mem. Ind. Mus.*, VII, p. 222.  
 1921. *Pheretima posthuma*, Bahl, *Quart. J. Mic. Sci.* LXV, pp. 349 and 354. (Circulatory system.)  
 1922. *Pheretima posthuma*, Stephenson, *Rec. Ind. Mus.* XXIV, p. 434.  
 1922. *Pheretima posthuma*, Bahl, *Quart. J. Mic. Sci.* LXVI, p. 56. (Cocoons.)  
 1923. *Pheretima posthuma*, Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 309.  
 1924. *Pheretima posthuma*, Stephenson, *Rec. Ind. Mus.* XXVI, p. 340.  
 1924. *Pheretima posthuma*, Stephenson, *Proc. Roy. Soc. London*, B, XCVII, p. 180. (Blood glands.)  
 1926. *Pheretima posthuma*, Stephenson, *Rec. Ind. Mus.* XXVIII, p. 258.  
 1926. *Pheretima posthuma*, Bahl, *Indian Zool. Mem.* I, p. 1.  
 1930. *Pheretima posthuma*, Nath, *Quart. J. Mic. Sci.* LXXV, p. 477. (Golgi Apparatus.)  
 1933. *Pheretima posthuma*, Nath, *Quart. J. Mic. Sci.* LXXVI, p. 138. (Golgi bodies.)  
 1934. *Pheretima posthuma*, Bahl, *Quart. J. Mic. Sci.* LXXVI, p. 567. (Castings.)  
 1936. *Pheretima posthuma*, Bahl, *Indian Zool. Mem.* I, 2nd ed., p. 1.

*Material examined*.—From the Indian Museum: 3 acitellate (and probably also 2 juvenile) specimens labelled "On ground near the cistern of extension Filter Bed No. 7. Pulta Waterworks. Pulta Waterworks Survey.", 4 partially clitellate or acitellate specimens labelled, "On the banks of New Filter Bed No. 3, Pulta Waterworks. Pulta Waterworks Survey.", 1 clitellate and macerated specimen labelled, "On sand in New Filter Bed No. 3. Pulta Waterworks. Pulta Waterworks Survey.", 1 juvenile and 45 clitellate specimens labelled, "Forest Rest House. Lachhiwala, Dehra Dun District. 29. ix-3. x. 35. Dr. S. L. Hora."

*Diagnosis*.—Octothecal, spermathecal pores minute and superficial, four pairs, on the posterior margins of v-viii, each pore at the centre of a transversely elliptical, greyish, translucent area. Male pores minute and invaginate, each pore on a tiny tubercle on the median wall near the roof of a slight parietal invagination with a longitudinally directed, crescentic aperture. Genital markings small, transversely elliptical tubercles, two pairs, in the setal circles of xvii and xix. Setae present ventrally on the clitellar segments: vi/37-43, vii/38-44, viii/36-43, xvii/15-20, xviii/17-21, xix/16-20, 90-104/iii, 106-129/viii, 63-75/xii, 64-86/xx. First dorsal pore on 12/13. Length 60-140 mm. Diameter 4-8 mm.

Septum 8/9 present and muscular. Intestinal caeca simple, small. Hearts of x and xi replaced by commissural loops connecting the supra-oesophageal and suboesophageal vessels. Testis sacs unpaired: of x ventral, of xi U-shaped; seminal vesicles included. Lumen in ental part of the spermathecal duct large and communicating with the narrowed lumen of the ectal portion through a pore in a vertical groove on the median face of a dorsally directed, shortly conical papilla. Diver-ticular stalk shorter than the ovoidal to ellipsoidal seminal chamber. Genital marking glands sessile on the parietes.

*Distribution*.—Lyallpur, Mian Mir, Lahore, Ludhiana, Hoshiarpur, Jullundur, Phagwara, Ferozepore, Kalka, Punjab; Ajmere and Udaipur,

Rajputana ; Dehra Dun, Saharanpur, Allahabad, Agra, Lucknow, Bindraban, United Provinces ; Kierpur, Pusa, Bihar ; Calcutta, Dattapukur, Khulna, Bongaon, Bhagalpur, Purneah, Dhalla, Netracona (Mymensing district), Raniganj (Burdwan district), Rajshahi, Saraghat, Comillah and Rangamati (Chittagong district), Bengal ; Bombay and Baroda, Bombay Presidency ; Gwalior, Central India. Outside of India : Burma (widely distributed, but absent from the western hills and the Shan Plateau), Andaman Islands, Siam, French Indo-China, the Malay Peninsula, Java, Sumatra, Philippines, Celebes, Christmas Island, Groot Bastaard, Ternate, New Hebrides, Santa Cruz Is., Amboine, Nias, Flores, Sebesi, Sumba, Nice (? France). (Recorded once from the Bahamas but never confirmed. According to Bahl, 1936, p. 8, found in Ceylon but no record of this can be found.)

