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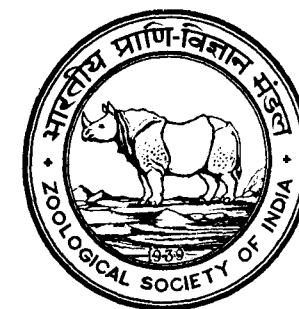
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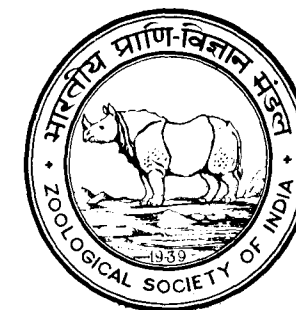
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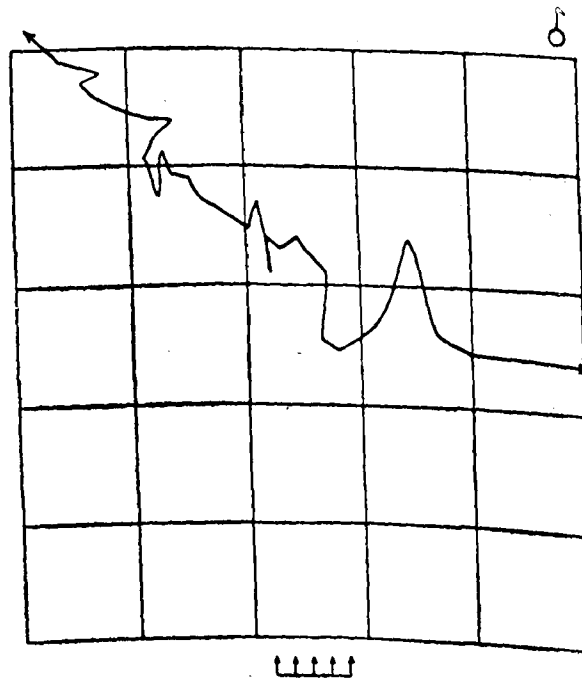


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- (2) *Orientation over far distances*:—It is mainly produced by way of the light and gravity senses. These give a general orientation in space and result in the coverage of longer distances or make it possible.

Up to date, orientation over far distances has, mainly for technical reasons, been less analysed. Here we still meet with surprises and therefore it may be of interest to give a survey on some of the work done in this field during recent years.

Course 1 (13.8.49)



Text-fig. 1. Directed locomotion of *Cicindela maritima* Latr. (After FRITSCH.)

Deliberately, we will not concern ourselves here with the chemical senses which from the functional point of view have to be looked at as senses of orientation in the near distances, since contact between the material perceived and the sensory organs has to be made. But the biological possibilities of the chemical senses result in orientation over long distances. For instance minimum concentration of solutions in water direct fishes, on their way up stream, in their selection of two possible rivers coming together at a certain point.

Here we shall concentrate on the orientating effect which is performed by light and gravity on the locomotion of animals. And out of all animals we

shall consider only the reactions of insects to stimuli received from gravity and light.

The selection of insects for our observations is made for several reasons.

1st: Long range orientation by light is very common in this systematic group.

2nd: This kind of orientation in insects shows all stages from the very simple reactions to the most complicated performances of so called astronomical navigation.

3rd: Gravity also often has an orientating influence on the locomotion of insects. Their ability to transpose in the central nervous system, stimuli from light and gravity from one to the other is of special interest.

4th: During recent years several investigations have produced interesting results in the study of long range orientation. Meanwhile many other problems in this field are still unsolved. Therefore a survey on the present situation may lead also to new questions for further research.

Orientation to light

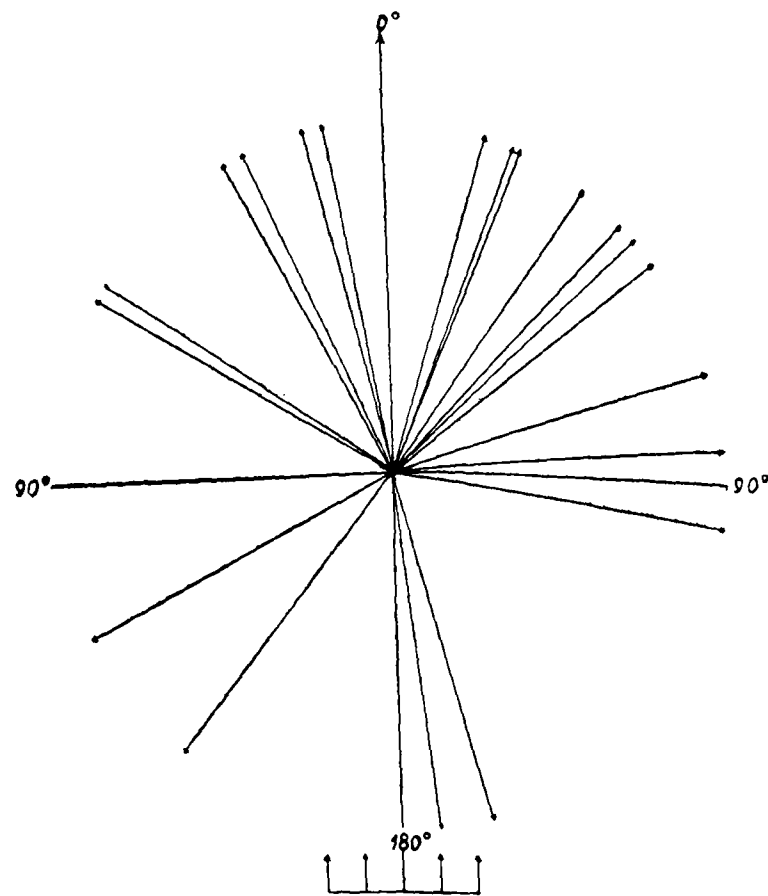
We start our considerations with the orientation to light. This form of orientation can be observed even in insects moving on more or less zigzag courses. The beetle *Cicindela maritima* living along European sea shores, when running under a net of rectangles for instance in 75% of the observed cases will move with the sun. (Fig. 2).

This may be interpreted as an optimal optical perception of the prey to be collected. Indeed the few beetles which were observed moving against the sun were found soon to burrow themselves or to start flying. This indicates that they were not looking for food and therefore not obliged to direct themselves towards the light (FRITSCH).

Similar patterns in behaviour have been found with ants. These show basical positive phototaxis leaving their nest (JANDER). Apparently the direction of the *Cicindela* is only in a general sense influenced by light. The physiological situation, perhaps the state of hunger, may to some degree decide if these insects will travel with or against the rays of the sun. We find therefore a phototaxis of little precision.

For directed, that is orientated, locomotion we still use the terminology of KÜHN for the orientation of animals in space. Following this conception we call *taxis* the orientation of a freely moving animal against a location from which a stimulus is going out. The animal is orientating itself in the descent of stimulus. A fly approaching the window of a room in straight line provides an example of positive *phototropotaxis*. It is keeping itself in

a symmetrical position in which each eye receives the same quantity of light in the same place. We call these orientated locomotions *positive* when they approach the place from which the stimulus is going out, or *negative* when they take the animal away from the place from which the stimulus is going out.



Text-fig. 2. Orientation to light of *Cicindela maritima* Latr. (After FRITSCH.)
Arrows at the base indicating direction of sun rays; radial arrows showing locomotion of beetles.

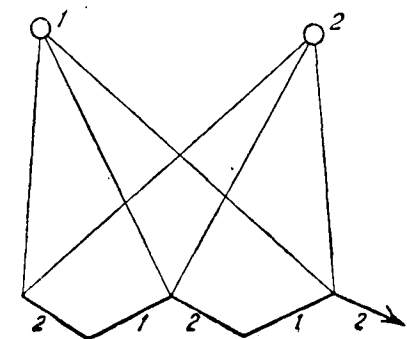
Menotaxis (or in the case of light, *photomenotaxis*) we call the relative orientation to the place the stimulus is coming from. In this case both eyes receive unequal quantities of light in different regions of the eyes. But this unequal situation in itself is kept constant by the moving animal. But this behaviour of photomenotaxis is also called *light compass movement* because it enables the animal to keep a fixed course. In the open an insect using the light compass orientates itself in such a way that it receives the rays of the sun with certain ommatidia of its complex eyes and then moves on a

course which keeps the sun's rays always in these same ommatidia. This kind of reaction was found first in ants by SANTACHI (1911) and later in bees by WOLF (1927). The original angle against the sun is determined spontaneously and can be changed. Since the sun's rays are parallel, light compass movement orientated by the sun puts the insect on a rectilinear course.

To demonstrate light compass movement in a dark room the so called two lights experiment (v. BUDDENBROCK) is used. (Fig. 3).

Text-fig. 3. The "two lights experiment".
(After v. BUDDENBROCK.)

Small circles indicating lights 1 and 2; the insect runs on course 1 when light 1 is on, and on course 2 when light 2 is on.



Some insects, crabs, worms, snails react in the same way directing themselves to one light and changing their direction accordingly by a predictable angle when the first light is shut off and another one is lit. The classical opinion until three years ago has been that only the direction of the light in the plane where the animal is moving mattered in this experiment. But in 1955 BIRUKOW and DE VALOIS found that the beetle *Geotrupes silvaticus* followed its course not only by the position of the light in the horizontal plane but was also influenced by the height of the light above this plane. In the experiments the beetle moved on a celluloid ball which was floating on quicksilver. The insect was fixed by a turning needle. So the distance to the light remained constant—as it would be in relation to the sun. A paper pointer fixed on the abdomen indicated the direction of the movement on a protractor scale.

Changing the height of the light makes the beetle either:

- (i) follow its old direction; or
- (ii) deviate to the left; or
- (iii) deviate to the right.

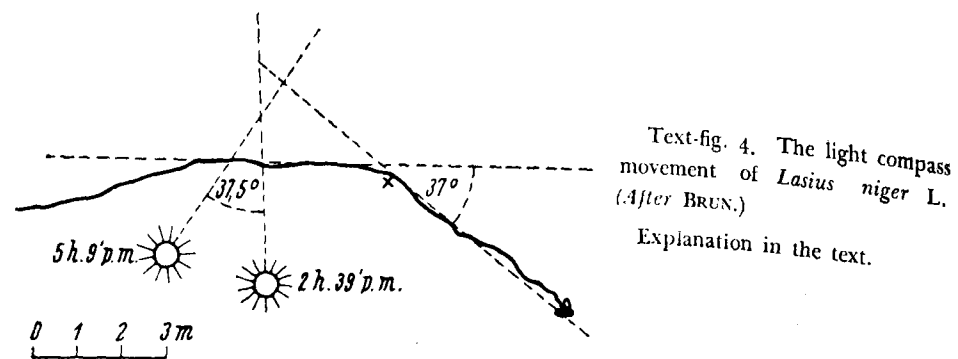
Deviation to the left was called negative, to the right positive. These deviations measured in angle degrees are equal to the height of the light in angle degrees.

In some cases individual beetles reacted with deviations in the same way to the same side on the lifting of the light. These animals could be kept on the old course by changing the azimuth in the opposite sense.

This fact suggests that height and azimuth are affecting as antagonists one and the same central nervous mechanism.

A lamp 90' high, that is vertically above the beetle, makes the insect rotate slowly around its vertical axis on the celluloid ball or move in narrow spirals freely on the ground.

The light compass movement following the sun should show deviations from a rectilinear course if the sun is permitted long enough time to move on its daily course across the sky. In fact BRUN could demonstrate in ants (*Lasius niger*) that the light compass could function only for short periods of time. Ants were kept in the dark for $2\frac{1}{2}$ hours. Released at the same point of their path where they had been arrested they moved in a new direction which was different from the old one by the same angle by which the sun had been progressing in the meantime. (Fig. 4). This result of BRUN's could be reproduced by JANDER only during the months of March and April. During the summer the ants reacted in a different way which we will discuss further on.



To sum up: During light compass movement or photomenotaxis the insect chooses a certain angle between the direction of its movement and the direction of the light. This angle is kept constant for some time. If the source of light is far away, then a rectilinear course will result from this behaviour. Changes in the position of the light are followed by corresponding changes in the course of the insect by the same angle. The relevant magnitude in any case is the angle between the directions of light and movement.

The following questions remain unsolved in this context:—

(i) Is there an influence of the height of the light source on the light compass movement also of insects other than *Geotrupes*? What effect does it have?

(ii) Which chain of physiological processes connects the eye facettes as receptor with the leg muscles as effector?

The second part of our considerations deals with possibilities of orientation where the angle between the directions of light and movement is changing but the course of the insect is kept fixed in only one direction.

A very impressive example of this "astronomical orientation" has been found by BIRUKOW (1957) with the water runner *Velia currens* (Heteroptera). When put on dry ground, these insects travel always southward. Doing this, they orientate themselves in the early morning in such a way that their left eye receives the light of the sun at right angles to the longitudinal axis of the body. Before midday the angle between the incoming sun's rays and the longitudinal body axis becomes smaller and smaller the position of the sun being fixed by facettes which change from side to front of the head until at noon this angle has become zero. During the afternoon the same angle is increasing in the right eye from zero to ninety degrees, the position of the sun being fixed first with the front facettes and then with facettes more and more sideways. In a dark room this can be shown experimentally by using a lamp so that during night time the fixing angle of *Velia* is turning back over the right eye from the side to the front and then in the left eye from the front to the side until the morning position is reached again. In day time the regular movement of the point which fixes the sun across both eyes results in always orientating the animal southward. One direction of movement only is kept: We have got an astronomical orientation in one sense.

The cockchafer *Melolontha melolontha* L. has an astronomical orientation in two senses, as found by COUTURIER and ROBERT. This kind of orientation enables the insect to find its way from the woods (that is, its place of feeding) to the field (where egg laying takes place) and back to the woods. When leaving their pupae and coming out of the earth these beetles fly first in spirals and then, optically attracted, direct themselves on a rectilinear course to the highest and darkest area above the horizon. By this first flight, before taking any food, the insects reach the woods. The direction of this flight determines the direction of all following uniform flights back to the field where the eggs are laid and the return to the places of feeding in the woods. This direction is found astronomically by the position of the sun or qualities of the cloudless sky. The covering of the sun or the sky disturb the direction finding ability of these beetles. The exclusively astronomical orientation of these long distance flights has been proved by carrying cockchafers across a long forest stripe, about $1\frac{1}{2}$ miles wide running from north to south. The insects were caught flying from the western border of the wood in a westerly direction into the open field where they lay their eggs. Brought to the east side of the same wood and left free they continued to fly westward, penetrating into the wood itself.

Female beetles returning from the egg laying places to the wood for feeding flew away from the wood when they were brought to its other side and released, a distance of 250 meters from the border of the wood.

We have met a sense of time already in the water runner without mentioning it specially. A similar *sense of time* enables the cockchafer which has been caught in the evening dusk to pursue its way in the sunshine of next morning in the same direction it was following the previous evening. The insect takes into account the relative movement of the sun in such a way that its original course does not change. Cooling beetles caught on their way to the egg laying areas down to $+ 2^{\circ}$ C for 10 days had no influence on their orientation ability afterwards. They took up their old course.

Summing up, we see that the cockchafers coming out of the ground before feeding find the wood optically. On this first flight the basis for the astronomical orientation which will always be used later must be laid. After 10-12 days of feeding the beetles are ready to lay their eggs and then return to the field they have come from by astronomical orientation. Also by astronomical orientation they come back to their feeding places after laying eggs.

The shuttling between the egg laying field and the feeding wood has been considered by SCHNEIDER as a homing reaction and compared to the behaviour of ants and bees. In the case of the cockchafers the place of egg-laying would then have to be thought of as the nest.

But since cockchafers possess only an astronomical orientation of both senses on the same road, back and forth, ants and bees have reached the highest level of orientation in space with their astronomical orientation in all possible directions. Starting from their nests these insects can shuttle between the feeding places and back thanks to their astronomical orientation.

We may now consider ants, whose astronomical orientation seems to be somewhat more primitive since JANDER found their astronomical orientation working only in summer. This author trained ants to carry their pupae, which were laid in the middle of an arena of 60 cm. diameter, into an artificial plaster nest. A graduated grass plate covering the arena permitted registration of the course which was inscribed into circular diagrams.

Formica rufa can orientate itself astronomically by the sun and by the full moon. If the sun or moon is obscured but the image of either is presented to the insects in a mirror, the insects orientate themselves now in relation to the reflected image. This mirror experiment was first used by SANTSCHE. Under a blue sky polarized light inhibits the mirror experiment with ants. When the sky is covered with clouds the ants orientate themselves by land marks. In the experiment for instance this can be done by using a black disk.

Blue sky-light is enabling the ants to orientate themselves astronomically without seeing the sun. In this case they direct their course by the one symmetry axis of the polarization phenomenon.

Phototaxis as basical orientation (p. 3) is changing into *Photomenotaxis* by a learning process. Ants leaving their nest are first of all positively phototactic, they move in searching loops and by these find their goal. Then during the first orientated runs between nest and goal and back initial deviations can be observed. If the light source is placed in front of the ant, at an angle of $+ 90^{\circ}$ on one or the other side of the direction of moving, or at smaller angles, the insect deviates in a positive phototaxis from the course leading to its goal. If the light source is behind the animal the deviation follows the pattern of negative phototaxis. If the light source is standing at an angle of 90° off the course the ants deviate positively on their way from the nest to the goal, negatively on their way back to the nest.

During the progressive training the initial deviations diminish more and more. This is understood as the consequence of photo-menotaxis superseding the basical orientation of phototaxis. Or in other words, the "higher centres" are gradually taking over.

A sense of time enables the ants to take the daily movement of the sun into account in their astronomical orientation. This seems to have to be learned individually since BRUN could not find this capacity in *Lasius niger*, but JANDER could show that these ants can co-ordinate their orientation with the movement of the sun only during the summer when older individuals are abundant, but not in the months of March and April when younger animals are supposed to constitute the majority of the population.

Bees also orientate themselves by the sun on their flights between the hive and the feeding place, as was first discovered by WOLF. But they prefer landmarks for their orientation as has been shown by v. FRISCH and his pupils. Only the first flight to a new feeding place which has been indicated by a "dancing" bee must always be directed by sun navigation as the only means of finding the way. WOLF originally had been of the opinion that there was a difference in the orientation reactions of bees starting from the hive after a period of detention and those which had been imprisoned for some time at the feeding place before they were permitted to fly home. This was refuted by MEDER only in 1958 who could prove that the time sense also enables bees which have been kept imprisoned for some time at the feeding place to take into account the relative movement of the sun which has taken place during their detention. That means that the time sense of bees is working exactly like that of ants.

The present position in regard to this second part, *viz.*, astronomical orientation, may be summed up as follows:—

The changing of the angle between the direction of the light coming from sun or moon, or from moving artificial light sources and the direction of the insects movement can result in:

- (i) Keeping a course in one direction,
- (ii) Keeping a course in both directions—coming and going,
- (iii) Keeping a deliberate number of courses in both directions.

A time sense makes possible sun navigation or astronomical navigation. The blue polarized light of the sky can also be used in astronomical navigation.

With this we have come to the important question: How does the sense of time work? This problem is still far from its solution, actually it has only just been put before us.

The "time sense"

As we have seen in the first part of this discussion a number of insects are able to use astronomical navigation to keep moving on a straight course. The most simple example of this kind of reaction is given by the water runner *Velia currens* (BIRUKOW 57). By changing from morning to evening the angle between its course and the direction of the incoming light this insect when put on dry land always moves southwards. In its usual habitat—water—this reaction would not be observed. In principle all kinds of astronomical navigation in insects are based on the capability of the animal to arrange its position to the sun in such a way that the relative movement of the sun during the day is taken into account. For this purpose the sun need not permanently remain in sight of the insect for the time sense works also in an insect which is kept imprisoned in the dark. Released after some time when the sun moved to another position in the sky the animal, using astronomical navigation will direct itself on to the same course it was keeping when captured and kept in a dark place. For this a new angle between the incoming light and the direction of movement has to be selected.

How does this time sense work?

Bees have a compensation mechanism or system of relation (KALMUS) permitting them to shuttle for several hours between their hive and the same feeding place by using sun navigation. The progress of the sun across the sky is taken into account by the bees which accordingly change the angle between the rays of the sun and the direction of their flights. Is this time sense innate? This question was taken up by KALMUS. v. FRISCH had made the fundamental discoveries of the sun navigation of bees in the northern hemisphere. KALMUS repeated the same experiments in the southern hemisphere, where the sun moves counter-clockwise. He observed the orientation of (1) local bees; (2) bees descended from queen bees which had been imported from the northern hemisphere after being inseminated there; (3) hybrids of both races.

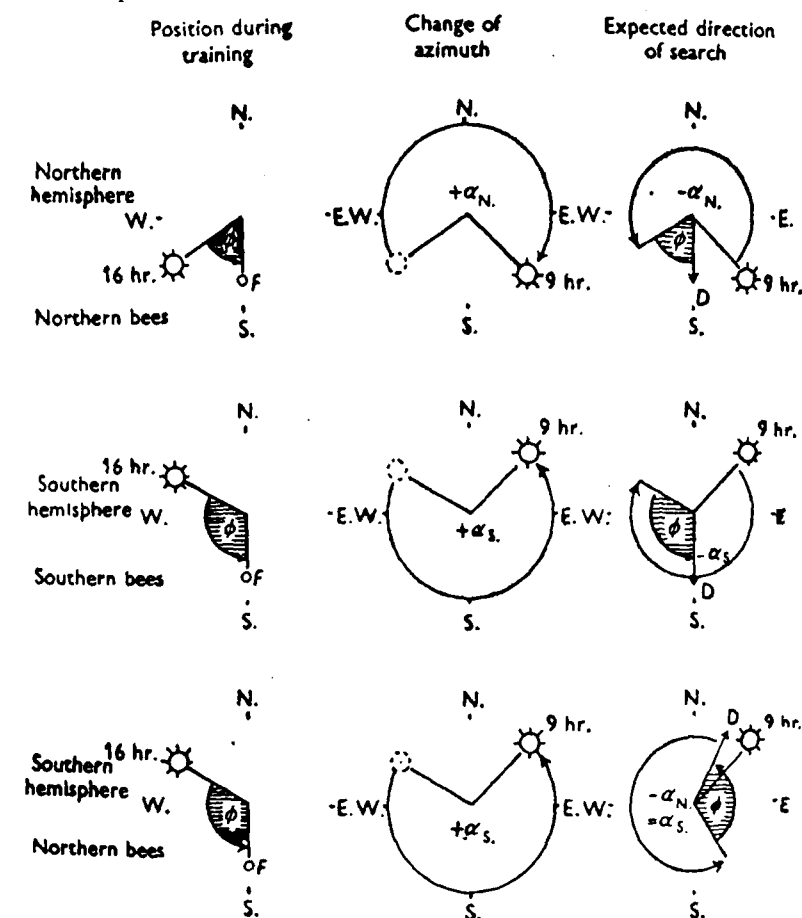
Brazilian bees were trained to feed in a region without landmarks 15° E. from N. Transported during the night into another, unknown region

without landmarks the bees searched for food in the direction of their previous training.

Descendants from queen bees inseminated in and imported from California were trained for two days in the same manner and then transported into an unknown region without landmarks. The next day the maximum frequency of searching bees had shifted counterclockwise around the four prepared feeding tables.