### ***Pheretima robusta* (Perrier).**

1872. *Perichaeta robusta*, E. Perrier, *N. Arch. Mus. Paris*, VIII, p. 112. (No type designation. Types from Mauritius and Manila, in the Paris Museum.)

1925. *Pheretima himalayana*, Stephenson, *Proc. Zool. Soc. London*, 1925, p. 893. (Type locality, Darjiling, India. Type in the British Museum.)

1934. *Pheretima robusta*, Gates, *Rec. Ind. Mus.* XXXVI, p. 264.

**Diagnosis.**—Quadrithecal, spermathecal pores minute and superficial, two pairs, on 7/8-8/9. Male pores minute and superficial, each on a small, transversely elliptical tubercle surrounded by several concentric furrows. Genital markings small, circular to elliptical tubercles, about 1 intersetal interval wide : on xviii presetal and postsetal, slightly median to the male pore lines (slightly lateral to the midventral line) ; presetal and postsetal on vii-viii, slightly median to the spermathecal pore lines ; on the spermathecal porophores, just behind the spermathecal pores. Setae : viii/19-31, xvii/24-31, xviii/18-24, xix/23-31, 34-40/iii, 50-53/viii, 54-59/xii, 63-70/xx. First dorsal pore on 11/12. Length, 120-140 mm. Diameter, 5-8 mm. Segments, 106.

Intestinal caeca simple but with short lobes on the ventral margins. Testis sacs unpaired and ventral. Spermathecal diverticulum with spheroidal to ellipsoidal seminal chamber usually shorter than the slender stalk. Genital marking glands stalked and coelomic.

**Distribution.**—Darjiling in the Eastern Himalayas. Outside of India : Burma (northern portion of the Shan Plateau only, at Namkham, Kutkai and Lashio), China (Provinces of Fukien, Szechuan, Chekiang, Kiangsu, Kiangsi and Hupei, also Hongkong), Philippines (?), Mauritius (?), Madagascar (?), West Indies (?).

### ***Pheretima taprobanae* (Beddard).**

1892. *Perichaeta taprobanae*, Beddard, *Proc. Zool. Soc. London*, 1892, p. 163. (Type locality, Ceylon. Types in the Oxford University Museum and the British Museum ?).

1929. *Pheretima taprobanae*, Aiyer, *Rec. Ind. Mus.* XXXI, pp. 15 and 72.

Indian specimens have not been available for study. Material in the British Museum has been examined and the account will be published elsewhere.

*Diagnosis.*—Bithecal, spermathecal pores minute and superficial, one pair, on the anterior margin of viii. Male pores minute and superficial, each on an indistinctly demarcated, circular, postsetal porophore. Genital markings small, circular, presetal, paired, on vi-xi and xviii-xxii. Setal circles present on all clitellar segments: viii/34-41, xvii/20-25, xviii/14-19, xix/19-25, 70/v, 77/x. First dorsal pore on 12/13. Length 80-145 mm. Diameter 4-7 mm. Segments 95-122.

Septum 8/9 present but membranous. Hearts of x and xiii lacking. Testis sacs unpaired and annular; seminal vesicles included. Spermathecal diverticulum with spheroidal to ovoidal seminal chamber and slender muscular stalk that passes into the anterior face of the duct at the parietes. Genital markings slight epidermal thickenings without internal glands.

*Distribution.*—Trivandrum, Travancore. Outside of India has been found in Ceylon, Madagascar and Brazil but is quite unknown from (or at least unrecognized within) the *Pheretima* domain.

#### APPENDIX TO THE GENUS *PHERETIMA*.

The reference listed below cannot be placed in any of the synonymies.

- 1917. *Pheretima hawayana*, Stephenson, *Quart. J. Mic. Sci.* LXII, pp. 260 and 267. (Pharyngeal glands.)
- 1918. *Pheretima hawayana*, Thapar, *Rec. Ind. Mus.* XV, pp. 69 and 71. (Blood glands.)
- 1919. *Pheretima hawayana*, + *P. barbadensis*, Bahl, *Quart. J. Mic. Sci.* LXIV, pp. 103 and 104. (Nephridia.)
- 1919. *Pheretima hawayana*, Stephenson and Ram, *Trans. Roy. Soc. Edinburgh*, LII, pp. 436, 438 and 439. (Prostates.)
- 1919. *Pheretima hawayana*, Stephenson and Prashad, *Trans. Roy. Soc. Edinburgh*, LII, pp. 457 and 460. (Calciferous glands.)
- 1924. *Pheretima hawayana*, Stephenson, *Proc. Roy. Soc. London*, B. XCVII, pp. 179 and 192. (Blood glands.)