The behavior of the hybrids was similar to that of the so called northern bees, but the number of experiments made was too small to provide any definite results. Studying the results of KALMUS we find the following:—The azimuth of the sun changes by about 15° per hour at KALMUS' observation spot—Piracicaba NW from S. Paulo in Brazil.

Sun navigation may be interpreted like this. (Fig. 5). A "northern" bee in the northern hemisphere was trained at 4 p.m. by feeding it on a table due south



Text-fig. 5. The "correlation system" of bees. (After KALMUS.)
Explanation in the text.

from its hive, that means 60° counterclockwise or "at the left" from the sun. Next morning at 09.00 a.m. when the azimuth has increased clockwise by $205^\circ - \alpha N$ — the bee comes again to the south for feeding.

KALMUS' hypothesis is that an internal correlation α system N counterclockwise compensates the relative movement of the sun by counterbalancing it.

A "southern" bee in the southern hemisphere — middle row — trained due south in the afternoon at 4 p.m. finds the next morning that the azimuth of the sun has increased counterclockwise, overlapping the angle of training $\alpha = 120^\circ$. Compensation should work clockwise by an angle $-\phi$.

The difference between "northern" and "southern" bees is that this compensation works counterclockwise or clockwise.

This difference can be interpreted in two ways:—

- (1) The individual bee learns the relative movement of the sun. To this idea of KALMUS, LINDAUER has come back.
- (2) A sense of compensation is innate. In this case the bees which have originally been imported from the northern hemisphere must have changed their compensation ability since coming to the southern hemisphere. This would mean that in the meantime they have undergone an "evolutionary change".

This second interpretation is supported by the behaviour of the "northern" bees which have been trained in the afternoon at 4 p.m. to find their food due south. Having a "northern" compensation mechanism with the angle αN increasing counterclockwise next morning the bees searched in the wrong direction instead of due South.

Similar behaviour was found by PAPI in *Talitrus saltator* Crustacea, - α Amphipoda), when he brought individuals from a population living near Pisa to Argentine. On the 24th VI. 55 at 2.38 p.m. in their homeland, animals of this species brought on dry sand some distance up the sea rays. By taking this course they were flying south and reaching the humid region near the sea. Members of the same Crustacea population which had been flown to Argentine across the equator moved at the same time, that means 10.38 a.m. with the same angle to the sun rays. But this behaviour orientated movement at their home coast of the *Talitrus* population can be compared with the flights of the cockchafer female: Also the Crustacea cally. In the case of the *Talitrus* the line of orientation was determined by the geographical situation of the strand itself.

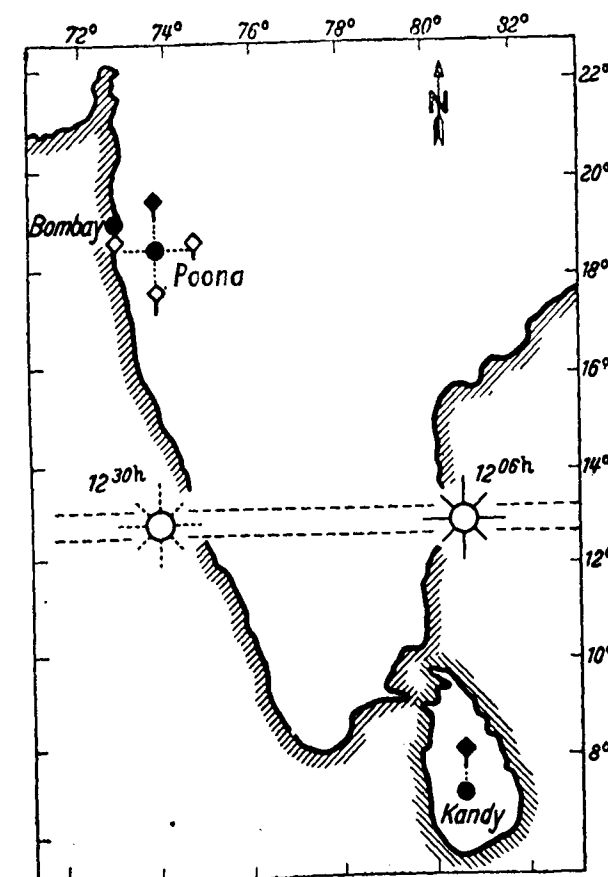
In this context of course it would be extremely interesting to find out how BIRUKOW's *Velia currens* would react south of the equator.

Now we come back to KALMUS's "northern" bees in the southern hemisphere: Their northern mode of counterclockwise compensation being based always on the time of the observation of the sun when feeding is shifting the maximum frequency at the feeding places from South to East and further to North and finally West.

Here the same situation is reached which prevailed at training time.

The change in the innate compensation mechanism since the arrival of the first honey bees from Portugal in Brazil in the year 1530 is still unexplained. It could perhaps be looked at as a genetic "selection", if sun navigation could be proved to play a role during the nuptial flight.

LINDAUER without reference to KALMUS's experiment has transported Indian bees first south of the tropic of Cancer from South to North. Fig. 6). In this experiment, which took place on the 24th of April 1956, the bees saw the sun at the time of observation first in the north and then, the following day in the south.



Text-fig. 6. Transport of Indian bees from south to north after training them to visit a feeding place north of their hive. (After LINDAUER.)
Explanation in the text.

These "south bees" were trained to visit a feeding place north of their hive. After being transported north themselves they searched for food at a table south of their hive. That means they went in the "right" direction in relation to the sun but "wrong" compared to their training. Bees from Ceylon were taken by LINDAUER to Munich. There they learnt in 43 days to orientate themselves astronomically, that means by sun navigation, under local conditions. Unfortunately their initial faults were not noted and it is not mentioned whether they showed a clockwise tendency.

Is there a possible explanation for the difference in KALMUS's and LINDAUER's results?

LINDAUER's bees coming from Ceylon had lived near the equator. Therefore for about half a year they had the sun in the south and the other half of the year in the north. It could not be excluded that this situation preconditioned them for a quicker change in their training.

KALMUS's bees lived in the next neighbourhood of the tropic of Capricorn, at a distance of only 59 minutes of latitude from it. Therefore they had the sun for nearly the whole of the year in the north.

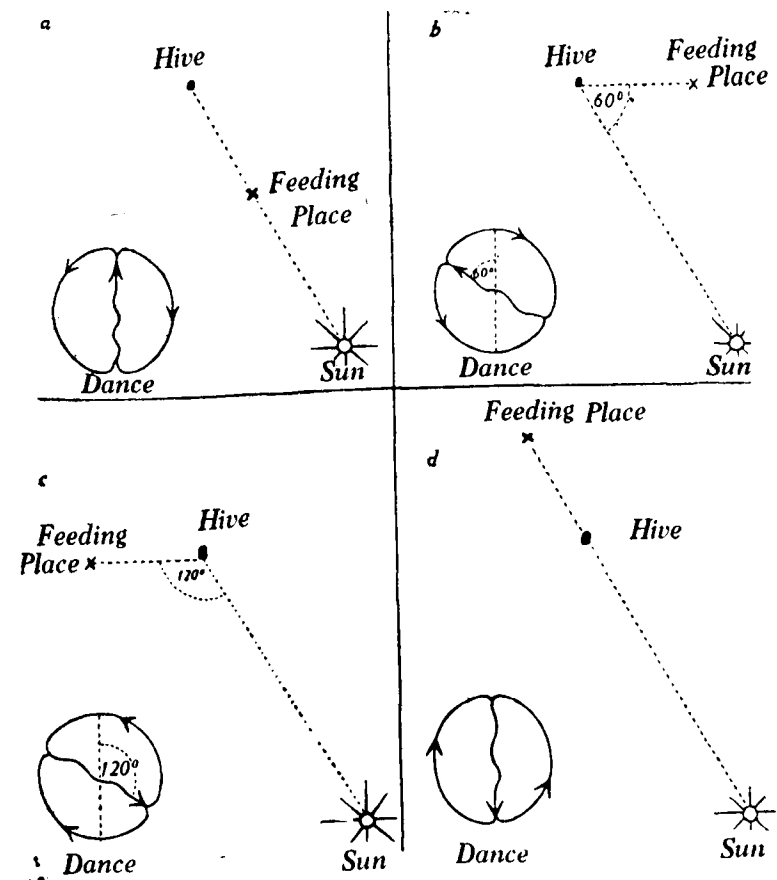
The so called dances of the bees on the vertical honey-comb form a certain angle between the direction of their middle dancing path and the force of gravity. This angle is the same as that which the bee, flying to its feeding place, observed between the direction of its flight and the sun's rays. (Fig. 7).

By lighting the hive and feeding bees in it, dances can be provoked experimentally at night time. These night dances are orientated in relation to the position of the sun at the respective time, in the same way as would be the case, during the day time.

This fact harmonies very well with KALMUS's hypothesis of the compensation mechanism. This hypothesis of KALMUS presumes that the moving leg of the angle—the one pointing to the sun—shows the situation of the sun also when the sun is in night position for the place of observation. If a double training has been applied to the bee in this sense that one feeding place is visited 1 h. after sun rise the other 1 h. before sunset then night dancing before mid-night indicates the "evening place," after mid-night the "morning place".

BIRUKOW (1957) has already pointed out the difference in the behaviour of *Velia curvens* which cannot keep its south direction during the night. Since the direction deciding spot in the eyes of *Velia* moves at night from the back of the right eye to the front, changing there to the left eye and

moving in the left eye from front to back the sun navigation of this insect can only work during day time.



Text-fig. 7. Dancing paths of bees (circular figures) in relation to their way between hive and feeding place (dotted line). (After v. FRISCH.)

Explanation in the text.

Further results of LINDAUER show that bees which have been raised by artificial light in the thermostat are unable to orientate themselves by the sun. But they learn to do so even when they are shown only parts of the sun track, for instance in the afternoon, for about one month.

To sum up: Changing of the angle between the direction of the light from sun, moon or an artificial light source and the direction of movement of the insect can result in obtaining either one direction in one sense, one direction in both senses (going and coming), or any number of directions in both senses. A sense of time makes sun navigation or astronomical

orientation possible. This kind of orientation can be used by the insect also where polarized blue sky light is visible.

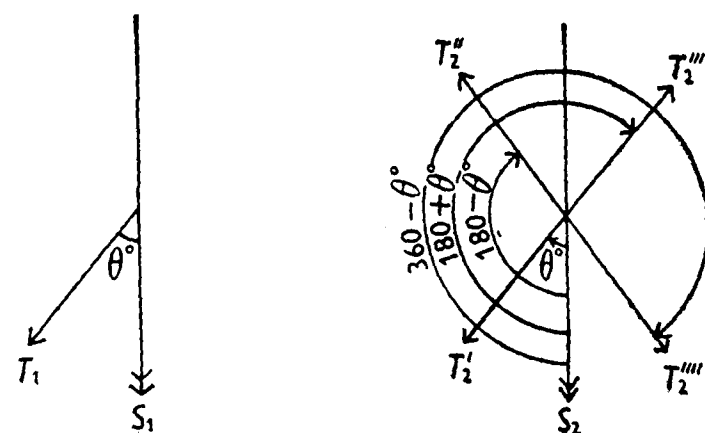
KALMUS's compensation hypothesis can serve as a basis for further research in this field.

The main question remains: How does the sense of time work?

Mentioning the bee dances we have noted that the directing angle can be transposed from light to gravity and back to light. This fact was found first in bees by v. FRISCH in 1946. BIRUKOW (1954) made the same observation with *Geotrupes Silvaticus*, and VOWLES with ants.

Geotaxis alone has been thoroughly analyzed by v. BUDDENBROCK observing movements on the sloping plane. Here I will not treat it as a form of basic orientation but only in its relation with menotaxis.

Ants can be considered as a good example for this kind of orientation. VOWLES observed light compass and gravity reactions in *Myrmica ruginodis* and *Lasius niger*. Ants run in a straight line in a horizontal plane by light compass, using a beam from a lamp and follow the same direction, when the running board is turned vertically orientating themselves by gravity. *Vice versa*, ants moving at a certain angle to gravity on a vertical board keep a corresponding angle to incoming light when the running board is turned horizontally. But this 2nd angle can appear in four relations to the original one. (Fig. 8). If Y is the angle which the ant first keeps and X the angle which it keeps after the turn of the plane these possibilities exist:



S_1 , first stimulus; S_2 , second stimulus; T_1 , first track; T_2' , T_2'' , T_2''' , T_2'''' , four possible second tracks.

Text fig. 8. Orientation of ants by light or gravity. (After VOWLES.)
Explanation in the text.

$$\begin{aligned} Y &= X \\ Y &= 180 + X \end{aligned}$$

$$\begin{aligned} Y &= 360 - X \\ Y &= 180 - X \end{aligned}$$

Also bees have been observed dancing with the "right" angle but to the "wrong" side of the vertical (v. FRISCH, LINDAUER).

VOWLES found that polarized light has the same orientating effect on ants as gravity and ordinary light and can in the same way be exchanged with the last two stimuli. VOWLES developed the hypothesis that one single taxis mechanism is responsible for compass reactions by light, gravity and polarized light. This mechanism is first adjusted during any movement. This adjustment then determines the orientation in relation to each of the three observed stimuli. This mechanism is selective in so far as it always uses one only of the stimuli out of the complex surroundings. The mechanism can remain unused when other factors, for instance landmarks, are directing the movement.

For the basis of the adjustment of the taxis mechanism we must, therefore, look to the central nervous processes.

JANDER has combined the ideas of BIRUKOW (1954) and VOWLES and developed a compensation theory of menotaxis. This means that efferent turning impulses would compensate the basic orientation of phototaxis and so lead to menotaxis as the observed result.

The ability to transpose stimuli of different sense modalities into each other, for instance light and gravity, has been found in several insects. But as far as we can understand it has only been developed into a way of communication ("language", v. FRISCH) in bees. A further analysis of these phenomena seems mainly to concern the physiology of central nervous system of insects.

If we try to trace a biological sense in the patterns of movements which we have treated here we may say:

- (1) Phototaxis leads the insect into its hunting or feeding area, it perhaps gives good optical conditions, and it conducts the animal through relatively long distances.
- (2) Photomenotaxis or light compass reaction leads the insect to cover long distances and reduces the probability of touching the same place several times.
- (3) Astronomical orientation enables the insect again to find known points in the landscape and to return to the starting point by the shortest way. In bees astronomical orientation can be communicated between individuals of the same species enabling new comers to find a place until then unknown to them.

As a fundamental lesson we can derive from our considerations that the variation of the specific perceptions and reactions, the so called "Umwelt" (J. v. UEXKULL,) makes detailed observations of each species necessary since no generalizations are permissible in this field of research.

Summary

1. The relevant magnitude in photomenotaxis is the angle between the directions of light and movement.
2. *Geotrupes silvaticus* is also influenced by the height of the light (BIRUKOW and DE VALOIS).
3. A sense of time enables certain insects to take the daily relative movement of the sun into account, i.e., to use astronomical orientation.
4. Observations on the astronomical orientation lead to the hypothesis that an internal correlation system compensates the relative movement of the sun by counterbalancing it (KALMUS).
5. Several insect species can transpose stimuli of different sense modalities into each other, e.g., light and gravity.

References

- BIRUKOW, G. 1954.—Photo-Geomenotaxis bei *Geotrupes silvaticus* Panz. und ihre zentralnervöse Koordination. *Z. vergl. Physiol.*, Berlin, **36**, pp. 176-211.
- BIRUKOW, G. 1957.—Tages- und jahreszeitliche Orientierungs-rhythmik beim Wasserläufer *Velia currens* F. (Heteroptera). *Naturwiss.*, Berlin, **44**, pp. 358-359.
- BIRUKOW, G. and DE VALOIS, R. L. 1955.—Über den Einfluss der Höhe einer Lichtquelle auf die Lichtkompassorientierung des Mistkäfers *Geotrupes silvaticus* Panz. *Naturwiss.*, Berlin, **42**, pp. 349-350.
- BRUN, R. 1914.—*Die Raumorientierung der Ameisen*. Jena.
- V. BUDDENBROCK, W. 1952.—*Vergleichende Physiologie*. I, Basel.
- COUTURIER, A. and ROBERT, P. 1956.—Orientation "astronomique" et déterminisme de la direction des grands vols chez *Melolontha melolontha* L. (Coléopt. Scarabaeidae). *C.R. Acad. Sci.*, Paris, **242**, pp. 3121-3124.
- V. FRISCH, K. 1946.—Die Tänze der Bienen. *Österr. zool. Z.*, Vienna, **1**, pp. 1-48.
- FRISCH, R. H. 1951.—Zur Biologie von *Cicindela martina* Latr. *Verh. d. Zool.* (Marburg 1950), Leipzig.
- JANDER, R. 1957.—Die optische Richtungsorientierung der Waldameisen (*Formica rufa* L.). *Z. vergl. Physiol.*, Berlin, **40**, pp. 162-238.
- KALMUS, H. 1956.—Sun navigation of *Apis mellifica* L. in the southern hemisphere. *J. exper. Biol.*, **33**, pp. 554-565.
- KÜHN, A. 1919.—*Die Orientierung der Tiere im Raum*. Jena (G. Fischer).
- LINDAUER, M. 1957.—Sonnenorientierung der Bienen unter der Äquatorsonne und zur Nachtzeit. *Naturwiss.*, Berlin, **44**, pp. 1-6.

- MEDER, E. 1958.—Über die Einberechnung der Sonnenwanderung bei der Orientierung der Orientierung der Honigbiene. *Z. vergl. Physiol.*, Berlin, **40**, pp. 160-164.
- PAPI, F. 1955.—Experiments on the sense of time in *Talitrus saltator* (Montague) Crustacea—Amphipoda). *Experientia*, Basel, **11**, pp. 201-202.
- SANTSCHI, F. 1911.—Observations et remarques critiques sur le mécanisme de l'orientation chez les fourmis. *Rev. suisse Zool.*, **13**, p. 303.
- SCHNEIDER, F. (cited after COUTURIER, A. & ROBERT, **29**, p.) 1956.—*Mitteil. Schweiz. ent. Ges.*, p. 69.
- V. UEXKULL, J. and KRISZAT, G. 1934.—*Streifzüge durch die Umwelten von Tieren und Menschen*. Berlin.
- VOWLES, D. M. 1954.—The orientation of ants. I. The substitution of stimuli. *J. exper. Biol.*, **31**, pp. 341-355.
- WOLF, E. 1927.—Über das Heimkehrvermögen der Bienen. II Mitt. *Z. vergl. Physiol.*, Berlin, **6**, pp. 221-254.

Callogobius seshaiyai, the name proposed for the Gobiid from the Vellar Estuary, Porto Novo.

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Introduction

In a recent publication (Jacob and Rangarajan 1959 b), a new Gobiid fish was described with figures but without a name. Since then, more specimens have been examined and we are convinced that this fish belongs to the genus *Callogobius* Bleeker and the name *Callogobius seshaiyai* is proposed for this. Besides the diagnostic characters, its differences from certain closely allied species were also pointed out in the earlier publication.

Callogobius seshaiyai sp. nov.,

As stated above, a description of this has already been published and in continuation of that, the measurements relating to the holotype specimen (No. F. 1908/2 deposited in the National Zoological collection with the Zoological Survey of India, Calcutta, are presented below:

- D 1. VI; D 2. I/13; A I/11; P. 17; V. 1/5; C. 17.
Total length—36.1 mm.
Height of body (at the level of the origin of the second dorsal)—5.1 mm.
Height of caudal peduncle—3.1 mm.
Length of head (from tip of snout to the cleft of the operculum)—7.1 mm.
Height of the head (at the level of the opercular cleft)—5.0 mm.
Length of caudal—10.0 mm.

(1) This species has been named after Professor R. V. Seshaiya in appreciation of his devotion to Zoology.

Distance from tip of snout to the origin of:—

I Dorsal	9.0 mm.
II Dorsal	14.0 mm.
Anal	14.4 mm.
Ventral	7.2 mm.
Caudal	26.1 mm.

Length of base of:—

I Dorsal	5.0 mm.
II Dorsal	9.4 mm.
Anal	9.0 mm.

Locality

The holotype specimen was collected during low tide from the exposed muds of a creek, near the estuarine station 'B', and where it joins the Vellar estuary. This region is less than two kilometres from the sea and is submerged under high salinity water during high tides. (Description of Vellar estuary and location of estuarine stations; vide Jacob and Rangarajan 1959 a). Paratype specimens are preserved in the Museum of this biological station.

This fish appears to be confined to the region mentioned, as it has not been obtained so far from any other region of the estuary. It makes 'U'-shaped or flask-shaped burrows in the soft mud and it appears probable that this and other ecological requirements limit its distribution.

Acknowledgements

Our thanks are due to Professor R. V. Seshaiya and Dr. M. L. Roonwal for their interest and Dr. P. Vijayaraghavan and Dr. K. Reddiah for help.

References

- JACOB J., and RANGARAJAN, K. 1959, a—Seasonal cycles of Hydrological events in Vellar estuary. *Proc. 1st. All India Congress of Zoology (Jabalpur)*. (In Press).
JACOB J., and RANGARAJAN, K. 1959 b.—A new Gobiid fish from Porto Novo. *J. zool. Soc. India*. 11 (2): 216-219.

Ribonucleic Acid During the Development of *Pila virens* (Lamarck)

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(Communicated by Prof. R. V. SESHAIYA, F.Z.S.I.)

(With 1 Text-Figure)

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Introduction

One of the recent trends in cytology and cytochemistry is the emphasis on nucleic acids and their role in the metabolism of the cell. The development in recent years of cytochemical and chemical techniques for the detection and quantitation of both types of nucleic acids by staining with basic dyes and digestion with nucleases, and the adoption of ultraviolet spectroscopy and tracer techniques have facilitated our understanding of the metabolism of nucleic acids during embryonic development of animals. The importance of nucleic acids in embryonic differentiation has been strongly emphasised by Brachet (1947). The investigations on the nucleic acids in embryogenesis carried out so far have been to a large extent confined to Amphibia and Echinodermata. Brachet (1940, 1942) and Krugelis *et al* (1954) have studied nucleic acids in Amphibia and Brachet (1932) (cited by Needham, 1950), Elson *et al* (1954), Callan (1949) and Elson and Chargaff (1952) have investigated in Echinodermata. Yao (1948) studied nucleic acids in the development of *Drosophila melanogaster*.

Raven (1945, 1946) investigated RNA in the development of *Limnaea* and Cleland (1951) investigated the nucleic acid content of various fractions by ultracentrifugation in *Ostra*. Berthier (1948) investigated RNA in the oogenesis of *Planorbis corneus*, Ranzoli (1953) in *Patella coerulea* and Minganti (1950) in *Limnaea*. The present study relates to the localisation of RNA in early oogenesis and during early development of *Pila virens*.

Material and Methods

Pila virens a fresh water Prosobranch commonly found in South India occurs in collections of water with plenty of succulent vegetation such as ponds, streams, and paddy fields. The eggs of this species are deposited on the banks of ponds a few inches above the water margin in a superficial burrow made for the purpose. Freshly laid eggs were used in this investigation. For the study of early oogenesis ovaries were removed from the animal and they were fixed in Serra's fixative (alcohol: formalin: acetic acid, 6: 3: 1) for 2 hours and stained in Pyronin-methyl green stain (Unna's stain) as recommended by Brachet (1938). Early stages of development and later embryos from laid eggs were also fixed in Serra's fixative for 1 hour. After fixation the different materials were dehydrated and embedded quickly at 56°C in paraffin wax. Sections were cut at 6 to 8 microns thickness. Staining was done in pyronin-methyl green and differentiated in alcohol quickly and mounted in Canada balsam after clearing in toluene. Control slides were also prepared by using ribonuclease and sections so treated did not bind pyronin.

The RNA in the following stages were studied: (1) Early oocytes to full grown oocytes (in early oogenesis) (2) freshly laid egg (3) cleavage (4) gastrula (5) veliger.

Observations

In the ovary the early oocyte contains a high content of RNA in its cytoplasm. During the growth of the oocyte there is a fall in the RNA content as judged by the decline in staining intensity (Fig. 1). The sudden



Text-fig. 1. Photomicrograph showing the relative content of RNA in the developing Oocytes of *Pila virens* Lamarck—Section—Serra—Pyronin—methyl green X ca 1000.
E.O., Early Oocyte. F.G.O. Further grown Oocyte. F.G.O'. Fully grown oocyte.

fall in the RNA content may probably be due to a rapid increase in the volume of the developing oocyte. In the unfertilized egg, the cytoplasm takes only a feeble stain indicating thereby the poor content of the acid. During fertilization an intense accumulation of ribonucleic acid near the animal pole is noticed when compared to other regions of the egg. A cytological study (Ramamoorthi, 1960) has shown that the male and female pronuclei are situated at this region of the egg. During segmentation stages a fall in RNA is noticed but at the time of gastrulation an enormous increase of RNA takes place in the endoderm and mesoderm cells. The ectoderm cells, however, showed a feeble content of RNA. In the early veliger a slight decline is observed in the endoderm and mesoderm cells compared to those in the gastrula. The region of the shell gland showed a high content of RNA.

Discussion

In *Pila*, as stated already, RNA decreases during oocyte growth. A decrease in RNA content during the growth of the oocyte has been observed by many investigators. Yao (1949) using cytochemical method observed a decrease of RNA during growth of the oocyte in *Drosophila*. In amphibia Brachet (1940, 1942) observed that the young yolkless oocytes are very rich in RNA but in later stages he found that the RNA decreases along an animal-vegetal gradient. A similar finding has also been reported in *Rana pipiens* by Bieber *et al* (1959). Ranzoli (1953) in *Patella* found that the RNA content of the cytoplasm is greatest when the relative amount of nuclear substance is maximal.

In *Pila*, during fertilization, an intense accumulation of RNA near the animal pole is noticed in contrast to other regions of the egg. The RNA content declines after fertilization followed by a drop during the segmentation stages, and a subsequent rise just before the onset of gastrulation. The cytochemical findings in *Pila* bear a close resemblance to the results of the chemical findings of Elson *et al* (1954). They found a drop in RNA immediately after fertilization, followed by a rise during blastulation and a second rise just before gastrulation.

In *Pila* also a rise of RNA content is noticed at gastrulation and is most conspicuous in the endoderm and mesoderm cells. But Raven (1945, 1946) found that the ectoplasm of *Limnaea* contained more RNA than the endoplasm and the mesomeres were rather poor in RNA. Investigations by several workers are suggestive of the close association of RNA with protein synthesis. Caspersson (1941) and Brachet (1942) demonstrated that cells which were actively engaged in protein synthesis contained a high content of RNA. Recent investigation by Brachet and Ficq (1956) provides evidence for the intimate relationship between RNA content and protein synthesis. As reported by the present author elsewhere (Ramamoorthi, 1959), a high alkaline

phosphatase activity is also noticed in the gastrula stage. A high phosphatase activity simultaneously with a high content of RNA is yet another indication of the occurrence of active protein synthesis at this stage. Thus the gastrula stage which is a prelude to differentiation of organ rudiments is metabolically also an important stage.

In *Pila* the shell gland which is in the form of ectodermal invagination in the early veliger shows a high content of RNA. Raven (1946) also made similar observations in *Limnaea*. A high alkaline phosphatase activity is also noticed in the shell gland region (Ramamoorthi, 1959).

Thus in *Pila* cytochemical studies provide information on the metabolism in the active regions of the egg and embryo during differentiation. Similar cytochemical studies of organ rudiments may be expected to throw some light on the specific metabolism in these regions.

Summary

1. The localisation of RNA in the early oogenesis and in embryos up to veliger stage in *Pila virens* has been studied cytochemically.
2. In the ovary the early oocyte contains a high content of RNA and during growth there is a fall in the RNA.
3. The unfertilized egg shows a poor content of RNA and during fertilization an intense accumulation near the animal pole has been noticed in contrast to other regions.
4. During segmentation there is a fall in RNA content and at the gastrula stage the RNA increases in the endoderm and mesoderm cells.
5. In the early veliger there is a decline of RNA in the endo- and mesoderm cells, and the region of shell gland shows the greatest activity.

Acknowledgements

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References

- BERTHIER, J. 1948.—Le fer dans l'ovogenèse Chez *Planorbis corneus*. *Bull. biol. Fr. Belg.*, **82**: 61.
- BIEBER, S. SPENCE, J. H. and HITCHINGS, G. H. 1959.—Nucleic acid and their derivatives and the development of *Rana pipiens*. I. Oogenesis. *Exptl. Cell Research.*, **16**: 202-214.
- BRACHET, J. 1940.—Etude histochemique des protéines au cours du développement embryonnaire des poissons de Amphibiens, et des oi seau. *Arch. Biol., Paris*, **51**: 167-202.

- , 1942.—La localisation des acides pentosenucleiques et less oeufs d' Amphibiens en voie de developpement. *Arch. Biol. Paris*, **53** : 207-257.
- , 1947.—The metabolism of nucleic acids during embryonic development. *Cold Spring Harbour Symp. Quant. Biol.*, **12** : 18-27.
- , 1947.—Nucleic acids in the cell and the embryo. *Symp. Soc. exp. Biol.*, **1** : 207-224.
- BARCHET, J. 1953.—The use of basic dyes and ribonuclease for the cyto-chemical detection of ribonucleic acid. *Quart. J. micr. Sci.*, **94** : (1) 1-10.
- BRACHET, J. and FICQ, A. 1956.—*Arch. Biol.*, **67** : 431.
- CALLAN, H. G. 1949.—Cleavage rate, oxygen consumption and ribosenucleic acid content of sea urchin eggs. *Biochem. et Biophysica. Acta.*, **3** : 92.
- CASPERSSON, T. 1941.—Studien uber den Eiweissum satz der Zelle. *Naturwissenschaften*, **29** : 33-43.
- CLELAND, K. W. 1951.—The enzymatic architecture of the unfertilized oyster egg. *Austral. J. exp. Biol. Med. Sci.*, **29** : 35.
- ELSON, D. and CHARGAFF, E. 1952.—Observations on the pentose nucleic acid composition in sea urchin embryos and in mammalian cell fractions. *Phosphorus metabolism*. Ed. W. D. McElroy and Bentley Glass. John Hopkins Press: Baltimore.
- ELSON, D., GUSTAFSON, T., and CHARGAFF, E. 1954.—The nucleic acids of the sea urchin during embryonic development. *J. Biol. Chem.*, **209** : 285-294.
- KRUGELIS, E. J., NICHOLAS, J. S., and VOSGIAN, M. E., 1952.—Alkaline phosphatase activity and nucleic acids during embryonic development of *Amblystoma punctatum* at different temperatures. *J. Exp. Zool.*, **121** : 489-504.
- MINGANTI, A. 1950.—Acidi nucleici e fos fatasi nello sviluppo della *Limnaea* Riv. di. biol., **42** : 295.
- NEEDHAM, J. 1950.—*Biochemistry and Morphogenesis*. Cambridge.
- RAMAMOORTHY, K. 1959.—Distribution of alkaline phosphatase during the early development of *Pila virens* (Lamarck). *Proc. Nat. Inst. Sci. India*, **25** : B(2) 87-89.
- , 1960.—Cytological and Chemical Studies in the Development of *Pila virens* (Lamarck) (Unpublished).
- RAVEN, CHR. P. 1945.—The development of the egg of *Limnaea stagnalis* L. from oviposition till first cleavage. *Arch. Neerl. Zool.*, **7** : 91.
- , 1946.—The development of the egg of *Limnaea stagnalis* L. from the first cleavage till the trochophore stage with special reference to its "Chemical embryology". *Arch. Neerl. Zool.*, **7** : 353-434.
- RAVEN, CHR. P. 1958.—*Morphogenesis. The analysis of Molluscan development*. Pergamon Press, London.
- RANZOLI, F. 1953.—Osservazioni citometriche sul comportments dei nucleoli ovogenesi di *Patella coerulea* L. *Caryologia*, **5** : 137.
- YAO, T. 1948.—Cytochemical studies on the embryonic development of *Drosophila melanogaster* 1. Protein sulphydryl groups and nucleic acids. *Quart. J. micr. Sci.*, **90** : (4): 401-409.

A Study of the Post-ovulatory Follicle in the Ovary of the Domestic Pigeon, *Columba livia**

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(With 1 Plate).

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Introduction

The post-ovulatory follicle in the oviparous vertebrates, though homologous to the mammalian corpus luteum, has received little attention in the past. In this paper an attempt is made to study in detail the histological changes occurring in the avian post-ovulatory follicle during its resorption and to compare it with the mammalian corpus luteum.

Giacomini (1896) and Sonnenbrodt (1908) made some preliminary observations on the post-ovulatory follicle (corpus luteum) in birds. Pearl and Boring (1918) claimed that a true "corpus luteum" is formed in the post ovulatory follicle of the fowl by the multiplication of the theca interna cells after the degeneration of the granulosa layer. Stieve (1918) and Hett (1918 and 1922) also made observations on the post-ovulatory follicles in birds. Novak and Duschak (1923), Fell (1925), and Cunningham and Smart (1934) denied the presence of a true corpus luteum in birds. The more recent studies on the problem are by Wynne-Edwards (1939), Davis (1942), Romanoff (1943), Rothschild and Fraps (1944) and by Marshall and Coombs (1957). Bretschneider and DeWit (1947) gave a good account of the follicular derivatives in vertebrates. Harisson (1948) and Brambell (1956) have reviewed most of the literature bearing on the post-ovulatory follicle and the corpus luteum in the vertebrate series.

* Part of a Thesis submitted for the Degree of Doctor of Philosophy of the Banaras Hindu University in 1959.

Materials and Methods

Birds were killed by decapitation and the ovaries containing post-ovulatory follicles were immediately removed and fixed in fluids like Bouin's, Allen's B-15, Zenker, Zenker-formol and Susa. Tissues were embedded in paraffin, sectioned $5-7\frac{1}{2}\mu$ and stained mostly in Heidenhain's iron-haematoxylin or Mallory's triple stain. Delafield's haematoxylin and Heidenhain's Azan stain were also tried. The presence, if any, of eggs in the oviducts was also noted.

Regression of the post-ovulatory follicle in the ovary of the domestic pigeon

A recently ovulated follicle is easily distinguishable from an atretic follicle by its larger size and by the presence of the aperture through which the egg has escaped out. Even after the closure of this aperture, a scar remains to mark the spot, and the edges of the follicle after ovulation look like lips bordering the point of discharge of the ovum.

In the ripe and unruptured follicle, the granulosa layer is thin and one-cell-layered and the theca is also thin with little fibrous tissue and few blood vessels in it.

The histological changes that take place during the involution of the post-ovulatory follicle of the pigeon can be described in five steps.

Stage I. (Pl. I, Fig. 1). Immediately after the expulsion of the ovum, the follicle shrinks in size, due to the contraction of the theca. The granulosa hypertrophies, becomes multi-layered and some of its cells become detached and come to lie in the follicular lumen. Erythrocytes resulting from haemorrhage of thecal capillaries may also be seen among the granulosa cells. The membrana propria appears as a very thin, wavy membrane between the theca interna and the granulosa layer. The theca interna has an inner cellular and an outer fibrous layer. No islets of the so-called 'luteal' cells of Pearl and Boring (1918) are seen in the theca interna. Blood capillaries and non-vascular spaces are common in both thecal layers, but those in the internal layer are more gorged with blood.

Stage II (Pl. I, Fig. 2). As a result of the hypertrophy of its cells the granulosa becomes many layered and have a syncytial appearance. Yolk globules are sometimes present in the follicular cavity and in the granulosa cells bordering the cavity (Pl. I, Fig. 3). These yolk globules are in all probability secreted by the granulosa cells after the shedding of the ovum. Vacuoles are commonly present in the granulosa cells. An important feature of this stage is the thickening of the membrana propria which now appears as a thick and wavy layer between the theca interna and the granulosa layer. This layer becomes ruptured at many places and is seen to

pucker into the granulosa layer (Pl. I, Fig. 3). The theca interna cells have a vacuolated appearance. Haemorrhage of the thecal capillaries lets the erythrocytes into the follicular lumen as well as into the granulosa layer. The theca externa becomes more fibrous and its capillaries have a shrunken appearance.

Stage III. (Pl. I, Fig. 4). The follicle further shrinks in size, the follicular cavity becomes very narrow, the granulosa cells more or less fill the lumen and the point of ovulation is closed by a plug of granulosa cells. The granulosa cells are vacuolated and their cytoplasm is devoid of any pigment granules. The membrana propria, at first, is very thick; then it fragments and gradually disappears. The theca interna cells are also vacuolated; fibroblasts occur among these cells as well as in the granulosa. The theca externa is very fibrous with shrunken capillaries. Strands of fibrous tissue from the theca externa extend into the granulosa layer through narrow channels right across the theca.

Stage IV. (Pl. I, Fig. 5). The follicle shrinks in size considerably and the lumen is completely filled by a mass of vacuolated granulosa cells. These cells have shrunken nuclei and reticulate cytoplasm devoid of any pigment. Both the theca externa and the interna are very fibrous and are no longer distinguishable as separate layers. The thecal capillaries are shrunk and are not distinguishable.

Stage V. (Pl. I, Fig. 6). The final stage of the post-ovulatory follicle is very much like the last stages of atretic follicles and it is hard to distinguish between the two. The follicle shrinks further more and the thecal covering becomes densely fibrous. Gradually the theca becomes thin and most of the vacuolated granulosa cells in the follicular cavity become pycnotic and diappear. Finally, all that remains of the ovulated follicle are a few cells entombed within the thin theca in the stroma of the ovary. The connective tissue from the surrounding stroma grows in and finally obliterates the follicle and the original position of the post-ovulatory follicle is marked by a fibrous scar in the stroma of the ovary.

In some cases, the final stage of involution shows a little variation in that the vacuolated cells present in stage IV disappear completely, and the lumen is occupied by fibrous tissue derived from the fibroblasts of the theca. This fibrous knot persists in the stroma for a longer while.

Discussion

The post-ovulatory follicle in the pigeon resembles in many respects, an atretic follicle. In both of them the granulosa cells play a predominant part; these cells ultimately become vacuolated and degenerate much in the same way in both cases. The two kinds of follicles remain in the ovary only for

a brief period. In fact, it is somewhat difficult to distinguish an old post-ovulatory follicle from an old atretic follicle.

Many attempts have been made in the past to compare the avian post-ovulatory follicle to the mammalian corpus luteum, since both of them are homologous (Pearl and Boring 1918; and Hett, 1922). The former authors reported that in the post-ovulatory follicle of the fowl the 'luteal' cells in the theca interna multiply, migrate into the lumen, and ultimately obliterate the cavity, giving rise to a glandular structure comparable to the mammalian corpus luteum. However, this homology is contested by many other investigators. Fell (1925), after a careful study, contradicted the findings of Pearl and Boring and reported that the cells which fill the lumen in the post-ovulatory follicle in the fowl are derived from the granulosa cells and showed considerable cytological difference from the 'luteal' cells of the theca interna. Moreover, she also showed that the yellow pigment in the granulosa cells was derived from the breakdown of erythrocytes and the formation of fat in these cells was due to fatty degeneration.

The findings in the pigeon support Fell (1925) in that a true corpus luteum does not exist in the avian ovary. In the post-ovulatory follicles of the pigeon, the theca interna does not contain any 'luteal' cells in the sense of Pearl and Boring (1918) and so the question of their multiplying and filling the lumen does not arise. The vacuolated cells that fill the lumen of the post-ovulatory follicle in the pigeon (Pl. I, Figs. 2, 3, 4 and 5) are entirely derived from the granulosa layer. Further, the yellow pigment said to be present in the post-ovulatory follicle of the fowl is absent in the case of the pigeon.

Davis (1942) also concludes that there is no corpus luteum in birds for the reason that the avian post-ovulatory follicle rapidly regresses and that there is no hypertrophy or proliferation of the granulosa cells as in the case of the mammalian corpus luteum. Cunningham and Smart (1934) and Harisson (1948) also hold a similar view. This view is further supported by the fact that Riddle and Schooley (1938) did not find progesterone in the avian post-ovulatory follicles. However, Hooker and Forbes (1947) Fraps, Hooker and Forbes (1948) and Fraps (1955) found considerable amount of progestin in birds and they believe that the post-ovulatory follicles and the atretic follicles are concerned in its production.

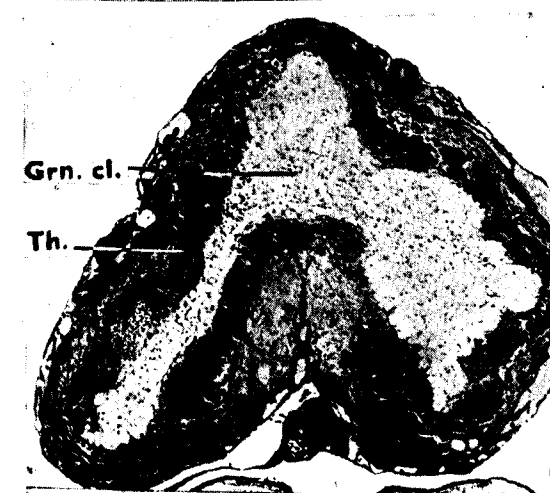
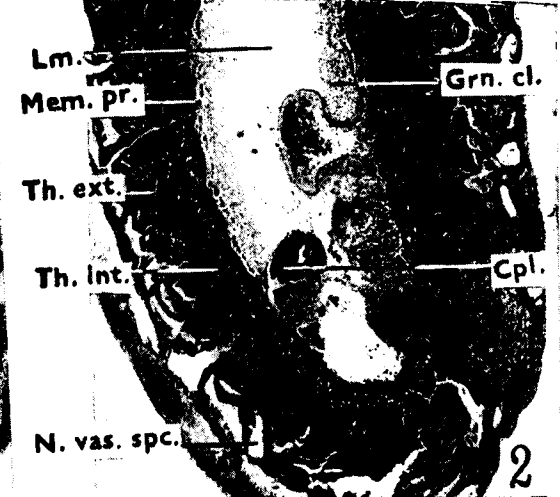
The process of involution of the post-ovulatory follicles in the pigeon closely resembles the process in oviparous amphibians and reptiles. The thickening of the membrana propria as seen in the post-ovulatory follicle of the pigeon (Pl. I, Figs. 2, 3 and 4) is also reported during the regression of the post-ovulatory follicles in amphibians and reptiles by Cunningham and Smart (1934). The granulosa cells fill the follicular cavity in these cases by hypertrophy. There is no multiplication of these cells by mitotic or amitotic

Explanation of Plate I

- Fig. 1. Photomicrograph of post-ovulatory follicle in stage I showing the hypertrophied granulosa layer, thickened theca and capillaries. X 30
- Fig. 2. Photomicrograph of post-ovulatory follicle in stage II showing the hypertrophied granulosa, haemorrhage of thecal capillaries, thickening of membrana propria and the fibrous theca. X 40
- Fig. 3. An enlargement of a portion of Fig. 2 showing yolk globules in the lumen adjacent to the hypertrophied granulosa cells and the thickened membrana propria. X 270
- Fig. 4. Photomicrograph of post-ovulatory follicle in stage III showing the follicular lumen filled with granulosa cells, the closing of the point of ovulation by a plug of granulosa cells and the hypertrophied membrana propria. X 50
- Fig. 5. Photomicrograph of post-ovulatory follicle in stage IV showing the vacuolated granulosa cells in the lumen and the thickened thecal layers. X 70
- Fig. 6. Photomicrograph of the post-ovulatory follicle in stage V showing the remnants of granulosa cells in the lumen and the fibrous theca. X 100

Key to Lettering of Figures

Cpl.	Capillary.
Grn. cl.	Granulosa cells.
Lm.	Lumen.
Mem. pr.	Membrana propria.
N. vas. sp.	Non-vascular space.
Ovl. pt.	Ovulation point.
Th.	Theca.
Th. ext.	Theca externa.
Th. int.	Theca interna.
Ylk. glb.	Yolk globules



division. However, Weekes (1934) reported mitosis and amitosis in the granulosa cells of the post-ovulatory follicles of certain lizards.

Signs of secretion of yolk into the lumen of the ovulated follicle as seen in the pigeon (Pl. I, Fig. 3) is seldom reported in the case of birds. However, Hett (1923, '24) found yolk being secreted into the lumen of the post-ovulatory follicle in *Triton vulgaris* and in the lizard, *Lacerta agelis*. According to Brambell (1956) this point is of interest because "it is suggestive of the secretion of liquor folliculi in the recently ruptured mammalian follicle as well as because of its bearing on the metabolism of yolk by the granulosa cells".

In the present state of our knowledge, it is difficult to ascribe any definite role to the post-ovulatory follicles in birds and other oviparous vertebrates. Rothschild and Fraps (1944) found that the removal of the ovulated follicle in the fowl, when the egg was in the oviduct, resulted in its retention in the oviduct beyond the normal time. Most eggs were retained from one to seven days. So these authors believe that the post-ovulatory follicle of the hen plays an important part in controlling the duration of the stay of the discharged ovum in the oviduct and its subsequent laying. Altland (1951) reported the presence of a well developed corpus luteum in the oviparous box-turtle, during the period when the egg is in the oviduct and the shell is being formed and thinks that the corpus luteum is concerned in this process. Weekes (1934) also found that the corpus luteum (post-ovulatory follicle) of the oviparous lizard, *Amphibolurus*, persists while the eggs are lodged in the oviduct. Hill and Gatenby (1926) reported the development of a well-organised corpus luteum in the ovary of *Ornithorhynchus* that underwent regression soon after ovulation.

These observations point to the possibility, as Rothschild and Fraps (1944) have pointed out, that the post-ovulatory follicle in oviparous vertebrates, "like its mammalian homologue, exerts an influence on the oviducal history of the ovum it once contained". In birds, the eggs are retained in the oviduct only for a short time. This may explain the fact that there is no organisation of the granulosa cells into a typical corpus luteum in the post-ovulatory follicles of birds.

Summary

1. Changes that take place during the involution of the post-ovulatory follicle of the pigeon have been split out in five steps.
2. The findings in the pigeon support the view that a true corpus luteum does not exist in birds.
3. The cells which fill the lumen of the post-ovulatory follicle of the pigeon are derived from the granulosa cells and not from the cells of the theca interna.