Stephenson did not distinguish between *hawayana* and *morrisi*, now recognized as specifically distinct, and often gave no clues that would enable recognition of his forms. The material involved apparently has not been preserved. For the present at least, the proper disposition of *P. hawayana* and *P. barbadensis* of the authors and dates just cited is impossible.

- 1889. *Perichaeta houlleti*, Bourne, *J. Asiatic Soc. Bengal*, LVIII, p. 111.

Figure 5, pl. 3, shows a "spermatheca seen turned forwards" Presumably then it is the posterior face of the spermatheca that is drawn. Since a stalked gland is shown passing to the posterior face the worm hitherto could have been referred to *campanulata*. With the finding, as an occasional abnormality (*vide* p. 204) of posterior glands passing to the spermathecal pore invaginations, identification is no longer possible unless information with regard to other characteristics is available. Since Bourne's specimens have not been preserved and in the absence of the necessary information the reference, at least for the present, cannot be properly placed,

1886. *Perichaeta burliarensis*, Bourne, *Proc. Zool. Soc. London*, 1886, p. 667.  
(Type locality, Burliar, Nilgiris, S. I.)  
1895. *Perichaeta burliarensis*, Beddard, *Monog.* p. 403.  
1900. *Pheretima burliarensis*, Michaelsen, *Das Tierreich*, X, p. 258.  
1909. *Pheretima burliarensis*, Michaelsen, *Mem. Ind. Mus.* I, p. 110.  
1910. *Pheretima burliarensis*, Michaelsen, *Abh. Nat. Ver. Hamburg*, XIX, (5), p. 11.  
1923. *Pheretima burliarensis*, Stephenson, *Oligochaeta*, in *F. B. I. Series*, p. 297.

This species, if a *Pheretima*, is quite unrecognizable. The only evidence for recognition as a *Pheretima* is the presence of the gizzard in x, and the presence of intestinal caeca in xxvi. Equally good evidence against recognition is the inclusion of segment xvii in the clitellum and the presence of two pairs of groups of enlarged setae on vii and viii. The supposed location of the gizzard in x cannot be considered as important evidence. In the same paper Bourne incorrectly placed the gizzard of his *P. stuarti* also in x. The location of the gizzard of *P. lawsoni* and *P. hulikalensis* is probably also incorrect.

*Perichaeta lawsoni* and *P. hulikalensis* Bourne 1886 are quite unrecognizable and the latter, according to Stephenson (1923, p. 290), "may be a *Megascolex*." *P. lawsoni* has the gizzard in x and intestinal caeca in xxvi. Bourne failed to mention the gizzard of *hulikalensis* and evidently had some doubt as to the caeca, "I believe intestinal diverticula are present in the usual position." Both species have a clitellum that includes segment xvii. Little is known of the earthworms of the Nilgiris (one species of *Megascolex* was briefly characterized by Bourne but has not been seen since). When the fauna of this region has been worked out it may be possible to refer Bourne's three species of *Perichaeta* more or less definitely to some species of *Megascolex*.

#### REFERENCES.

- Aiyer, K. S. P. An account of the Oligochaeta of Travancore. *Rec. Ind. Mus.* XXXI, 1929.  
Bahl, K. N. On the significance of the enteronephric nephridial system found in Indian earthworms. I. Evidence from their habits and castings. *Quart. J. Mic. Sci.* LXXVI, 1934.  
Bahl, K. N. *Pheretima*. In "*Indian Zoological Memoirs*", 2nd ed. (Lucknow, 1936).  
Gates, G. E. The earthworms of Burma. III. *Rec. Ind. Mus.* XXXIV, 1932.  
Gates, G. E. The earthworms of Burma. IV. *Rec. Ind. Mus.* XXXV, 1933.  
Michaelsen, W. Oligochaeta. *Das Tierreich*, X, 1900.  
Michaelsen, W. *Die Geographische Verbreitung der Oligochaeten*. (Berlin, 1903).  
Michaelsen, W. The Oligochaeta of India, Nepal, Ceylon, Burma and the Andaman Islands. *Mem. Ind. Mus.* I, 1909.  
Michaelsen, W. Die Oligochaetenfauna der vorderindisch-ceylonischen Region. *Abh. Nat. Ver. Hamburg*, XIX, (5), 1910.

- Stephenson, J. On some Indian Oligochaeta, mainly from southern India and Ceylon. *Mem. Ind. Mus.* VI, 1915.
- Stephenson, J. On a collection of Oligochaeta from various parts of India and Farther India. *Rec. Ind. Mus.* XIII, 1917.
- Stephenson, J. *Oligochaeta*. In, *Fauna of British India Series* (London, 1923).
- Stephenson, J. The Oligochaeta of the Indawgyi Lake (Upper Burma). *Rec. Ind. Mus.* XXXI, 1929.