4. The granulosa cells fill the follicular lumen by hypertrophy only. Mitosis or amitosis of the cells is not seen.

5. The involution of the post-ovulatory follicles of the pigeon closely resembles the process as it obtains in the case of the oviparous amphibians and reptiles.

6. Some signs of secretion of the yolk into the lumen of the ovulated follicle of the pigeon are evident but not corroborated by the findings of previous workers.

7. The significance of the post-ovulatory follicles in oviparous vertebrates is not clear. There is some evidence to show that the post-ovulatory follicle of oviparous vertebrates may be exerting some influence on the oviducal history of the ovum it once contained.

Acknowledgements

I am greatly indebted to Dr. A. B. Misra, Professor of Zoology, Banaras Hindu University, for suggesting the problem, guidance and help. I am also grateful to the Ministry of Education, Government of India, for the award of a Senior Research Scholarship, which made this work possible.

Literature cited

- ALTLAND, P. D., 1951.—Observations on the reproductive organs of the box-turtle. *J. Morph.*, **89**: 499-615.
- BRAMBELL, F. W. R., 1936.—Marshall's Physiology of Reproduction I (1) XIX + 688 pp. London (Longmans).
- BRETSCHNEIDER, L. H. AND J. J. D. DEWIT, 1947.—*Sexual Endocrinology of non-mammalian Vertebrates*. Amsterdam (Elsevier).
- CUNNINGHAM, J. T. AND W. A. M. SMART, 1934.—Structure and origin of Corpus luteum in lower vertebrates. *Proc. roy. Soc. (B)*, London, **116**: 258-281.
- DAVIS, D. E., 1942.—The regression of the avian postovulatory follicle. *Anat. Rec.*, **82**: 297-307.
- FRAPS, R. M., 1955.—The varying effects of sex hormones in birds. *Mem. Soc. Endocr.*, **4**: 205-219.
- FRAPS, R. M. C. W. HOOKER AND R. T. FORBES, 1948.—Progesterone in blood plasma of the ovulating hen. *Science*, **108**: 86.
- FELL, H. B., 1925.—Histological studies of the gonads of the fowl. III. The relation of the 'luteal' cells of the ovary of the fowl to the tissue occupying the atretic and discharged follicles. *Quart. J. micr. Sci.*, **60**: 591-609.
- GIACOMINI, E., 1896.—Contribuzione all'istologia dell' ovario dei selaci. *Ricerca Lab. Anat. Norm. Roy. Univ. Roma*, **5**: 80-120.
- HARRISON, R. J., 1948.—The development and fate of the corpus luteum in the Vertebrate Series. *Biol. Rev.*, **23**: 296-351.
- HETT, J., 1918.—Das Corpus luteum der Dohle (*Colaeus monedula*). *Arch. f. mikr. Anat.*, **97**: 718-838.
- , 1922.—Das Corpus luteum der Vogel. *Verh. Anat. Ges. Jena*, **31**: 153-159.
- , 1923.—Das Corpus luteum des Moiches (*Triton vulgaris*). *Z. Ges. Anat. Z. Anat. Entw. Gesch.*, **68**: 243-271.
- , 1924.—Das Corpus luteum der Zauneidechse (*Lacerta agilis*). *Z. mikr. Anat. Forsch.*, **1**: 41-84.

- HILL, J. P. AND J. B. GATENBY, 1926.—The corpus luteum of the Monotremata. *Proc. Zool. Soc. Lond.*, **47**: 715-763.
- HOOKER, C. W. AND T. R. FORBES, 1947.—A Bioassay for minute amounts of progesterone. *Endocrinol.*, **41**: 158.
- MARSHALL, A. J. AND C. J. F. COOMBS, 1957.—The interaction of environmental, internal and behavioural factors in the rook, *Corvus f. frugilegus* L. *Proc. Zool. Soc. Lond.*, **128**: 545-589.
- NOVAK, J. AND J. DUSCHAK, 1923.—Die Veränderungen der Follikelhüllen beim Haushuhn nachdem Follikelsprung. *Zeit. f. Anat. u. Ent.*, **69**: 483-492.
- PEARL, R. AND A. M. BORING, 1918.—The corpus luteum in the ovary of the domestic fowl. *Amer. J. Anat.*, **23**: 1-35.
- RIDDLE, O. AND J. SCHOOLEY, 1938.—Tests indicating absence of progesterone in fowl ovary. *Anat. Rec.*, **72**: 59.
- ROMANOFF, A. L., 1943.—Growth of avian ovum. *Anat. Rec.*, **85**: 261-267.
- ROTHSCHILD, I. AND R. M. FRAPS, 1944.—On the function of the ruptured ovarian follicle of the domestic fowl. *Proc. Soc. Exp. Biol. Med.*, **86**: 79-82.
- SONNENBRODT, H., 1908.—Dis Wachstumsperiode der Oocyte des Huhnes. *Arch. f. Mikr. Anat.*, **72**: 415-480.
- STIEVE, H., 1918.—Die Entwicklung des Eurstockseis der Dohle (*Colaeus monedula*). *Ibid.*, **92**: 137.
- WEEKES, H. C., 1934.—The corpus luteum in certain, oviparous and viviparous reptiles. *Proc. Linn. Soc. N. S. W.*, **59**: 380-391.
- WYNNE-EDWARDS, U. C., 1939.—Intermittent breeding of the Fulmar (*Fulmarus glacialis*) with some general observations on non-breeding in sea birds. *Proc. Zool. Soc. Lond.*, **109**: 127-132.

On a new species of the genus *Heteromicrocotyle* (Monogenea : Microcotylidae) from the gills of *Caranx affinis* Rupp*

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(From the Central Marine Fisheries Research Station, Mandapam Camp P.O.,
South India.)

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Introduction

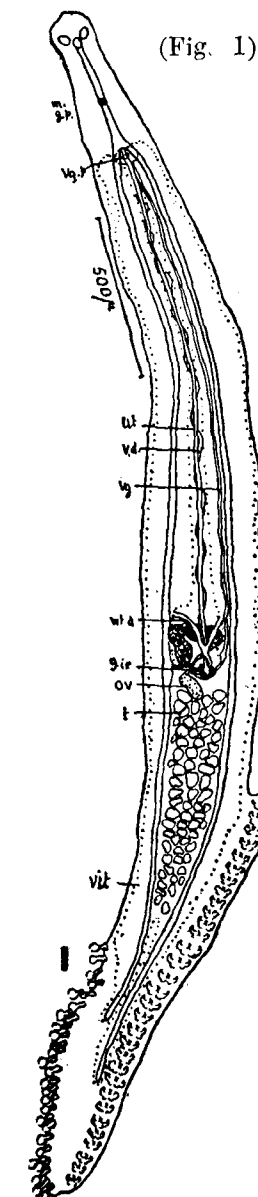
The present communication deals with a new species of the genus *Heteromicrocotyle* Yamaguti (1953) and is represented by two specimens which were collected from the gills of *Caranx affinis* Rupp obtained at Mandapam. Incidentally this forms the first record of the genus from India also. It differs from the only known species, viz., *Heteromicrocotyle carangis* Yamaguti (1953) and hence a full description of it is given.

Heteromicrocotyle indicus n.sp.

(figs. 1-5).

The worms are elongate with a narrow body; their length ranges from 2.61 mm. to 3.75 mm. and their maximum width is from 0.20 mm. to 0.38 mm. across the middle region of the body. Haptor is distinctly marked off from the body and is about one third the total length of the worm (with

reference to the longer side). The haptor is asymmetrical both in the extent of the two sides as well as in the nature of the clamps on them. The longer side has 29 to 31 clamps and they are of the microcotylid type. The size of the clamp ranges from $45 \times 106 \mu$ to $58 \times 117 \mu$. The shorter side is two third the length of the longer row and has the 'pyragraphorus-type' clamps whose number ranges from 24 to 28. Their size ranges from $70 \times 39 \mu$ to $106 \times 48 \mu$. Terminal lappet and anchors are not present.



(Fig. 1).

Mouth is sub-terminal. The buccal suckers are aseptate and their size ranges from $24 \times 36 \mu$ to $42 \times 62 \mu$. The size of the pharynx is from $32 \times 32 \mu$ to $48 \times 35 \mu$. The intestinal bifurcation is situated at a distance equal to one ninth of the total length from the anterior end. The caeca extend posteriorly into the haptor, the shorter one terminating at a distance equal to one seventh of the total length from the posterior extremity, whereas the longer one extends further to a length equal to one third the distance between the end of the shorter caecum and the posterior extremity.

Gonads occupy the anterior half of the hinder half of the worm. The number of testes ranges from 60 to 67; approximately the posterior two thirds of the testicular zone is overlapped by the longer side of the haptor. The size of the testis ranges from $20 \times 14 \mu$ to $44 \times 40 \mu$. Vas deferens opens at the penis which is armed with a corona of 16 hooks each 9μ to 10μ long. Male genital pore is median and is situated at a distance equal to two thirds of the length from the anterior end of the worm to the intestinal bifurcation. The genital pore is armed with two anterior groups of four spines each, two posterior groups also of four spines each and in between and on either side of these are two stout large hooks each measuring 25μ . In the groups of four spines two are longer each 35μ long and two are shorter each 29μ long.

Ovary is pre-testicular and its size ranges from $48 \times 28 \mu$ to $56 \times 28 \mu$. Ovary and the oviduct extend to a length approximately equal to one third the length of the testicular region. The distal end of the oviduct is directed backwards and is continued by a narrow duct which curves in front of the ovary and enlarges into

* Formed part of thesis approved for the Degree of Doctor of Philosophy of the University of Madras.

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Legend for Figures

Fig. 1. *Heteromicrocotyle indicus* n.sp. (ventral view).

Abbreviations.

g.i.c. genito-intestinal canal, m.g.p. male genital pore.
ov. ovary, t. testes, ut. uterus, v.d. vas deferens,
vg. vagina, vg.p. vaginal pore, vit. vitellaria,
vit.d. vitelline duct.

Figs. 2-5. *Heteromicrocotyle indicus* n.sp. (continued).

Fig. 2. Enlarged view of the gonadal region and their ducts, (ventral view).

Fig. 3a. Terminal region of the female and male ducts,

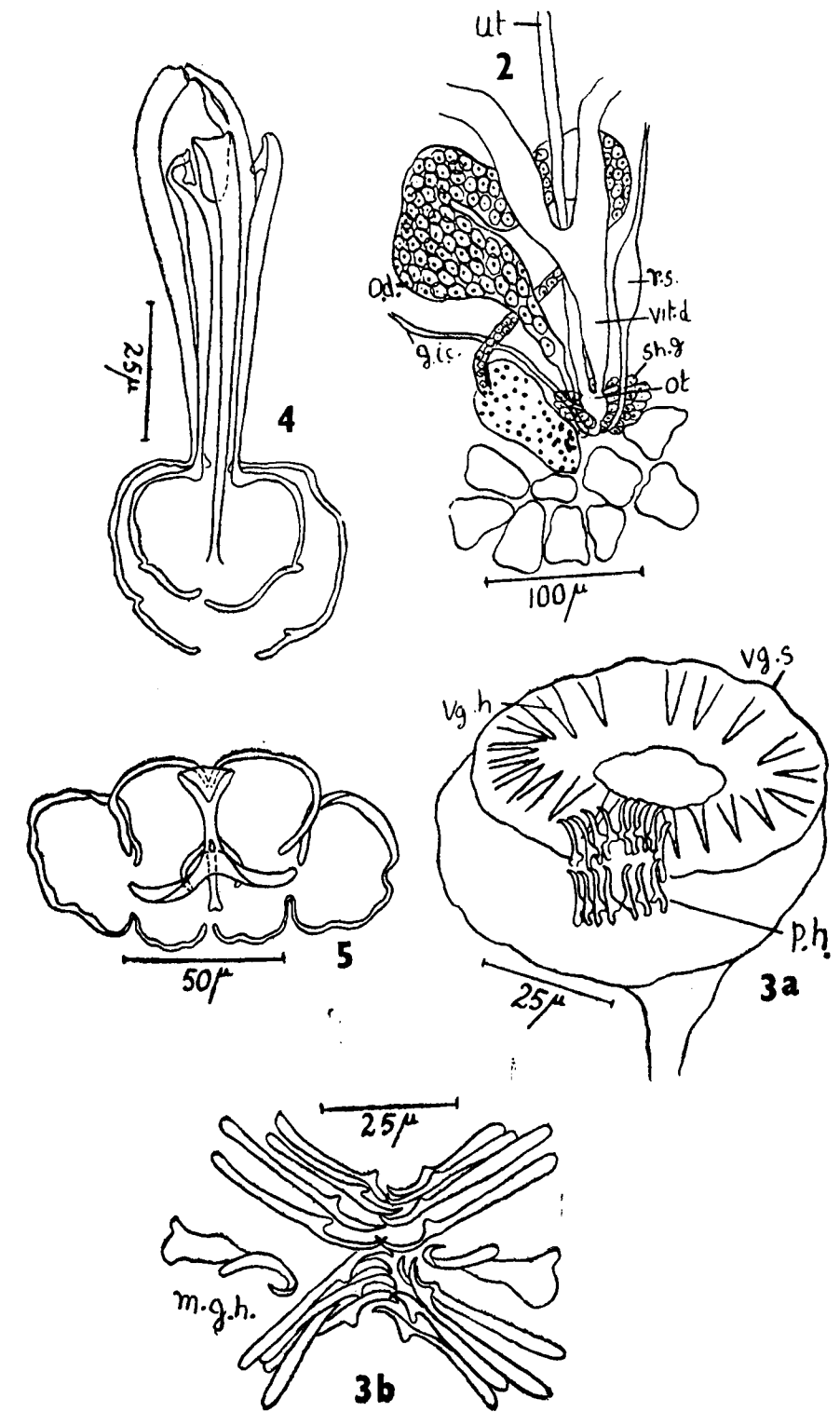
Fig. 3b. Male genital hooks,

Fig. 4. 'pyragraphorustype' clamp (ventral view),

Fig. 5. Microtylid-type clamp.

Abbreviations.

m.g.h. male genital hooks, ot. ootype, o.d. oviduct. p.h. penis hooks,
r.s. receptaculum seminis,
sh.g. shell gland,
vg.h. vaginal hook,
vg.s. vaginal sucker.



the ootype, surrounded by the shell glands. Beyond the ootype the oviduct is continued as the *uterus* which is median and opens posterior to the male pore.

Vitelline follicles extend from the level of the intestinal bifurcation to the end of the crura posteriorly. The transverse vitelline ducts originate immediately anterior to the level of the oviducal field and unite to form the common vitelline duct about one third the oviducal length from the beginning of the oviducal field. The common vitelline duct extends to a length approximately equal to one third the oviducal length and opens at the ootype. Genito-intestinal canal runs obliquely in front of the ovary. It opens at the ootype at one end and into the right caecum at the other. *Vaginal opening* is median and is situated just behind the intestinal bifurcation. It is surrounded by a sucker whose size ranges from $54 \times 72 \mu$ to $72 \times 77 \mu$. It is armed with 20 spines each measuring from 9μ to 11μ in length. The vaginal canal is continued posteriorly close to the inner side of the left caecum and opens at the oviduct just behind the ootype. About the level of the distal end of the oviduct the vaginal canal is enlarged into the receptaculum seminis and its size is from $45 \times 20 \mu$ to $56 \times 26 \mu$.

Remarks: The only other species known of this genus *Heteromicrocotyle* is *H. carangis* Yamaguti (1953), described from Macassar from the gills of a *Caranx* sp. *H. indicus* differs from *H. carangis* in the following features. Penis has a corona of 16 hooks instead of the cirrus with small spines as described for *H. carangis*; vaginal opening is just behind the intestinal bifurcation and is armed with spines in *H. indicus* whereas in *H. carangis* it is unarmed and situated about half way between the intestinal bifurcation and the ovary. Hence *H. indicus* is described as a new species.

Specific diagnosis: *Heteromicrocotyle* having a penis armed with 16 hooks, arranged in the form of a corona; male genital pore median, armed with two anterior groups of four spines each, two posterior groups also of four spines each and in between and on either side of these are two stout large hooks. Vaginal opening is median, just behind the intestinal bifurcation and surrounded by a sucker armed with 20 spines. Worms' length is from 2.61 mm. to 3.75 mm. and width 0.20 mm. to 0.38 mm. Clamp-size is from $45 \times 106 \mu$ to $58 \times 117 \mu$, the 'pyragraphorus type' clamp is from $70 \times 39 \mu$ to $106 \times 48 \mu$; testes number 60 to 67 and ovary size is from $48 \times 28 \mu$ to $56 \times 28 \mu$.

Summary

A description of *Heteromicrocotyle indicus* n.sp. based on two specimens collected from the gills of *Caranx affinis* Rupp. obtained at Mandapam is presented.

Acknowledgments

It gives me great pleasure to record my deep sense of gratitude to Dr. N. K. Panikkar and Dr. S. Jones for their help, co-operation and encouragement during the period of my work at the Central Marine Fisheries Research Station. I am grateful to the Ministry of Education, Government of India for the award of the Senior Research Scholarship.

Reference

- YAMAGUTI, S., 1953.—Parasitic worms mainly from Celebes, Pt. 2. Monogenetic trematodes of fishes. *Acta Medicinæ Okayama*, 8 (3): 203-256.

Soil Nematodes from Madras City*

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Communicated by Prof. P. K. MENON

(With 10 Text-Figs)

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Introduction

In the field of Helminthology, there has long been a want of taxonomical and ecological account of the free living nematodes in India. When compared to the reports on the free-living nematodes from the other parts of the world, it looks as though this branch of Helminthology viz., Nematology, has been almost neglected till now in our country. During the past half a century, much information on the morphology and bionomics of the free-living nematodes has been made available, through the researches of many workers in the various parts of the world—especially the pioneering works of Bastian (1865) with his monograph on the Anguillulidae, of Butschli (1876) who gave a re-arranged version of Bastian's (1865) classification and of de Man (1884) with his five ecological groups of the soil nematodes.

Following de Man's (1884) report, other workers turned to the study of nematology. Among them was Cobb (1917, 1918, 1920) whose outstanding contribution to the science of nematology can be said to have laid the foundations for the modern methods in estimating the nema population of the soils. In one monograph (Cobb 1917) on the genus *Mononchus* he described

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a large number of species of which not less than 54% were new ones, and in another (Cobb 1920) one hundred and eighty were new. Steckhoven (1941) commenting on the discovery of new species by many workers, stated that, "no less than 90% of the species of *Acrobeles* described by Thorne (1925) were new to science and Steiner alone created 150 new species of *Mer-mithidae*, which means an increase of 300%" (over the known species). Proceeding further he stated that, "the number of the species of the genus *Mononchus* discovered between 1934 and 1949 had trebled". In a statistical list from 1920 to 1941 of the nemas from the various habitats, he mentioned that, "whereas the number of the marine nemas discovered, have increased by 111%, outnumbering the other forms, the fresh-water forms have increased only by 36%, the soil-inhabiting by 51%, the parasites of vertebrates by 64% and that of invertebrates by 41%".

Another notable contribution to the field of Nematology was that of Micoletzky (1922) who described six ecological types of nematodes of the soil. Thorne (1939) in the U.S.A. published a monograph on the *Dorylaimoidea* (fresh-water nematodes) and Steckhoven (1941) brought out a manual describing the nematodes parasitic on plants. In 1951 Goodey published a monograph of the soil and fresh-water nematodes, in which he gave a list of all the nematode species from the various parts of the world.

Many soil nematodes feed on plant debris and some feed on plant tissues. This observation led to the study of the parasitic nematodes of plants. The present day work in nematology is mostly the study of the plant parasitic nematodes. In this field large contributions have been made by Steiner (1936, 1949) and Thorne (1925, 1941, 1949) from the U.S.A. and Goodey (1933, 1951) and his associates from England.

Previous Work in India

Stewart in 1914 gave an account of a few species of nematodes from Chilka lake. In 1926 Bhatia recorded some fresh water forms from Lahore. Krishna Iyer (1933) reported about the root-gall nematode *Heterodera marionii* (Cornu) Goodey, while Venkata Rayan (1933) recorded *Anguillulina cecidoplaster* forming leaf galls on *Andropogon pertusus* Wild. Mayne and Subramanyam (1933) gave an account of the nematode worms in relation to Cockchafer and mealy bug problem in Coorg. Dastur (1936) reported about the nematode diseases of rice in Central Provinces. In 1936 Kreis gave an account of some free living nematodes of Madras during some stray dredgings in Cholavaram lake. Iyer (1944) recorded *Criconema rusticum* Micoletzky 1921 in Travancore. Thirumalachar published a note on the eelworms of the cotton plant in 1946. An account of the nematode diseases of the Coffee plant was given by Venkata Rayan in 1947 and the root-knot nematode was observed on potato-tubers in Simla by Thirumalachar in 1951.

It is obvious from the above that there has not been a regular flow of information about the free living and plant parasitic nematodes in India.

The Present Work

The present work was taken up mainly for taxonomical purposes with ecology as a side issue. The work was very much handicapped for want of proper literature. However, it was over come with the invaluable help rendered with a generous supply of photostat copies, reprints etc., by Dr. G. Steiner and Dr. A. L. Taylor of the U.S. Agricultural service, Washington and by the late Dr. T. Goodey from England. But for their help the present work would not have been possible.

Methods and Materials

Cobb's (1918) method was adopted in collecting the soil samples, but instead of the volume 2.84" x 2" as specified by Cobb, 2" x 1" meal tubes were used to collect soil samples. With the first insertion at a spot, the top two inches layer of the soil was obtained. By a second insertion in the same spot the next two inches of soil (from 2" to 4") was obtained. By the third insertion, soil from 4" to 6" was collected. Several such samples were taken mixed well and divided into aliquots. An aliquot was tied up in a small piece of mull cloth (80—100 counts) and suspended in a funnel of water, the stem of the funnel having a rubber tube closed by a pinch cock. This set-matodes in the soil, crept through the meshes of the cloth and settled down in the water. The pinch cock was released and the nematodes in the water were collected in a test tube, and set aside for sometime to allow the nematodes to settle down. The supernatant water was decanted and the nematodes in the small volume of water at the bottom were transferred to a watch glass for counting and processing. Since most of the nematodes were very small (0.5 mm to 1.0 mm) a hair needle made of human hair or pig hair (sharpened at one end) tied to a match was used to pick up the nematodes.

Processing Soil Nematodes for Microscopical Studies

The nematodes held in a small volume of water were killed by gentle heat of a spirit lamp flame. Since it is a well known fact that the nematodes do not readily render themselves to the treatments of ordinary stains and alcohols ("which in most cases is unsatisfactory and unnecessary"—Baylis and Daubney 1926), the simpler method advocated by Cobb (1918) was followed for purposes of anatomical studies and sketching. The nematodes were temporarily mounted in water. The finer details were examined under high power objectives. Illustrations were made out of many individuals of the same form and compared*. Out of these forms, the one having a greater

* "Some of the details shown in the diagrams can be seen only with the aid of the highest powers of the microscope, skillfully used under favourable circumstances. The reader therefore, will not expect readily to see in his specimens, all the features depicted in the illustrations as they have been prepared from favourable specimens selected from a large number" (Cobb 1918).

proportion of clarity regarding the body characters was chosen as the type specimen and described in detail.

The nematodes were fixed in acetoformal fixative (Goodey 1949, 1951). After fixation overnight the specimens were transferred to a cavity slide with a few drops of Cotton Blue—Lactophenol (.0025% — .001%) which had been previously warmed to 50° — 60°C. The intensity of the Cotton Blue stain was controlled under the microscope, after which the nematodes were transferred to a fresh drop of plain lactophenol on a slide. A coverslip was then added and the edge sealed with lactophenol gum. The mounted specimens (type species) were then deposited in the departmental museum for future references **.

The present work deals with the soil nematodes of the sub-class: Phasmidia, Chitwood and Chitwood 1933. The following five new species and one new variety are described in this paper.

1. *Rhabditoides coprophaga longicaudatus* var.nov.,
2. *Bunonema madrasicum* sp. nov.,
3. *Diploscapter orientalis* sp.nov.,
4. *Cephalobus minor* sp.nov.,
5. *Eucephalobus verrucosus* sp.nov.
6. *Eucephalobus setensis* sp.nov.,

1. *Rhabditoides coprophaga longicaudatus* var. nov.

Total : Two females Text fig. 1

*Measurements : L= 0.5 mm to 0.65 mm ; a=25 — 27
b=5.3 — 5.8 ; c=3.31 ; V=50% — 51%

** Throne (1949) commenting on the type species stated that, "many nematode genera are based on type specimens which have not been preserved well and the original descriptions and figures are meagre and require extensive emendation. In many instances, there is little possibility of anyone's ever collecting topotypes (specimens secured in the exact locality in which the type was secured). Therefore it is proposed that representative species be designated for such genera and that these species be described in detail, and used as basic material for future comparative work. Designation of the representative species would of course be superseded by an emended description of the type should later workers collect specimens."

*L=Total length of the body.

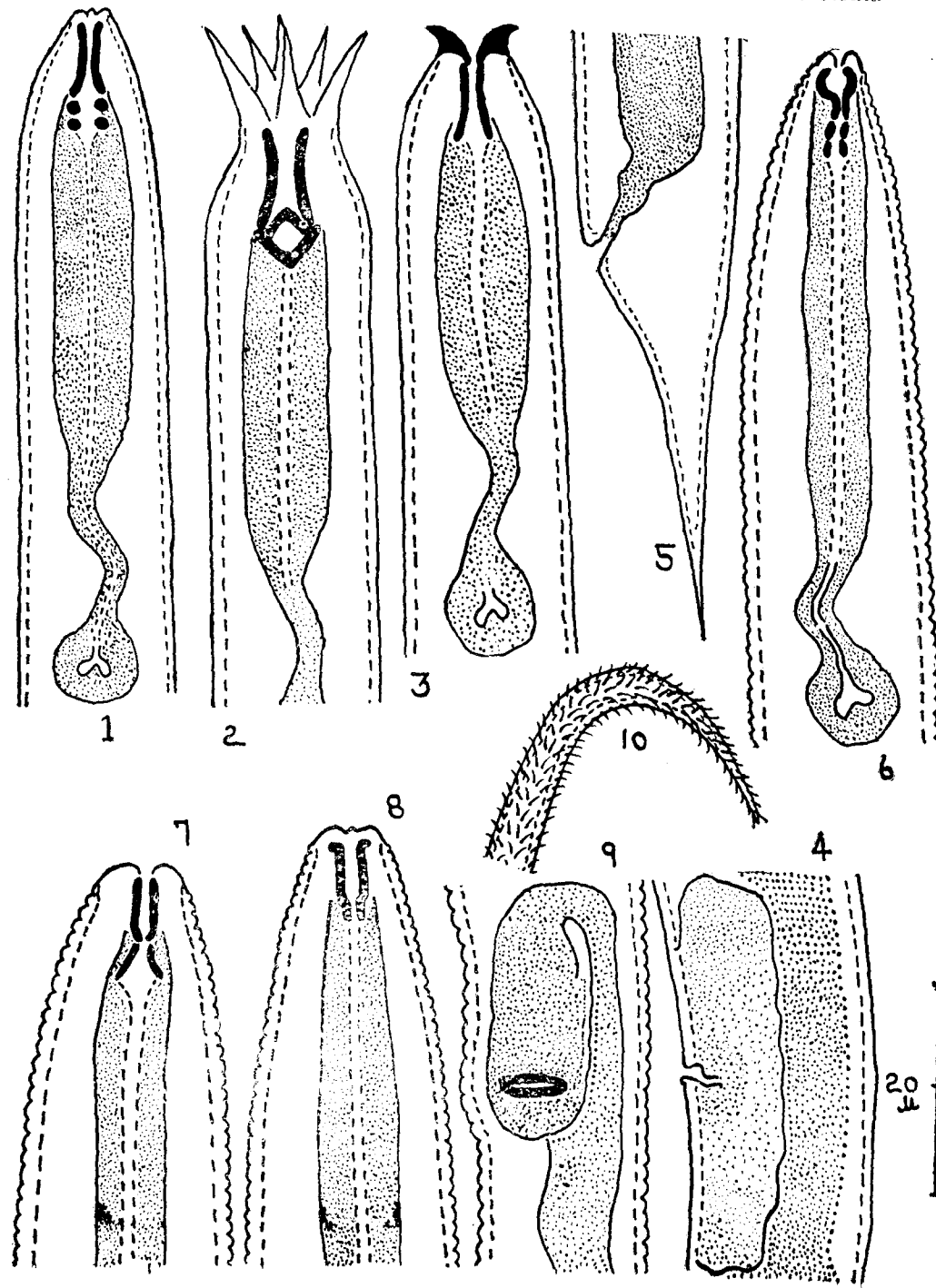
a=Total length of the body.
Greatest width of the body.

b=Total length of the body.
Length of the oesophagus.

c=Total length of the body.
Length of the tail.

V=Position of the vulva from the
anterior end, expressed in terms
of percentage. (%)

Body small and slender with faint cuticular striae. Head narrowed off from the rest of the body, with six faintly seen lips devoid of bristles. Stoma



long, with concave sides, $18.464 \mu / 2.308 \mu$ being eight times longer than broad. Oesophagus 0.095 mm. long rhabditiform. Excretory pore near the valvated bulb. Nerve ring encircles the isthmus near the bulb. Intestine and its parts call for no special mention.

Ovaries two, outstretched and reflexed, with a simple slit-like equatorially placed vulva. Tail 0.19 mm. long, conical with a very long terminal filament. Anal diameter 23.06μ .

No male was recorded.

Habitat : Soil near the roots of *Canna indica*.

Locality : Marina Gardens.

Rhabditoides coprophaga longicaudatus var. nov., closely resembles *R. coprophaga* Goodey (1929) in its general characters, but has a tail which is twice as long as that of Goodey's specimen. Further, the body is stouter and the head end is devoid of bristles.

Holotype, 1 Female } Both mounted on the same slide and labelled "*Rhabdi-*
Paratype, 1 Female } *toides coprophaga longicaudatus* var. nov., Slide
deposited in Zoology Museum, Presidency College, Madras.

2. *Bunonema madrasicum* sp. nov.,

Total : 1 Female only Text fig. 2

Measurements : L= 0.82 mm. a. =17; b=4.3; c= ?; V=?

Body stout and robust, with a smooth cuticle devoid of warts. Under the cuticle are arranged pinhead-like bodies in the form of papillae, in pairs, each pair opposing the pair on the other side, probably corresponding to the "warts" which Goodey (1951) reported for this genus, these being very conspicuous from the region of the ovary down to the tail where they resemble the caudal papillae. Head well set-off, nearly 1 and $1/3$ times as long as broad, with the flaps merging to form a funnel-like structure, the edges being drawn into six pointed processes. Neck 7μ wide.

Stoma rhabditiform, with concave sides, made of protorhabdions, resting on a rhomboidal telorhabdial structure. Oesophagus rhabditiform with a muscular precorpus, an isthmus and a valvated terminal bulb. Isthmus as long as the precorpus. Intestine densely granulated and the anus could not be located. Only one ovary was clearly seen due to the dense nature of the intestine. It was not possible to locate the vulva. Tail conical tapering to an acute point, convex dorsally, slightly bent ventrally and without caudal processes.

No male was recorded.

Habitat : Soil near sewage pool.

Locality : T Nagar.

Bunonema madrasicum sp. nov., resembles *B. pusillus* Fuchs (1930) only in the shape of the concave nature of the stoma, but differs from it, in not having the warts. Of the various species of *Bunonema* described by Fuchs (1930), under the name of *Rhodolaimus*, only *Rhodolaimus pusillus* (Syn. *Bunonema pusillus*) shows some resemblance to this new species in its stomal characters.

Holotype: 1 Female specimen mounted and labelled "*Bunonema madrasicum*" and deposited in Zoology Museum, Presidency College, Madras.

3. *Diploscapter orientalis* sp. nov.,

Total: 4 Females Text figs. 3, 4, 5.
Measurements: L=0.49 mm; a=15.7; b=4.9; c=10.7
V=56%.

Body short and moderately thick. Head 9μ wide, with a dorsal and a ventral hook, the lateral lips being apparently absent. Neck 7μ wide, with the amphid looking like a faint slit near the base of the head. Stoma rhabditiform, 16μ long, with concave sides, measuring 2.3μ wide at the narrow middle part and 6.3μ below it.

Oesophagus rhabditiform, 0.101 mm. long with a short isthmus and valvated metacarpus, while the cardia is very obscure. Intestine densely granulated with a slit-like anus. Ovaries paired, outstretched and reflexed with a slightly protuberant vulva having apparently prominent lips. Vagina tubular and transverse. Tail conical, sharply tapering to a filament, with a somewhat blunt terminus.

No male was recorded.
Habitat: Soil near sewage pool.
Locality: T Nagar, Madras.

Diploscapter orientalis sp. nov., resembles *D. pachys* Steiner (1942) in its general characters of the head, hooks, stoma, oesophagus ovary and the tail, but differs from it in having the amphid slightly dislodged subdorsally to the stoma, the latter being not cylindrical but concave in the middle. The length of the isthmus is almost equivalent to that of the precorpus. The metacarpus is short, well offset, bulboid (23μ wide) and is wider than the precorpus (18.5μ). The tail is also fairly long (10.6μ). The distance between the anus and the phasmid is equivalent to the post-anal body diameter. Further the vulval slit is less than half the body diameter.

Holotype: 1 Female specimen mounted and labelled "*Diploscapter orientalis*" sp. nov., and deposited in Zoology Museum, Presidency College, Madras.

Paratypes: Did not preserve well.

4. *Cephalobus minor* sp. nov.,

Total: 8. Females - 7 and Juvenile - 1 Text fig. 6
Measurements: L=0.53 mm - 0.65 mm; a=15.20; b=3.84;
C=5.9 - 7; V=!

Body slender and annulated, the annuli being 2μ apart. Head 5μ wide, slightly narrowing from the posterior part, separated by a neck which is 7μ wide. Head not well set off, and has four blunt lips of which two are seen in face view. The papillae and probolae seem to be amalgamated. Amphids not visible. Stoma cephaloboid, 7μ long, 2μ wide and globet-like with a wide part made of cheilostom and a stem-like part made of proto-and telostoms. The wall of the stoma is well reinforced.

Oesophagus covers almost the entire stoma, and is with a uniform muscular precorpus, very short isthmus and a terminal vulvated metacarpus. Intestine vacuolated, and opens out by a slit-like anus. The nature of the ovary could not be made out due to the dense structure of the intestine. The position of the vulva is not clear. Tail gradually tapering to a fine point, conical and bent slightly at the apex.

No male in the collection.
Habitat: Sandy soil.
Locality: Gopalapuram.

Cephalobus minor sp. nov., is related to *C. persegnis* Bastian 1865, in its general characters of lips, stoma, oesophagus, cuticular annulus etc., but differs from it in having a more prominent isthmus. The cheilostoms are semicircular. The tail is actually pointed and not blunt as in *C. persegnis*.

Holotype: 1 Female mounted and labelled "*Cephalobus minor*" and deposited in Zoology Museum, Presidency College, Madras.

Paratypes: 4 Females. Did not preserve well.

5. *Eucephalobus verrucosus* sp. nov.,

Total: 1 female only Text fig. 7
Measurements: L=0.57 mm; a=16.7; b=4; c=5.14
V=54.4%

Body short, annulated, the annulus being 2.3μ wide near the head end and wider in the mid body region. Head 6.2μ wide, not well offset, with four lips of which two are seen on face view, and are devoid of bristles. Amphid very obscure.

Stoma 16.2μ long, 3.1μ wide being nearly five times, longer than broad and with two parts: a 'U' like part made of cheilostoms and a somewhat

posteriorly conical part made of proto-and telostoms. Oesophagus cephaloboid, 0.142 mm. long with a cylindrical precorpus a short slender isthmus and posterior valvated metacarpus. The cardia is very obscure. The intestine runs straight and opens out by a slit-like anus, the rectum being oblique. The ovary is single while the vulva is slightly protruberant. The tail is conical ventrally bent with an acute terminus.

No male in the collection.
Habitat : Sandy soil.
Locality : Gopalapuram.

Eucephalobus verrucosus sp. nov., is related to *E. leres* Thorne (1937) in the general characters, the annulations of the cuticle, the nature of the tail, oesophagus and the ovary, but differs from it in having the stoma in two parts, an anterior 'U' like part and a posterior conical one. The vulva is slightly protruberant. The lips are blunt. Further the stoma is very long, nearly five times as long as broad.

Holotype: 1 Female mounted, and labelled "*Eucephalobus verrucosus*" and deposited in Zoology Museum, Presidency College, Madras.

6. *Eucephalobus setensis* sp. nov.

Total : 1 female only Text figs. 8, 9, 10
Measurements : L=0.593 mm. a=15.2 ; b=4.22 ; c= ?
V=56%

Body moderately thick, in the middle, tapering fore and aft. Cuticle annulated in single series, the annules being 2.308μ apart. Head not well set off, 6.924μ wide with four blunt lips which are faintly seen. Stoma short, cephaloboid thrice longer than broad with short telostom. Stoma measures 6.924μ 2.308μ . Oesophagus cephaloboid, 0.14 mm. long, the precorpus being four and half times longer than the isthmus. Metacarpus small and valvated. Intestine with yellow granules. Anus not clear.

Ovary single, anterior outstretched and reflexed. Vulva protruberant with an oval slit. Uterus muscular and postvulval in position. Tail long, ventrally bent in its posterior region, whip-like with an acute terminus. The tail is studded with minute fine bristles.

No male was available.
Habitat : Sandy soil
Locality : Lloyds Road.

Eucephalobus setensis sp. nov., resembles *E. oxyuroides* (de Man 1876), Steiner (1936), in the nature of the cuticular annules, oesophagus, ovary and

tail; but differs from it in that the lips are blunt and not acute. The telostom alone forms the narrow part of the stoma. The precorpus is more than four times longer than the isthmus. The vulva is more prominent. The tail is studded with minute fine bristles.

Holotype: 1 Female mounted, and labelled and deposited in Zoology Museum, Presidency college, Madras.

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References

- BASTIAN, C. H. 1865.—Monograph on the Anuillulidae etc. *Trans. Linn. Soc.* 25: 73-184.
BAYIS, H. A. and DAUBNEY, R. 1926.—A synopsis of the Families and Genera of Nematoda London.
BHATIA, K. L. 1926.—Fresh water Nematodes of Lahore. *Proc. Indian. Sci. Congr.* Calcutta 12 (10): 185.
BUTSCHLI, O. 1876.—Untersuchungen über freilebende Nematoden und die Gattung Chaetognotus. *Z. Wiss. Zool.* 26: 363-413.
CHITWOOD, B. G. 1933b.—A revised classification of the Nematoda. *J. Parasitol.* 20 (2): 130.
— and CHITWOOD, M. B. 1933.—The characters of a protonematode. *Ibid.* 20 (2): 131.
COBB, N. A. 1917.—The Mononchs (Mononchus Bastin, 1865) a new genus of free living predatory nematodes. *Soil Science* 1: 431-486.
—, 1918a.—Filter-Bed Nemas. Nematodes of the slow sandfilter beds of American cities etc. *Contrib. Sci. Nematol.* 7: 189-213.
—, 1918b.—The free living nematodes—*Fresh water Biology* (by Ward & Whipple.) London: 459-505.
—, 1918c.—Estimating the nema population of the soil *U.S. Dept. Agric. Tech. Circular* 1: 1-48.
—, 1920.—One hundred new Nemas. *Contrib. Sci. Nematol.* 9: 217-343.
DASTUR, J. F. 1936.—A new nematode disease of rice in Central Provinces. *Proc. Indian. Acad. Sci.* 4: 108-121.
FUCHS, G. 1930.—Neue an Broken und Russel Kefern Gebende Nematoden, halbparasitische und wohnung-sejmelter. *Zool. Jahrb. Abt. Syst.* 59: 505-646.
GOODEY, T. 1929.—On some new and little known free-living nematodes. *J. Helminth* 7(1): 27-62.
—, 1933.—*Plant parasitic nematodes and the diseases they cause* London.
—, 1949.—Laboratory methods for work with plant and soil nematodes. *Tech. Bull.* No. 2. *Min Agri & Fish. H. M's Stationery Office, London.*
—, 1951.—*Soil and fresh water Nematodes* (A monograph) Methuen, London.
HYMAN, L. H. 1951.—*The Invertebrates* Vol. III. London.

- IYER, R. P. 1944.—Occurrence of *Criconeema rusticum* Micoletzky 1921 in Travancore. *Proc. 31st. Indian. Sci. Congr.* Delhi, Pt. III p. 88 (Abstract).
- KREIS, H. A. 1936.—Sussewasser—Nematoden aus der umgebung von Madras (Indien) *Rev. Suisse Zool.* 43 (4): 641-645.
- KRISHNA IYER, P. N. 1933a.—Some experiments on the control of the root-gall nematode in South India. *Madras. Agric. Jour.* 21 (3): 98-109.
- , 1933b.—Further experiments on the root-gall nematode *Heterodera marionii* (Cornu) Goodey in South India. *Indian J. Agric. Sci.* Calcutta. 3: 1064-1071.
- MAN DE, J. 1884.—Die frei der reinen Erde und Sussenwasser lebenden Nematoden (der Niederlandischen fauna) Leiden.
- , 1885.—Helminthologische Beitrage. *Tijd. ned. dier ver.* II: 1-126.
- MAYNE, W. W. SUBRAMANYAM, U. K. 1933.—Nematode worms in relation to the Cockchafer and mealy bug problem in Coorg. *Bull. Mysore. Coffee. Exper. Stn.* II: 34.
- MICOLETZKY, H. 1922.—Die freilebende Erde Nematoden. *Arch. Naturg. Abt. A.* 87 (8/9): 1-650.
- STECKHOVEN, S. T. H. 1941.—*A manual of Agricultural Helminthology* E. Brill, Leiden.
- STEINER, G. 1936.—Opuscula misselania nematologia IV. 4. observations on *Tricephalobus longicaudatus* (Butschi 1873). *Proc. Helm. Soc. Wash.* (3) 2: 74-80.
- , 1942.—Opuscula miscellanea nematologica. IX. *Hoya carnosus* R. BR. The common wax plant as host of the root-knot nematode and of a new Rhabditid, *Diploscapter pachys*, N. Sp. *Proc. Helm. Soc. Wash.* 9 (1): 32-38.
- , 1949.—Plant nematodes the grower should know. Part I. *Soil. Science, Soc. Florida, Proc. IV B.* for 1942 (issued April 1949).
- STEWART 1914b.—Report on a collection of free living nematodes from Chilka lake on the east coast of India. *Rec. Ind. Mus.* X 245-254.
- THIRUMALACHAR, M. J. 1946.—Preliminary note on the eelworms of the cotton plant. *Proc. Ind. Sci. Congr.* 273-228 (Abstract).
- , 1951.—Root-knot nematode on potato tubers in Simla. *Current. Sci.* 20. 104.
- THORNE, G. 1925.—The genus *Acrobeles* Von Linstov. *Trans. Amer. micr. Soc.* 44 (4). 171-210.
- , 1937.—A revision of the nematode family cephalobidae Chitwood & Chitwood 1934. *Proc. Helminth. Soc. Wash.* 4(1). 1-16.
- , 1939b.—A monograph of the nematodes of the Super family Dorylaimoidea. *Capita, Zoologica.* 8(5). 1-261.
- , 1941.—Some nematodes of the family Tylenchidae which do not possess a valvular median oesophagial bulb. *Great. Basin. Naturalist.* Utah. 2(2). 37-85.
- , 1949.—On the classification of the Tylenchida, new order (Nematoda, Phasmidia). *Proc. Helminth. Soc. Wash.* 16(2). 37-73.
- VENKATARAMAN, S. 1933.—Tylenchus forming leaf galls on *Andropogon pertusus*, Wild. *J. Indian Bot. Soc.* II pp. 243-247.
- , 1947.—Diseases of Coffee. *Mysore. Agric. Jour.* 25. 1-2. 3-20.

Parasitic Copepods from Indian fishes I. Family Chondracanthidae Milne Edwards, 1840

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(With 10 Text Figs)

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Introduction

So far only five species of family Chondracanthidae have been described from marine fishes from India and Ceylon. In this paper one more species, of the genus *Heterochondria* Yu, 1935 is described, and a key to the genera of the family Chondracanthidae is given.

Subfamily - Chondracanthinae

Heterochondria Yu, 1935

Heterochondria longa sp. nov.

(Text figs 1-10)

Host—*Pseudorhombus arsius*, and *P. triocellatus*.

Locality—Estuary of river Rishikluya (Orissa) and Madras.

Female—Cephalon is more or less circular, and is fused with the first thoracic segment, which forms a short neck. The rest of the thoracic segments are fused to form a long cylindrical trunk. The genital segment is smaller than the trunk and is slightly longer than broad. Posteriorly its width is decreased to nearly half of the width in the anterior region. The abdominal segments are two in number and nearly equal in length. The anal laminae are as long as the abdomen and tapering posteriorly.

* Published with the kind permission of the Chief Research Officer.

First pair of antennae are biramous. The basal segment is broad. The ventral ramus is the continuation of the basal segment and is not furnished with any spines or setae. The dorsal ramus is longer and cylindrical and is furnished with four long setae at its free end. This biramous condition



Heterochondria longa sp. nov.

(1) Female (2) First and second antennae (3) Mandible (4) Second maxilla (5) First maxilla (6) Maxilleped (7) First and second leg (8) Genital segment, abdomen and anal lamina (9) Male (10) Cephalothoracic appendages of male.

Key to Lettering

A1—First antenna.	CT—Cephalothorax	MX1—First maxilla.
A2—Second antenna.	ES—Egg sacs	MX2—Second maxilla.
AD—Abdomen.	GS—Genital segment.	MXP—Maxilleped.
AL—Anal lamina.	ML—Male.	T—Trunk.

of the first antenna has been shown in *Acanthochondria cornuta* by Heegaard (1947) according to whom this bifurcation is "purely secondary and has nothing to do with a division into a bifurcate limb". Second pair of antennae are two jointed. The basal segment is fused with the head and the second segment is a small blunt claw. The mouth parts are situated ventrally in the central region of the head. The upper lip is slightly curved

and its posterior border is fringed with small setae. Mandibles, two jointed and the anterior tip is slightly covered by the upper lip. The basal segment is broad and the terminal segment is lanceolate, both the margins are strongly denticulated. The inner margin has 24-25 big triangular teeth which become smaller towards the tip whereas the outer margin has smaller teeth. The distal one-ninth of this margin is smooth. At the base of the mandible is a small palp with two simple setae representing first maxilla. Second maxillae are two jointed. The basal segment is broad and the terminal segment is tapering to a short curved point. The posterior margin is beset with small teeth, whereas the anterior margin has two small teeth. Near the base of the terminal joint a small forwardly directed palp is present on the basal segment. This palp constitutes the endopod of this limb and the terminal toothed joint represents the exopod. This biramous condition of the limb is clearly shown by the developmental studies of *Acanthochondria cornuta* by Heegaard (1947, fig. 135, pp. 161, 165 and 208). Maxillepedes comparatively large and two segmented. The basal segment is nearly twice as long as broad. The second segment is broader in the distal half where it has two short lobes furnished with small setae which are probably sensory in function. The terminal claw is curved and is provided with an accessory smaller claw on its inner margin. The base of the claw is covered by a sheath. Two pairs of thoracic legs are present. The first pair is situated at the posterior margin of the cephalothorax. It is biramous and each ramus indistinctly two jointed. The second pair of legs is situated in the anterior region of the thorax. Each leg is uniramous and one jointed.

The egg-sacs are multiseriate and longer than the body. The eggs are spherical.

Male:—The male is very small and is attached to the genital segment of the female with the help of its second pair of antennae.

The cephalothorax is large and globular and covered dorsally by a carapace. The trunk is small and not clearly segmented. The last segment bears two simple caudal rami as in the female. The first pair of antennae are one jointed. The second pair of antennae are prehensile and consist of a large basal segment and a small curved terminal claw. The upper lip is bigger than that of the female. The mouth parts are like those of the female except that the maxillepedes are devoid of the accessory claw and the sensory lobes. The thoracic appendages are absent.

Measurements* :—Female. Total length, 1.885; cephalothorax, 0.246 × 0.229; neck, 0.072 × 0.217; thorax, 1.406 × 0.406; genital segment, 0.159 × 0.145; abdomen 0.058 × 0.043; anal lamina, 0.072 × 0.029; egg sac, 3.335 × 0.159; egg, 0.087 diam.

Male—Cephalothorax, 0.203 × 0.174; trunk, 0.13 long.

Types in collection of the Central Inland Fisheries Research Station, Barrackpore.

* All measurements are in millimeters.

Remarks—S. C. Yu (1955) created a new genus *Heterochondria* with two species *H. longicephalus* (Yu and Hu 1932) and *H. similis* (Yu and Hu 1932) from *Pseudorhombus arsius* and *Crossorhombus azureus* respectively. The present new species belongs to this genus. Yu and Hu (1932) termed the long thorax as the genital segment, but they have shown in their diagram a separate small genital segment on which the openings of the uterus are situated. The first leg according to them is single lobed and not biramous as in the present species. *H. longa* n. sp. differs from *H. longicephalus* in the structure of the cephalothorax and relative size of the body parts. The thoracic legs of *H. longicephalus* are bigger than those in the present species. It differs from *H. similis* in the size of the thorax and the egg strings and the mouth parts.

Discussion—Chondracanthidae was placed under Lernaeoidea of G.O. Sars by Scott and Scott (1912) and under the sub-order Lernaeopodoida by Wilson (1932). Oakley (1930) placed it along with Ergasilidae under Cyclopiformes and Gurney (1933) concurred with this view. Heegaard (1947) also came to the same conclusion after studying the development of the representative genera of the families Caligidae, Lernaeidae, Lernaeopodidae, and Chondracanthidae. He placed Chondracanthidae and Ergasilidae under his group FISTULATA, which is more or less like Cyclopiformes of Oakley. Also his group PECTINATA is equivalent to Caligiformes. The presence of pigmy-male in Lernaeopodidae and Chondracanthidae does not necessarily show any close relationship of the two families as is seen from the developmental stages in the two families.

Oakley (1930) divided Chondracanthidae into two subfamilies Chondracanthinae and Lernentominae. Ilg (1918) created a new subfamily Pharodinae with the type genus *Pharodes* Wilson, 1935. Dehouteville (1951) gave a good diagrammatic key to these three subfamilies. Oakley (1930) gave a very good review of the family Chondracanthidae, and added five new genera by removing some species, (mostly from *Chondracanthus*), to be placed under these new genera. Wilson (1932) gave a key to the fifteen genera of this family. Since then many new genera have been created and now there are twenty six genera under this family.

There has been some confusion regarding the systematic position of some species and genera of this family. Wilson (1932), did not include *Disphaerocephalus* Oakley, in the key to the genera and placed the type and only species *D. (C) ornatus* T. Scott, 1900, of this genus under his new two species differ in the structure of the body and so the two genera *Disphaerocephalus* and *Chondracanthopsis* have been retained here as valid genera. *Chondracanthus cottunculi* Rathbun, was placed under *Chondracanthopsis* by Oakley (1930), under *Chondracanthus* by Wilson (1932), and under *Acanthocanthopsis* by Heegaard (1945). From the diagram and the description given by Wilson (1932) it appears that this species should belong to *Chondracanthopsis*.

Key to the females of the genera of the family Chondracanthidae

- | | | |
|--|-----|--|
| 1. Body elongate; oviscas straight, cylindrical. | ... | 2 |
| 1. Body short; wider than long; oviscas twisted. | ... | Pharodinae-17. |
| 2. Head produced in a cephalic neck, antennae separate from the mouth parts, latter at the base of the neck. | ... | Lernentominae-3. |
| 2. Head not produced in a cephalic neck, mouth on the ventral surface of the head, and not markedly separated from the antenna. | ... | Chondracanthinae-7. |
| 3. Lateral protrubances on head present thoracic legs rudimentary or absent. | ... | 4 |
| 3. Lateral protrubances on head absent thoracic legs well developed. | ... | 6 |
| 4. Head small, trunk four segmented, processes and legs absent. | ... | <i>Medisicuste</i>
Kroyer, 1863. |
| 4. Head large, trunk two segmented, leg rudiments present. | ... | 5 |
| 5. Anterior trunk with two dorsal processes, lateral process absent, leg rudiments bipartite. | ... | <i>Lernentoma</i>
Blainville, 1882. |
| 5. Anterior trunk with two dorsal processes, posterior trunk with two pairs of lateral processes, leg rudiments tripartite. | ... | <i>Oralien</i>
Bassett-Smith, 1898. |
| 6. Neck broad and short. | ... | <i>Rylovia</i>
Markewitsch, 1940. |
| 6. Neck as long as thorax. | ... | <i>Brachiochondrites</i>
Markewitsch, 1940. |
| 7. Head not distinctly separated from the body, all trunk segments fused together. | ... | 8 |
| 7. Head fused with first thoracic segment, other segments free or fused together. | ... | 9 |
| 7. Head fused with first two thoracic segments cephalic, dorsal, ventral or lateral processes absent, two pairs of bifid legs, second leg larger than the first leg. | ... | <i>Humphraysia</i> Leigh
Sharpe, 1934. |
| 7. Head not fused with the trunk segments. | ... | 12 |
| 8. Body long, vermiform and without knobs or processes; two pairs of biramous legs. | ... | <i>Anderina</i> Brian, 1939. |
| 8. Body not vermiform, anterior thoracic region with a median dorsal processes; one pair of legs. | ... | <i>Ceratochondria</i> Yu,
1935. |
| 8. Anterior thoracic region forming a long neck, no processes present on the body; one pair of bifid setose legs. | ... | <i>Schehrasade</i> Leigh
Sharpe, 1934. |
| 9. All thoracic segments distinctly separated, each segment with lateral processes, second segment with a pair of dorsal processes; one pair of legs. | ... | <i>Juanettia</i> Wilson,
1921. |
| 9. All thoracic segments fused without any processes or knobs on the body. | ... | 10 |

10. Thoracic legs absent. ... *Brachiochondria* Shiino 1957.
10. Thoracic legs present. ... 11
11. Trunk inflated, two pairs of legs, first pair bipartite, second pair undivided with a spine; second antennae tripartite. ... *Triphyllacanthus* Oakley, 1930.
11. Trunk not inflated; two pairs of legs, first pair biramous second pair uniramous, one jointed; second antenna two jointed. ... *Heterochondria* Yu, 1935.
11. Trunk slightly inflated posteriorly; two pairs of legs biramous and two jointed; head with a frontal plate. ... *Prochondracanthus* Yamaguti, 1939.
12. Cephalic barbs absent. ... 13
12. Cephalic barbs present. ... 14
13. All thoracic segments fused, thoracic legs one or two pairs. ... *Elias* Kroyer, 1863.
13. First thoracic segment free, other three segments fused; three pairs of lateral processes, turned ventrally, one process and two knobs on the dorsal side head deflexed; legs two pairs biramous, rami one jointed. ... *Chondracanthodes* Wilson, 1932.
13. First two thoracic segments free other segments fused; round knobs along the margin and transverse dorsal laminae on the body; head not deflexed; two pairs of uniramous one jointed legs, rami boot-shaped. ... *Chondracanthopsis* Wilson, 1932.
14. All thoracic segments fused together trunk with postero-lateral projections and two median genital lobes. ... *Immanthae* Lingh-Sharp, 1934.
14. First thoracic segment free, lateral and dorsal processes on trunk absent; one pair of legs uniramous and bilobed at the tip. ... *Pseudochondracanthus* Wilson, 1908.
14. First two thoracic segments free, other segments may be free or fused. ... 15
15. Dorsal knobs or processes on the body. ... 16
15. Dorsal knobs and processes absent, only one pair of lateral processes at the posterior corners of the body; caudal rami absent; two pairs of legs, uniramous or biramous, rami one jointed. ... *Acanthochondria* Oakley, 1927.
16. Head triangular; one pair of dorsal processes on second thoracic segment; three rows of tubercles, two lateral and one mid-dorsal on the fused thoracic region; two pairs of legs, first pair biramous. ... *Disphaerocephalus* Oakley, 1930.
16. Head small; dorsal, ventral and lateral processes present on the thorax; two pairs of bi or tripartite legs. ... *Chondracanthus* La Roche, 1811.
16. Head small; three mid-dorsal and one ventral knob present, no processes on the body, two pairs of bifurcated legs. ... *Acanthocanthopsis* Heegaard, 1947.

17. Head separate from the trunk, latter with three pairs of lateral processes; second antennae with terminal claws. ... *Diocus* Kroyer, 1863.
17. Head fused with the thorax, latter with one pair of lateral processes bearing knobs and lobes; second antennae multifid horns. ... *Tanypleurus* Steenstrup and Lutken 1861.
17. Head fused with first thoracic segment, thorax produced laterally, into large nodular second antennae with one claw. ... *Pharodes* Wilson, 1935.

Key to the males of the genera of the family Chondracanthidae

1. Leg rudiments entirely lacking. ... 2
1. Two pairs of legs present. ... 6
1. Five pairs of legs present. ... 11
2. Cephalon separated from thorax. ... 3
2. Cephalon fused with first thoracic segment. ... 4
3. Trunk with four segments. ... *Immanthae* Leigh Sharpe, 1934.
3. Trunk segments fused together. ... *Acanthocanthopsis* Heegaard, 1947.
4. Cephalothorax not larger than thorax, caudal rami simple. ... *Heterochondria* Yu, 1935.
4. Cephalothorax larger than thorax. ...
5. Caudal rami two jointed. ... *Brachiochondria* Shiino, 1957.
5. Caudal rami conical. ... *Ceratochondria* Yu, 1935.
5. Caudal rami absent. ... *Brachiochondrites* Markewitch, 1940.
5. Caudal rami divided distally. ... *Pseudochondracanthus* Wilson, 1908.
6. Legs uniramous, rami one segmented. ... 7
6. Legs biramous; head fused with first thoracic segment; exopod of the leg armed with setae, endopod unarmed; caudal rami stout, conical and armed. ... *Chondracanthodes* Wilson, 1932.
6. Legs uniramous; antennal area separate, trunk four segmented; each ramus of the leg has one seta; caudal rami setiform. ... *Medesicaste* Kroyer, 1863.
7. Head separate from thoracic segments. ... 8
7. Head fused with first thoracic segment. ... 9
7. Head fused with two thoracic segments. ... 10
8. Trunk five segmented, first two thoracic segments bearing legs fused; caudal rami small and lanceolate; maxillipeds two segmented. ... *Elias* Kroyer, 1863.
8. Trunk five segmented, first two thoracic segments bearing legs fused; caudal rami small and lanceolate; maxillipeds two segmented. ... *Anderina* Brian, 1939.

9. Trunk four segmented, rami of the legs with two setae, caudal rami conical and well developed ... *Chondracanthus* la Roche, 1811.
9. Trunk non segmented with inconspicuous demarcation between thoracic segment and genital portion; rami of legs with three setae, caudal rami pointed ... *Prochondracanthus* Yamaguti 1939.
10. Trunk five segmented, first leg laminate with two setae, second leg with one spine ... *Ovalian* Bassett-Smith, 1848.
10. Trunk with four segments, rami of the leg with 2-4 setae, caudal rami seta like ... *Acanthochondria* Oakley, 1930.
10. Trunk with three segments, rami of the leg laminate with two setae, caudal rami with one seta ... *Chondracanthopsis* Wilson, 1932.
10. Trunk not segmented, rami of legs laminate, caudal rami simple ... *Rylovia* Markewit Scch, 1940.
11. First two pairs of legs biramous, each ramus one segmented, third and fourth pairs of legs knob like ... *Diocus* Kroyer, 1853.
11. First four pairs of legs biramous, rami two segmented and well armed with setae, fifth pair of legs uniramous, one segmented with one seta each ... *Juanettia* Wilson, 1921.

Summary

One new species of *Heterochondria* Yu, 1935 (*H. longa* sp. nov.) is described, infecting the gills of *Pseudorhombus arsius* and *P. triocellatus*. A key to the genera of Chondracanthidae is also given.

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References

- BASSETT-SMITH, P. W., 1898 a.—Some new parasitic copepods found on fishes at Bombay. *Ann. Mag. Nat. Hist.* (7). 1: 1-17.
- BASSETT-SMITH, P. W., 1898 b.—Further new parasitic copepods found on fishes in the Indo-Tropical region. *Ann. Mag. Nat. Hist.* (7). 2: 77-98.
- BASSETT-SMITH, P. W., 1898 c.—Some new rare parasitic copepod found on fishes in Indo-Tropical region. *Ann. Mag. Nat. Hist.* (7). 2: 354-372.
- BRIAN, A., 1932.—Copepodes parasites recuillis Par M. E. Dartevelle a l'embouchure du fleuve Congo. *Rev. Zool. Bot. afr. Tervueren* 32: 175-198.
- DELAMARE-DEBOUTTEVILLE, C., 1951 a.—Presence de la sous famille de Pharodinae Ilg. Copepod (Copepodes-Chondracanthidae) en Mediterranee et remarques sur la classification et la biologie des Chondracanthidae. *Arch. Zool. expt. gen.* (Notes et Revue) 87: 139-151.
- DELAMARE-DEBOUTTEVILLE, C., 1951 b.—Description du male du genre *Disphaerocephalus* Oakley (Copepod: Chondracanthidae). *Archiv. Zool. expt. gen.* (Notes et Revue), 87: 152-155.
- DELAMARE-DEBOUTTEVILLE, C., 1951 c.—Sur la biologie des Chondracanthidae (Crustacees Copepodes) C. R. Acad. Sci. Paris. 232: 117-119.

- GURNEY, R., 1933.—British freshwater copepods. 3 Vols. Ray. Society London.
- GURNEY, R., 1945.—Some notes on the development and classification of Parasitic copepoda. *Ann. Mag. nat. Hist.* (11) 12: 121-127.
- HEEGAARD, P. E., 1943.—*Acanthochondria bulbosus* a new Chondracanthid from the Yellow sea. *Vid. Gnsk. Medd. dansk. naturh. Foren. kbh.* 107: 1-36.
- HEEGAARD, P. E., 1947.—Contributions to the phylogeny of the Arthropods: Copepoda. *Spolia Mus. Hauniensis.* 8: 1-1236.
- HEEGAARD, P. E., 1949.—Notes on parasitic copepoda *Vidensk. Medd. dansk. naturh. Foren. kbh.* 111: 235-245.
- ILG, P. L., 1948.—Pharodinae a new subfamily of Chondracanthidae (Crustacia Copepoda) and a description of *Pharodes biakensis* n. sp. from New Guinea *J. Wash. Acad. Sci.* 38: 404-412.
- KIRTISINGHE, P., 1950.—Parasitic copepods of fish from Ceylon. *Parasitology* 40: 77-86.
- LEIGH-SHARPE, W. H., 1930 d.—*Chondracanthus neali* n. sp. a parasitic copepoda of *Mala-cocephalus laevis*. *Parasitology*. 22: 468-470.
- LEIGH-SHARPE, W. H., 1934.—Commensal and parasitic Copepoda. *Siboga Exped.* 29 B: 1-43.
- MARKEWITZ, A. P., 1956.—Parasitic Copepods from fishes of Soviet Russia Akademic Nauk. Ukraine S.S.R.: 1-246 (In Russian).
- OAKLEY, C. L., 1930.—The Chondracanthidae (crustacea copepoda) with a description of five new genera and one new species. *Parasitology* 22: 182-201.
- SCTOT, T. AND SCOTT, A., 1912.—The British parasitic Copepoda 2 vols. Ray. Society. London: 1-254.
- SHIHO, S. M., 1957.—Parasitic Copepods on Japanese fishes 14. Three species from *spheroides alboplumbeus* (Richardson) *Rep. Fac., Fesh. Pref. Univ. Mic.* 2: 376-391.
- THOMPSON, I. C. AND SCOTT, T., 1903.—On copepoda. *Ceylon, Pearl. Oyster. Rep.* 1: 227-307.
- WILSON, C. B., 1932.—Copepods of the Woods-hole region, Massachusetts *Bull U.S. Nat. Mus.*
- WILSON, C. B., 1935.—Parasitic copepods from Dry Tortugas *Pap. Tortugas. Lab.* 29. No. 452: 327-347.
- YAMAGUTI, S., 1939.—Parasitic copepods from fishes of Japan. Part 6. Lernaeopodoida I. *Vol. Jubilate pro. Prof. S. Yoshida* 2: 529-578.
- YU, S. C., 1935.—Studies on parasitic copepods of China belonging to the family Chondracanthidae. *Bull. Fan. Inst. Biol. Peking.* 6: 1-16.
- YU, S. C. AND WU, H. W., 1932.—Parasitic copepods of the flat fishes from China. *Bull. Fan. Inst. Biol. Peking* 3: 55-75.

Observations on the Morphology and Sporogony of a new Coccidian, *Adelea hyalospora* from the Gut of a Centipede, *Rhysida longipes** (New port.)

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Introduction

Coccidian parasites are fairly common inhabitants of Chilopods and as many as ten species belonging to the five genera, *Adelea*, *Adelina*, *Eimeria*, *Barrouxia* and *Echinospira* have so far been described from centipedes. While examining the gut contents of a centipede, *Rhysida longipes*, I came across a Coccidian, which appeared to be a new species of the genus *Adelea*. The hosts occur in fairly large numbers during the months October—February living underneath the loose soil and decaying leaves of Cashewnut trees in the University Campus. The infection was first noticed in October 1955 in a small percentage of the hosts examined. Subsequent examination, however, of a large number of hosts did not show this parasite though most of them harboured another coccidian *Adelina dimidiata*, the development of which has already been studied in detail by several workers.

Owing to the limited amount of material available, only the main features in the life-history have been outlined here.

As early as in 1875 Aime Schneider described a sporozoan, *Adelea ovata* from the gut of a centipede, *Lithobius forficatus* and at that time the precocious association of the gametocytes of the form was strangely not suspected to have any sexual significance and it was described as a gregarine. Subsequently Sidlecki (1899) gave a fairly detailed account of its life history and placed it in the Coccidia. Seven other species of *Adelea*, *A. simplex* from

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the intestine of the larvae of a Coleopteran, *Gyrinus* sp. (Schneider, 1885), *A. dimidiata* from the gut of the centipede, *Scolopendra morsitans* (Schneider, 1885 b) *A. tipulae* from the intestine of the larvae of a dipteran, *Tipula* sp. Leger, 1897), *A. mesnili* from the fat bodies of a lepidopteran, *Tineola biselliella* (Perez, 1899), *A. akidium* from the body cavity and intestine of two genera of Coleoptera, *Akis* and *Olacrates* (Leger, 1900), *A. transita* from the body cavity of an Embiodea (Insecta) *Embia soleri* Rambur (Leger, 1904) and *A. zonula* from the fat bodies of a coleopteran, *Blaps mortisaga* (Moroff, 1906) were described subsequently.

Hesse (1911) found a Coccidian parasite in the coelomic cavity of an aquatic oligochaete, *Slavina appendiculata* which resembled *Adelea ovata* in several respects but differed from it in having spherical oocysts with rigid walls containing perfectly spherical sporocysts, instead of an elongate ovoid thin walled polysporocystid oocyst with disc-like sporocysts as in *A. ovata*. He considered these differences as sufficiently fundamental to warrant creating a new genus *Adelina*. In this genus he not only placed the Coccidian from *Slavina appendiculata* under the name *Adelina octospora* but also transferred to this genus all the seven species of *Adelea* except the type species *A. ovata*, all of which possessed the characteristic oocyst and sporocyst structure of *Adelina*. He considered *Adelea ovata* as a solitary representative of the genus.

Chagas (1910) described a Coccidian *Adelea hartmanni* from the gut of a Brazilian plant bug, *Dysdercus ruficollis* L where the oocyst gives rise to only three sporocysts, each of which gives rise to 4 sporozoites. Subsequently Machado (1911) transferred this form to a new genus *Chagasella* based on the number of sporocysts and sporozoites. The Coccidian, *Adelea pachylebrae* described by deMello (1921) from an Indian Mollusc, *Pachylebra moesta* has an oocyst with two sporocysts each with two sporozoites. Wenyon (1926) doubts the validity of this form being included in the genus *Adelea*. The present form therefore appears to be the second species of the genus *Adelea* so far reported.

Material and Methods

The centipedes were collected from underneath decaying leaves of Cashewnut trees in the University Campus. By isolating the hosts and examining the faecal matter for the presence of oocysts it was possible to detect the infected ones. The intestine of the infected hosts was fixed in Alcoholic Bouin's fluid and serial sections taken which were stained with Heidenhain's Iron-alum haematoxylin. Fresh examination of the oocysts were made in normal saline or Ringer's fluid. The oocysts kept in a 2.5% solution of Potassium dichromate solution sporulated in about 4—5 days.

Observations on the Parasite

Schizogony:

An early sexual differentiation of the schizonts into two kinds, one producing merozoites which ultimately develop into females and another which

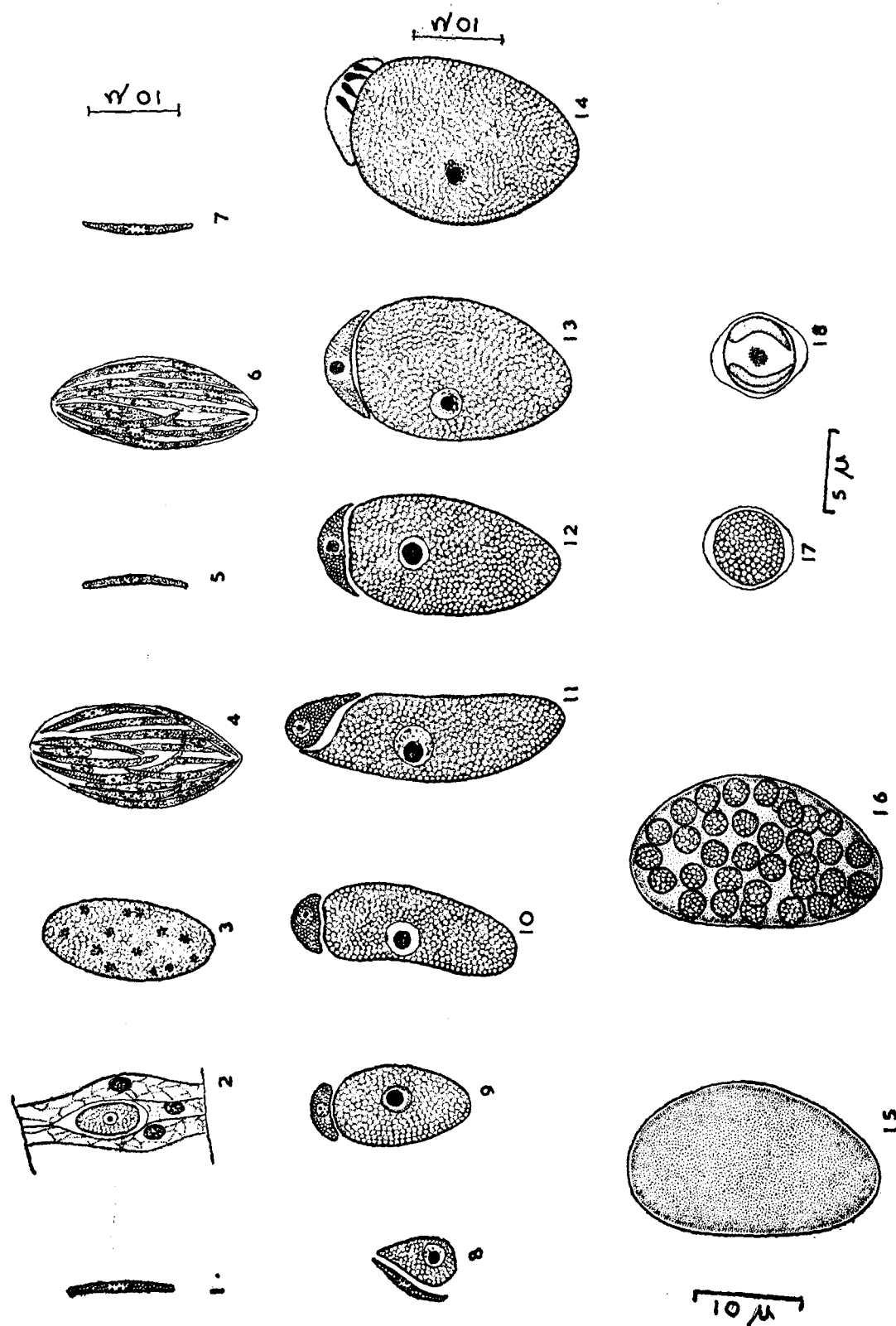


Fig. 1. Merozoite from section. Fig. 2. Later stage in its growth. Fig. 3. Early schizont. Fig. 4. Merozoite bundle 1st type. Fig. 5. A single merozoite shown separately. Note distinct karyosome. Fig. 6. Merozoite bundle and type. Fig. 7. A single merozoite shown separately. Note absence of karyosome in the nucleus. Fig. 8. Early association stages. Note a well developed karyosome in the female and absence of karyosome in male. Figs. 9-13. Later stages in development of male and female sporoblasts. Fig. 14. Fully formed gametocytes. 4 microgametes can be seen the microgametocyte. Fig. 15. Fresh oocyst. Fig. 16. Oocyst showing fully formed sporoblasts. Fig. 17. A fresh sporoblast—Note hyaline episporangium which is thickened at the poles. Fig. 18. A single sporoblast showing two sporozoites.

produced the males was observed. The schizont which ultimately produces the merozoites developing into the female or the macrogametocyte measures $16 \times 13.5 \mu$. Each schizont divides into 18—20 merozoites (Figs. 4 and 6). The merozoites are elongate and vermiform with finely alveolated cytoplasm the nucleus of which is placed in the centre consisting of a distinct nuclear membrane and a number of deeply staining chromatin granules placed all along its inner margin. In addition to the peripheral chromatin a deeply staining central karyosome can also be distinguished. The merozoites measure about $10.5-12 \mu \times 2.0 \mu$ and the nucleus measures $3.5 \mu \times 2.0 \mu$ (Plate 14, Fig. 4).

The second type of merozoite is similar to the first but it lacks a central karyosome in its nucleus (Fig. 7). The number of merozoites produced by the schizont is slightly less being only 14—16. Each merozoite measures $11 \mu - 12 \mu \times 1.5 \mu - 2.0 \mu$ (Fig. 6). These merozoites develop into the male gametocytes. The two types of schizonts can be distinguished only by the nature of the merozoites ultimately formed and not in the earlier stages of schizogony.

When the developing schizonts have been stained for paracytogen using Bauer's technique they did not show any differential distribution of this reserve polysaccharide as has been observed in the case of *Adelina dimidiata* (Joyet-Lavergne, 1926). Though typical achromatic figures have not been observed some of the division stages of the nuclei showed 6—8 chromosomes. From what is known of other Coccidians this number perhaps represents the haploid number. When the nuclear divisions are completed the schizont segments into as many elongate vermiform merozoites as there are nuclei. In general no residual cytoplasm has been observed but in some a few refringent granules were seen in the centre of the merozoite bundle. The living merozoites exhibit slight twitching and bending movements. The cytoplasm appears hyaline with a translucent area in the centre representing the nucleus. It would appear possible that the merozoites may either be released into the lumen of the gut by a rupture of the epithelium before they invade fresh cells and develop or they may directly enter the neighbouring cells in the epithelium.

Association Stages:

As in other members belonging to this family association between the gametocytes takes place at a very early stage and the male and the female gametocytes can be identified by the size of the parasite and the structure of the nucleus (Fig. 8). In the earliest association stage observed the female gametocyte was ovoidal and measured about $7 \mu \times 5 \mu$. The cytoplasm is alveolated with a few refringent granules scattered all over the body. The nucleus is situated in the centre consisting of a single deeply stained endosome and a few extra-endosomic chromatin granules. The early male gametocyte is elongated and vermiform measuring $10 \mu \times 25 \mu$ with a centrally placed nucleus. The chromatin is distributed all along the inner margin of

the nuclear membrane and one or rarely two of them are slightly larger than other. The male gametocyte at this stage strikingly resembles the merozoite that lacks a karyosome and presumably it develops from such merozoites.

The macrogametocytes grow rapidly and reach a size of about $30\mu \times 14\mu$ (Figs. 9 to 13). The cytoplasm is alveolated with a number of refringent granules scattered all over the body. These granules are of the nature of the polysaccharide, paraglycogen. The nucleus is rounded and placed at about the middle of the body. A deeply stained endosome which is slightly eccentric in position, surrounded by a clear space all around is present inside the nucleus. A few chromatin granules are also seen scattered peripherally in the nucleoplasm. The mature macrogametocyte is ovoidal measuring about $34\mu \times 24\mu$ (Fig. 13). The nucleus has increased in size as also the endosome and there is no evidence of any extra-endosomic chromatin at this stage. The cytoplasm is alveolated and is filled with a large number of paraglycogen bodies. In some instances the entire cytoplasm is practically filled with this inclusion. In spite of examining a large number of mature female gametocytes I have not come across any stage showing extrusion of nucleolar chromatin either into the nucleoplasm or into the cytoplasm. There is also no indication of any reduction division taking place in the macrogametocyte before fertilisation.

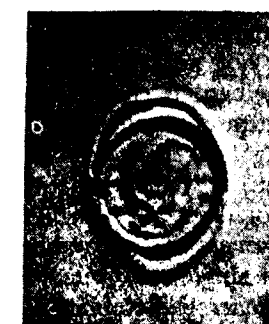
In the fully grown condition the microgametocyte is very much smaller than the female and measures $9\mu \times 4\mu$ (Fig. 13). The cytoplasm is more closely alveolated. It also stains deeper with haematoxylin and contains fewer refringent granules which are generally present at the two poles of the parasite. The nucleus which is placed in the centre is spherical and one or two of the chromatin granules which were larger than the others in the earlier stages of the growth have increased further in size. The others break up into fine granules which are distributed on a fine network. While these changes are taking place in the nucleus the microgametocyte shortens with a simultaneous increase in width and it becomes closely applied to the macrogametocyte. The fully formed microgametocyte is either rounded or oval measuring $9\mu \times 4\mu$. Though I have examined a large number of microgametocytes while they are still in the epithelium, I have not come across any stage suggesting nuclear division, prior to the formation of the microgametes. In some of the microgametocytes free in the lumen of the intestine, however, I have seen four deeply staining comma-shaped bodies representing the male gametes and it is therefore presumed that the microgametes are formed only after the liberation of the parasites into the lumen (Fig. 14). These bodies are intensely Feulgen positive.

Owing to the limited amount of material available the details of the sporogony could not be studied. The unsegmented oocysts are passed out along with the faeces probably as soon as fertilisation is completed (Fig. 15). The oocyst wall is double when they are passed out. There is no thickening at the poles as in typical Eimerids or as in *Adelina*. When such

oocysts are kept in a medium of 2.5% solution of Potassium dichromate for about four days at room temperature, the sporoblasts are formed (Fig. 16., Photo 19). In the majority of cases, they range in number from 36—42, but in a few instances the number was as many as 48. The oocyst is bean-shaped measuring $36\mu \times 21\mu$ one side of which is slightly concave and the other slightly convex or flat. The sporoblasts are oval in shape and disc-like measuring $7.5\mu \times 5.25\mu$ having an outer hyaline episporon which lies in close contact with the sporoblast wall. (Fig. 17, Photo 20). At the two poles the episporon is conspicuous. The wall of the sporoblast is made up of two valves united all along the median longitudinal line and a suture can be made out along the line of fusion. Sporulation is completed in about 8—10 days under laboratory conditions. Each sporoblast develops two sporozoites. The sporozoites are sausage-shaped closely applied to the wall of the sporocyst. In fresh preparations the sporozoite is slightly larger than the merozoite and it measures $11\mu \times 2.5\mu$. The cytoplasm is hyaline and the nucleus which appears translucent in fresh material is situated at the broader end (Fig. 18).

Discussion

The present form from the centipede, *Rhysida longipes* resembles *Adelea ovata* from *Lithobius forficatus* in having a polysporocystid oocyst and disc-like sporocysts. The oocysts are, however, bean-shaped instead of elongate ovoid as in *A. ovata*. The presence of a hyaline episporon for the sporocysts



Photographs :

Fig. 19. An oocyst showing fully formed sporoblasts.

Fig. 20. A single sporoblast showing two sporozoites. Note hyaline episporon.

is characteristic of the present species. The early sexual differentiation of the merozoites is also characteristic of the present species. For these reasons the present form is considered as a new species of the genus *Adelea* and the name *Adelea hyalospora* is suggested to accommodate this form on account of the presence of a characteristic episporic for the sporocysts.

I have not been able to observe any bipolar arrangement of the merozoites in the present form which is said to be characteristic of all the *Adeleidea* (Naville, 1931).

Leger and Duboscq (1902) described in *Adelina dimidiata* two types of schizogony which they considered produced the male and female merozoites respectively. Schellack (1913), however, did not confirm this dimorphism. Moroff (1906) described three types of schizogony in the case of *A. zonula* one occurring early in the infection in which a large schizont gives rise to 16—40 merozoites, a second smaller forming 16—24 merozoites and a third occurring only at the time of gametogenesis in which the nuclei are disposed in two rows forming two groups of merozoites at the ends of schizonts. Moroff interpreted the second type as schizogony in which microgametocytes are formed and the third in which the macrogametocytes are formed.

Joyet Lavergne (1926) observed in *Adelina dimidiata* a bipolar distribution of cytoplasmic inclusion in the schizonts. The anterior end from which the males are formed contained the constituents characteristic of the male forming cells such as mitochondria, little paraglycogen and a small quantity of reserve lipoids while in the posterior end there was little chondriome, many paraglycogen granules and a large quantity of reserve lipoids all characteristic of the female gamete. In *Klossia helicina* Naville (1927) found that the schizont undergoes two divisions to form four cells one of which forms the macrogametocyte and another the microgametocyte. The other two may or may not remain undifferentiated. According to Naville (1931) a bipolar arrangement is characteristic of all *Adeleidea* and he considered that the bipolar arrangement as an indication of a sexual polarity, the microgametocytes being formed at one end of the schizont and the macrogametocytes at the other. Yarwood (1937) noticed in *A. cryptocerci* that although the difference is not detectable at the time of division, the occurrence of macro and microgametoblasts together in isolated groups indicates their common origin from single schizonts. Growth and appearance of food reserve globules in the macrogametoblasts differentiate them from the microgametoblasts.

Summary

1. The morphology and life-history of a new Coccidian from the gut of a centipede, *Rhysida longipes* is described.
2. Two types of merozoites produced by different types of schizonts develop into the micro-and macrogametocytes.

3. The microgametocytes are oval or rounded and each one gives rise to four comma-shaped microgametes.

4. The macrogametocytes are oval and contain a large quantity of reserve food material in the form of paraglycogen.

5. Oocysts are bean-shaped, thin walled and polysporocystid. The sporocysts are oval in shape and the wall is made up of two valves which fuse along the longitudinal line. There is a hyaline episporic with a characteristic thickening at the poles.

6. The present coccidian is placed in the family *Adeleidea* on account of the early association of the gametocytes. It belongs to the genus *Adelea* on account of its thin walled polysporocystid oocysts and disc-like sporocysts but differs from the only described species of the genus in the presence of a hyaline episporic for the spores. The shape of the oocyst is also different from the type species and hence it is described as a new species of *Adelea* for which the name *Adelea hyalospora* is proposed.

Acknowledgments

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References

- CHAGAS, C., 1910.—Estudos de citologia em nova especie de Coccidio, *Adelea hartmanni*, do intestino do *Dysdercus ruficollis* L. *Mem. Inst. O. Cruz.*, 11: 168-185.
- HESSE, E., 1911.—Sur le genre *Adelea* a propos d' une nouvelle Coccidie des oilgochates. *Arch. Zool. exp. gen.*, 7 (N & R): 15-20.
- JOYET LAVERGNE, 1926.—Recherches sur le cytoplasme des sporozoaires. *Arch. Anat. mir.*, 22, 1.
- LEGER, L., 1897.—Coccidies nouvelles du tube digestif des myriapodes. *C. R. Acad. Sci.*, 124: 901-903.
- , 1900.—Sur la presence d' une Coccidie coelomique chez *Olacrates abbreviatus*, Ol. *Arch. Zool. exp. gen.* 8 (N & R): 1.
- , 1904.—Sporozoaires parasites de 1' *Embia solieri* Rambur. *Arch. f. Arch. f. Protistenk.*, 3: 358-367.
- LEGER, L. AND DUBOSCQ, O., 1902.—Sur 1' *Adelea dimidiata* coccidiodes Leger et Duboscq. Coccidie parasite de la *Scolopendra oraniensis lusitanica* Verh. *C. R. Assoc. Franc. Avanc. Sci.*, 31 (i): 714-716.
- MACHADO, A., 1911.—Nouvelle coccidiose de 1' intestin d' un hemiptere (Note preliminaire) *Bull. Soc. Path. Exot.*, 4: 616-617.
- MOROFF, T., 1906.—Untersuchungen ueber Coccidien I. *Adela zonula* nov. sp., *Arch. f. Protistenk.*, 8, 17-52.
- NAVILLE, A., 1927.—Recherches sur le cycle evolutif et chromosomique de *Klossia helicina*. (A. Schneider) *Arch. f. Protistenk.*, 57: 427-474.
- , 1931.—Les sporozoaires *Memories de la societe de physique et d' histoire naturelle de Geneve.*, 41: 1-223.

- NAVILLE, A. AND PEREZ, C., 1899.—Sur une Coccidie nouvelles *Adelea mesnili* n. sp., parasite coelomique d' un lepidoptere. *C. R. S. C. Biol. Paris.*, 5: 694-698.
- PEREZ, C., 1903.—Le cycle evolutif de l' *Adelea mesnili*, coccidie coelomique parasite d' un lepidoptere. *Arch. f. Protistenk.*, 2: 1-13.
- SIEDLECKI, M., 1899.—Etude cytologique et cycle evolutif de *Adelea ovata* Schneider. *Ann. Inst. Pasteur* 13: 169-192.
- SCHNEIDER, A., 1895.—Contributions a l' historie des gregarines des invertebres de Pairs et de Roscoff. *Arch. Zool. exp. ger.* 4: 11-15.
- , 1885.—Coccidie nouvelles on pen connues. *Tablettes Zoologiques*. Poitiers 1.
- SCHELLACK, C., 1913.—Coccidien untersuchungen. II Die Entwicklung von *Adelina dimidiata* A. Schn., einem Coccidium aus *Scolopendra cingulata* Latr. *Arb. K. gesundheit.* 45: 269-316.
- WENYON, C. M., 1926.—*Protozoology*, 2 Vols. Bailliere, Tindall and Cox. London.
- YARWOOD, E. A., 1937.—The life-cycle of *Adelina cryptocerci* sp. nov., a coccidian parasite of the roach *Cryptocercus punctulatus*. *Parasitol.*, 29: 370-390.

Further Cytological Studies in Pulmonata (Mollusca : Gastropoda)

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(With 16 Text-figs.)

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Introduction

The chromosomes of four species of Stylommatophora and three of Basommatophora have been described previously by the author (Natarajan, 1958 a, b, '59). In continuation of these studies, the author has investigated now the chromosomes of eight more pulmonates. Of these, six belong to Stylommatophora and two to Basommatophora as shown below.

Order: Stylommatophora:—

1. *Euplecta travancorica* (Benson);
2. *Macrochlamys vilipensa* (Benson);
3. *Mariella dussumieri* Gray;
4. *Achatina fulica* Fer.;
5. *Rhachis punctata* (Anton);
6. *Laevicaulis alte* (Fer).

Order: Basommatophora:—

1. *Lymnea luteola* Lamarck;
2. *Indoplanorbis exustus* Deshayes.

The present paper embodies the results of these investigations.

Material and Methods

In Table I is given the list of specimens studied, their systematic position according to the classification of Thiele (1931) and the places of their occurrence.

Table I showing the systematic position and places of collection of specimens employed in the present study.

No.	Name of the species	Superfamily	Family	Subfamily	Place of collection
ORDER: STYLOMMATOPHORA					
1.	<i>Euplecta travancorica</i> (Benson)	Ariophantacea	Ariophantidae	Ariophantinae	Kodaikanal hills,
2.	<i>Macrochlamys vilipensa</i> (Benson)	do	do	Macrochlamy-dinae	Chidambaram
3.	<i>Mariella dussumieri</i> Gray	do	do	Girasinae	Kodaikanal hills,
4.	<i>Achatina fulica</i> Fer	Achatinacea	Achatinidae		Annamalai. nagar.
5.	<i>Rhachis punctata</i> (Anton)	Vertiginacea	Enidae	Napaeinae	do
6.	<i>Laevicaulis alte</i> (Fer.)	Soleolifera	Vaginulidae		do
ORDER: BASOMMATOPHORA					
1.	<i>Lymnaea luteola</i> Lamarck		Lymnaeidae		do
2.	<i>Indoplanorbis exustus</i> Deshayes		Planorbidae		do

The ovotestes were removed from freshly collected specimens as quickly as possible and were transferred to the various fixatives. Of these, Carnoy's 1:3 acetic alcohol, Sanfelice's mixture and 10% neutral formalin proved to be excellent. Sections were cut at 8 micron thickness and stained in Heidenhain's iron haematoxylin, crystal violet and Feulgen. Acetocarmine and aceto-orcein squashes of the ovotestes especially after pretreatment with alpha-bromo-naphthol were found to be of very great help in the study of metaphase chromosomes.

Observations

Order: Stylommatophora.

1. *Euplecta travancorica* (Benson): Fig. 1 represents a spermatogonial metaphase plate of this species in a polar view. The karyotype consists of 54 metacentric elements, all of them appearing typically 'V' shaped with equal arms and median centromeres.

A karyogram (Fig. 2) shows all the fifty-four chromosomes resolving into 27 homologous pairs, of which five are bigger in size while the rest are all alike. The karyotype is thus made up of,

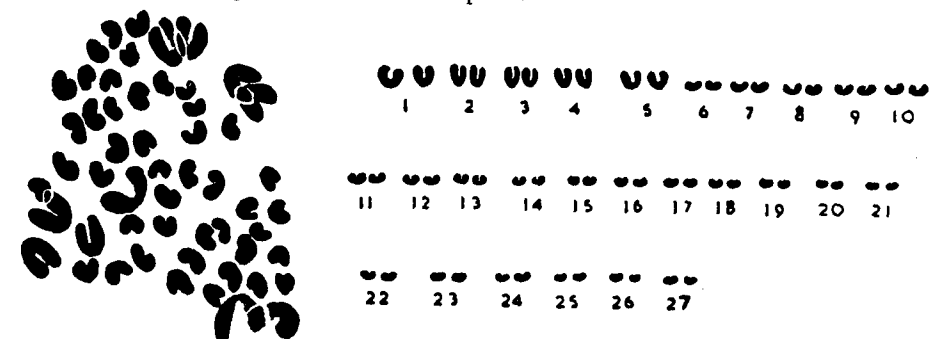


Fig. 1. Spermatogonial metaphase plate of *Euplecta travancorica* (Benson) in a polar view—camera lucida drawing from acetocarmine squash. X ca 6000.

Fig. 2. Karyogram showing the spermatogonial chromosomes of *Euplecta travancorica* (Benson) arranged in order of size. X ca 3000.

- five pairs of big chromosomes (pairs 1 to 5) and
- twenty-two pairs of smaller chromosomes (pairs 6 to 27).

2. *Macrochlamys vilipensa* (Benson): The karyotype of this form consists of sixty metacentrics as can be made out very well from fig. 4. A karyogram drawn from this is shown in fig. 3. Of the thirty homologous

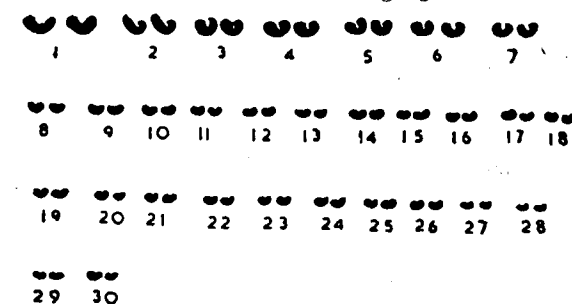


Fig. 3. Spermatogonial chromosomes of *Macrochlamys vilipensa* (Benson) arranged serially in order of their size. X ca 3000.

pairs, seven appear big while the others are more or less uniform and small. A critical analysis of the karyotype, however, shows that,

- (a) six pairs of big chromosomes (pairs 1, 3, 4, 5, 6 and 7) have equal arms with median centromeres,
- (b) one pair of big chromosomes (pair 2) is 'J' shaped with unequal arms and hence with sub-median centromeres, and
- (c) all the smaller elements have median centromeres.

3. *Mariella dussumieri* Gray: Fig. 5 shows the well spread out spermatogonial chromosomes of this form. All the 50 chromosomes are metacen-

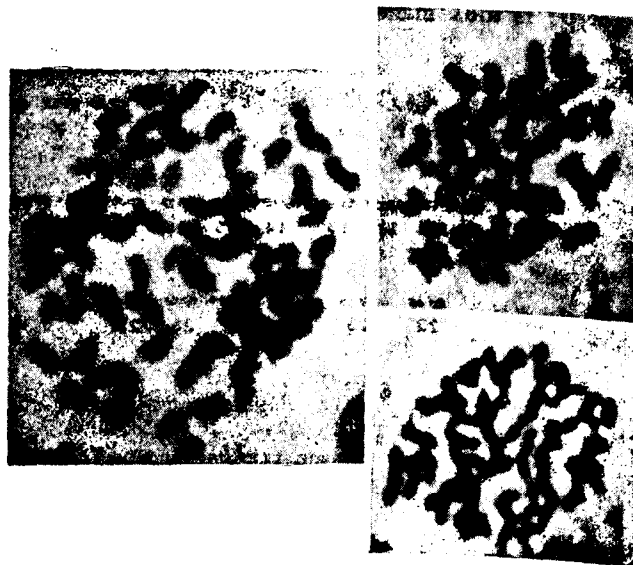


Fig. 4. Spermatogonial prometaphase chromosomes of *Macrochlamys vilipensa* (Benson)—photomicrograph—acetocarmine squash. X ca 4500.

Fig. 5. Spermatogonial chromosomes of *Mariella dussumieri* Gray—Photomicrograph—acetocarmine squash preparation. X ca 4000.

Fig. 6. Photomicrograph of a spermatogonial metaphase plate of *Rhachis punctata* (Anton) in a polar view,—acetocarmine squash. X ca 4000.

trics and these resolve into 25 homologous pairs when arranged serially in order of their size. (Fig. 7).

Thirteen pairs of chromosomes appear bigger in size than the rest. Of these bigger elements, two pairs (pairs 1 and 10) are 'J'-shaped with sub-median centromeres while the remaining eleven pairs are typically 'V'-shaped with median centromeres. The appearance of the twelve pairs of smaller chromosomes with arms of equal length suggest the occurrence of median centromeres in them.

4. *Achatina fulica* Fer.: A spermatogonial metaphase in polar view is shown in fig. 9 which shows clearly the sixty metacentric elements of the karyotype. These, when arranged serially in order of their size (Fig. 10)

resolve into 30 homologous pairs. On a more critical examination it is seen that four pairs of big chromosomes are typically 'V' shaped with median

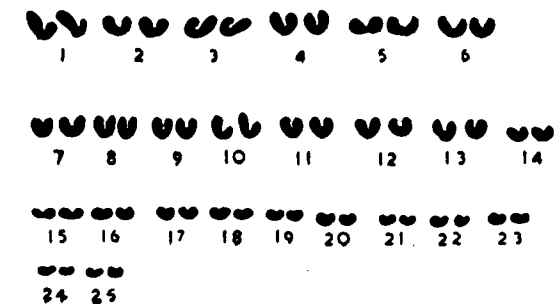


Fig. 7. Homologous pairs of spermatogonial chromosomes of *Mariella dussumieri* Gray serially arranged in order of size. X ca 3000.

centromeres, two pairs of big chromosomes are 'J' shaped with unequal arms and sub-terminal centromeres and the rest are all small, showing median constrictions indicative of median centromeres.

5. *Rhachis punctata* (Anton): The diploid chromosome number is 48 in this species. A spermatogonial metaphase in polar view is shown in fig. 6, which also reveals clearly that all the chromosomes are metacentrics. When arranged serially, they resolve into twenty-four homologous pairs (Fig. 8) of which ten appear bigger in size than the rest.

A critical analysis of karyotype gives the following results:

- (a) Nine pairs of chromosomes are big (pairs 1 to 9) and 'V' shaped with equal arms possessing median centromeres.
- (b) One pair of big chromosomes appears with unequal arms and hence with sub-median centromeres.
- (c) The fourteen pairs of smaller elements are uniform both in size and shape, having median centromeres.

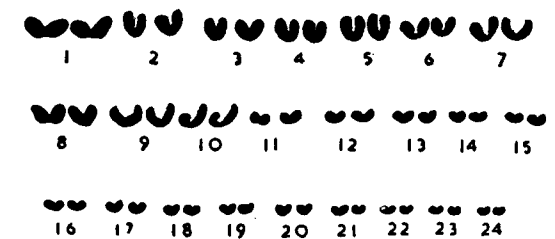


Fig. 8. Homologous pairs of spermatogonial chromosomes of *Rhachis punctata* (Anton) serially arranged in order of size. X ca 3000.

6. *Laevicaulis alte* (Fer.): The spermatogonial chromosomes of this form in polar view is shown in fig. 11. $2n=34$ in this species and all the chromosomes are small in size in general when compared with the other Stylommatophoran forms. Still, the two size groups could be distinguished in them and all of them appear to have only median centromeres.

A karyogram of the spermatogonial complement is shown in fig. 12 from which it may be seen that three pairs of chromosomes (pairs 1 to 3) are bigger in size while the remaining fourteen pairs appear smaller and more uniform in size and shape.



Fig. 9. Spermatogonial metaphase chromosomes of *Achatina fulica* Fer. in a polar view camera lucida drawing—Feulgen squash. X ca 6000.

Fig. 10. Spermatogonial chromosomes of *Achatina fulica* Fer. arranged in order size serially. X ca 3000.

Order: Basommatophora.

1. *Lymnaea luteola* Lamarck: In fig. 13 is represented a spermatogonial metaphase of this species in a polar view, which shows the 34 chromosomes very well. Further all the elements are founded or oblong shaped with no apparent constrictions.

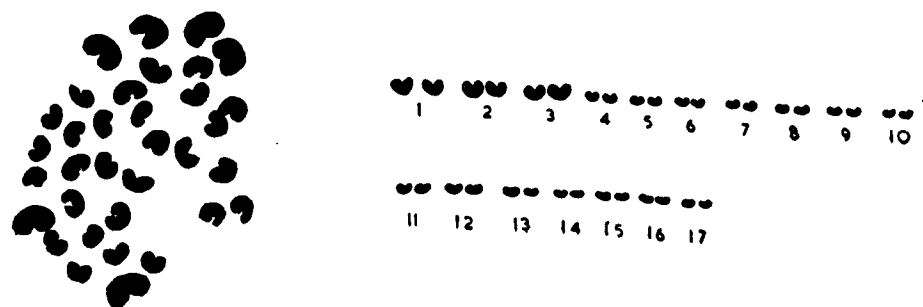


Fig. 11. Polar view of spermatogonial metaphase of *Laevicaulis alte* (Fer.) camera lucida drawing—acetocarmine squash. X ca 5000.

Fig. 12. Karyogram showing the spermatogonial chromosomes of *Laevicaulis alte* (Fer.) serially arranged according to size. X ca 3000.

When arranged serially in order of their size, the elements resolve into seventeen homologous pairs (Fig. 14), of which three pairs are big while the remaining fourteen pairs are small. The bigger ones are oblong but the smaller elements are more rounded and dot-shaped.

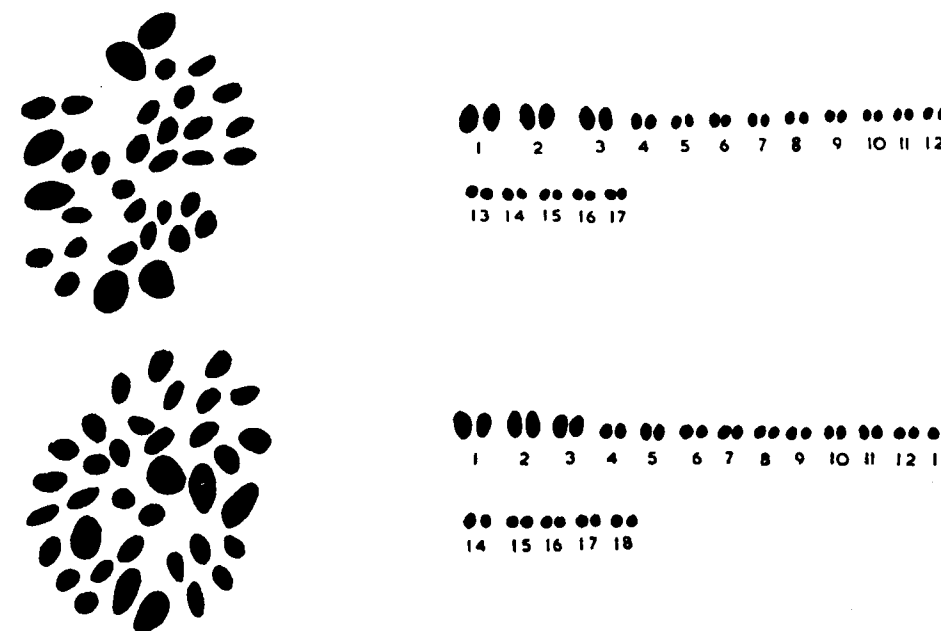


Fig. 13. Spermatogonial metaphase chromosomes of *Lymnaea luteola* Lamarck—Camera lucida drawing from a acetoorcein squash preparation. X ca 5000.

Fig. 14. Spermatogonial chromosomes of *Lymnaea luteola* Lamarck arranged in order of their size serially. X ca 3000.

Fig. 15. Spermatogonial chromosomes of *Indoplanorbis exustus* Deshayes—acetocarmine squash—camera lucida drawing. X ca 5000.

Fig. 16. Homologous pairs of spermatogonial chromosomes of *Indoplanorbis exustus* Deshayes serially arranged in order of size. X ca 3000.

2. *Indoplanorbis exustus* Deshayes: In this form $2n = 36$ as could be seen from fig. 15. All the elements of the karyotype appear rounded or oblong in shape and show no constructions. Of the eighteen homologous pairs shown in the karyogram (fig. 16) three pairs appear big in size while the remaining fifteen pairs are smaller and rounded.

Discussion

The present work on the chromosomes of eight species of Pulmonates together with the earlier findings (Natarajan, 1958 a, b, '59) on seven species, enables us to arrive at some definite conclusions with regard to the number and morphology of the chromosomes of this sub-class.

Altogether, the author has studied the chromosomes of ten species of Stylommatophora belonging to five families, and the diploid chromosome number varies between 34 and 64 in all these species. In the families

Vaginulidae and Oncidiidae $2n = 34$ to 36 , while in Ariophantidae, Enidae and Achatinidae, the number ranges from 48 to 64 . So far, the chromosome numbers of only about fifty species of this order belonging to eight families are known (Makino, 1951). The studies by the present author contribute to the knowledge of pulmonate chromosomes in ten species belonging to five more families which have been so far not studied at all. The previous studies by other investigators show that the range of diploid chromosome number in this order is between 32 and 62 . In the members of the families Arionidae and Succineidae $2n = 32$ to 44 (Perrot, '38; Inaba, '45; Beeson, '60) while in the families Limacidae, Camaenidae, Helicidae, Bradybaenidae, Polygyridae and Philomycidae the range is from 44 to 62 (vide Makino, '51; Beeson, '60). It would thus appear that the order Stylommatophora is rather a heterogeneous one showing a wide range of variation in the number of chromosomes.

On the other hand, the present investigation as well as the previous one (Natarajan, '59) on the chromosomes of five species of Basommatophora belonging to the families Lymnaeidae, Planorbidae and Ellobiidae show that the diploid chromosome number of this order is almost constant varying only between 34 and 36 . Previous work on the chromosomes of this order on 20 species belonging to the families Amphibolidae, Planorbidae, Physidae and Siphonariidae (Lecalvez and Certain, '50; Makino, '51; Inaba and Tanaka, '53 and Inaba, '53) also shows that the diploid number of this order varies only between 32 and 36 . Only three exceptions to this typical condition have so far been reported. The highest number of 59 chromosomes obtained in *Ancylastrum* (Lecalvez and Certain, '50) must, as suggested by the authors themselves, be due to polyploidy. Kowalsky (1933) reported that $n = 8$ in *Melampus boholensis* of the family Ellobiidae (cited by Makino under the family Amphibolidae) but it has been definitely shown (Natarajan, '59) that in another species of *Melampus* (*M. ceilonicus*) as well as in two other different genera of the same family (*Cassidula* and *Pythia*) the diploid chromosome number ranges only between 34 and 36 . So also, though Mahoney (1940) reported that $n = 6$ in *Physa gyrina* of the family Physidae, Le Calvez and Certain (1950) and Inaba (1953) have recorded that $n = 18$ in three different species of *Physa* they studied. Consequently, the earlier records of Kowalsky and Mahoney seem to be open to doubt and need reinvestigation.

Thus, cytologically the order Basommatophora appears to be more uniform and stable.

When we consider the karyotypes of the Stylommatophorous forms included in the present study, there seems to be a general resemblance in the morphology of the chromosomes in all of them. That is, the karyotypes of all the species contain only metacentric chromosomes, which are further divisible into two well defined size groups. In spite of these common features, however, each karyotype is still conspicuous and distinct. In addition to the differences in chromosome numbers, the differences in the morphology of the

chromosomes also show up very well as distinguishing features of each karyotype. For example, in the three different species of *Cryptozona* studied (Natarajan, '58) the number as well as the morphology of the chromosomes are variable. In *C. bistrialis* $2n = 54$ with the complement made up of six big elements and 48 smaller ones. In *C. semirugata* $2n = 56$ with eight big and forty-eight smaller elements while in *C. belangeri* the diploid number is 64 with the karyotype consisting of eight big and fifty-six small chromosomes. In other three genera of the same family (Ariophantidae) viz., *Mariella*, *Euplecta* and *Macrochlamys* the diploid chromosome numbers are 50, 54 and 60 respectively. The karyograms (Figs. 7, 2 and 3) clearly show the differences between them. It can also be further seen that though $2n = 54$ in *Cryptozona bistrialis* and *Euplecta* in the karyotype of the former there are six bigger chromosomes while in the latter ten such elements are present.

The cytological conditions in Basommatophora are also similar. The investigations by the author on five members of Lymnaeidae, Planorbidae and Ellobiidae show that their karyotypes consist of round or oblong shaped chromosomes with no apparent constrictions. Further the chromosomes also fall into two definite size groups. Previously Inaba (1953) and Inaba and Tanaka (1953) have also reported that there occur only rounded or oblong shaped chromosomes in all the six species of Basommatophorous snails they studied. However, the studies by the author on different species of this order shows that karyotype of each form differs from that of another either in number or in morphology (size) of the chromosomes.

As stated earlier, there exists no critical or detailed work on the chromosomes of Pulmonata in general, almost all the previous studies being restricted to recording of the chromosome numbers only. As such it is not possible here to make any reference or comparison of the results of the present study with any of the previous works. However, the importance and significance of the study of especially the morphology of the chromosomes in the identification of the karyotypes of different species of Pulmonates is well brought out by the present study, which also brings to light the marked differences between the two orders of Pulmonata (Stylo—and Baso—mmatophora) both in number as well as the morphology of the chromosomes.

The study of the chromosomes of fifteen species of Pulmonates by the author shows clearly that all the elements of all the karyotypes resolve into homologous pairs. Further, the behaviour of the chromosomes during spermatogenesis is also normal (Natarajan, unpublished). Therefore, it seems that sex chromosomes that can be identified at the cytological level are absent in all the forms studied. The absence of sex chromosomes in these forms lends support to the view expressed by White (1954) that the various authors like Perrot (1930) who claimed at one time or other to have discovered sex chromosomes in such groups as flukes, snails and earthworms, were mistaken either in their observations or in their interpretations.

The aquatic Basommatophora are always considered as a primitive and basal group. Morton (1958) has stated that the family Ellobiidae of this

order is the most primitive one while the other families like Lymnaeidae and Planorbidae must be considered as more highly specialised. But cytologically, we could not trace any difference between the families, the order as a whole appearing as a primitive one with stabilised karyotypes which do not show wide variations.

Of the order Stylommatophora, the family Succineidae is considered as the primitive one while the superfamily Helicacea is generally taken as the most highly advanced. Morton (1958) has, however, added that almost every superfamilial has at some time contributed a specialised shell-less line. Cytological findings also seem to point to the same view. First of all, the occurrence of almost unbroken series of 32 to 64 chromosomes in the different families of this order seem to suggest only a tendency towards an increase in the number of chromosomes during the course of evolution of this group as stated by Husted and Burch (1946). But the secondary specialisation to the slug habit however, appears to have led towards a decrease in the number of chromosomes again. For example, of the six species of the superfamily Ariophantacea studied the shelled forms viz., *Cryptozona*, *Euplecta* and *Macrochlamys* have diploid chromosome numbers of 54 to 64 while in the slug *Marrella* $2n = 50$. So also the highly specialised and the entirely slug families like Onchidiidae, Vaginulidae and Arionidae show very low numbers of 32, 34 and 36.

However, it must be pointed out here that the above assumptions still await support from further extensive data on the chromosomes of Pulmonata.

Summary

1. The number and morphology of the chromosomes of six species of Stylommatophora and two species of Basommatophora have been studied.
2. In five species of Stylommatophora belonging to the families Achatinidae, Ariophantidae and Enidae $2n = 48$ to 64 while in *Laevicaulis* of the family Vaginulidae $2n = 34$.
3. Of the order Basommatophora, $2n = 34$ in *Lymnea* of the family Lymnaeidae and $2n = 36$ in *Indoplanorbis* of the family Planorbidae.
4. From a cytological point of view, the order Stylommatophora appears to be more advanced while Basommatophora appears to be more primitive.
5. The sex chromosomes are absent in all the pulmonates studied.
6. The two orders of Pulmonata show marked variations both in number and morphology of the chromosomes.

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References

- BEESON, G. E., 1960.—Chromosome Numbers of slugs. *Nature*, **186**: 257.
- HUSTED, I., & P. R. BURCH, 1946.—The Chromosomes of Polygyrid snails. *Amer. Nat.*, **80**: 410.
- INABA, A., 1945.—Chromosome Numbers in some Land snails. (In Jap.) *Jap. J. Malac.*, **14**: 97.
- , 1950.—Studies on species of Pulmonate Mollusks based on chromosome number. (In Jap.) *La. Kromosomo*, **7**: 295.
- , 1953.—Cytological studies in Molluscs. I. Chromosomes in Basommatophoric Pulmonates. *J. Sci. Hiroshima Univ. Ser. B.*, **14**: 221.
- , and Tanaka, 1953.—Studies on the chromosome numbers of some freshwater Gastropods. *Ibid.*, **14**: 213.
- KOWSLOWSKY, F., 1933.—Zur Anatomie der Auriculide *Melampus boholensis* H. & A. Adams. *Jena Z. Naturwiss.*, **68**: 117.
- LE CALVEZ, J. & P. CERTAIN., 1950.—Donnees carvologiques sur quelques Pulmones basommatophores. *C. R. Acad. Sci. Paris*, **231**: 794.
- MAHONEY, S., 1940.—Spermatogenesis with special reference to certain extranuclear bodies in the Pulmonate, *Physa gyrina* Say. *Univ. Colo. Stud.*, **26**: 81.
- MAKINO, S., 1951.—*An Atlas of the chromosome Numbers in Animals*. Ames: Iowa State College Press.
- NATARAJAN, R., 1958a.—Chromosomes of three species of South Indian Pulmonate snails of the genus *Cryptozona* Morch. *Curr. Sci.*, **27**: 311.
- , 1958b.—Chromosomes of some Estuarine Basommatophorous Snails. (Mollusca: Pulmonata) from Portonovo. *J. zool. Soc. India*, **10**: 103.
- , 1959.—Chromosomes of the slug *Oncidium verraculatum* Cuv. (Mollusca: Gastropoda: Pulmonata). *Ibid.*, **11**: 30.
- PERROT, J. L., 1930.—Chromosomes et heterochromosomes chez les Gastropodes pulmones. *Rev. suisse Zool.*, **37**: 397.
- , M., 1938.—Etude de cytologie comparee chez les Gastropodes pulmones. *Ibid.*, **45**: 487.
- PERROT, J. L. & M. PERROT., 1938.—Note sur les chromosomes de cinq especes de Limnees. *C. R. seances de la Soc. de Phys. et d'Hist. nat. de Geneve.*, **55**: 92.
- THIELE, J., 1931.—*Handbuch der systematischen Weichtierkunde*. 1, 2, Jena.
- WHITE, M. J. D., 1954.—*Animal Cytology and Evolution*. II Edn. Cambridge: University Press.

Studies on the Gall Insect *Dactylethra candida* Meyrick (Galechidae) and its parasites

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(With 1 Table and 6 Text figs)

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Introduction

This paper records some of the results of an investigation on the biology of the insects associated with stem galls on the wild indigo plant *Tephrosia purpurea* Pers. (Leguminaceae). The caterpillars of *Dactylethra candida* Meyrick produce stem galls on this plant. Brief descriptions of this gall have been given by Mani (1948) and Nayar (1948). Kalyanam (1957) recorded observations on the Hymenopterous parasites attacking the gall-maker. After (1939, 1952). Other important contributions on the subject are by Carter (1936) Barber (1938), Parr (1940), Short (1947), Nystrakis (1947) and Sakimura (1947). The present study relates to the structure of the gall and the relationship between the gall maker and its parasites.

Material and Methods

Samples of the gall were collected from plants and *Tephrosia purpurea* Pers. occurring wild along the railway bunds near the Coleroon river and on the banks of Vellar Estuary at Porto novo. Specimen tubes of 3" x 2½" size were used for rearing the gall insects. Sections of the gall were taken by using Carnoy's 1:3 acetic alcohol as fixing agent. For the initial fifteen minutes the fixation was under a partial vacuum, and cold infiltration also was

Observations

The adults of *Dactylethra candida* (10 to 11 mm. in length—Fig. 1), though capable of flight spend most of the time resting on the stems or on the underside of the leaves of *T. purpurea*. The adult life rarely exceeds 4 days, and during this period they do not feed. For obtaining the eggs and larvae, over a dozen pupae were taken in a rearing tube, and this together with a conical flask containing water and a shoot of *T. purpurea* dipping into it were placed under a bell jar. Within two days after hatching the moths laid numerous eggs on the stem of the twig. The eggs are small, (425 micra in length), cylindrical and ridged on the surface. They are scattered along the stem and are lightly fastened to its surface (Fig. 2). The eggs hatch in eight days (January), and the first stage larvae (0.51 mm. in length) are found to crawl on the stem and they generally remain in the tender parts of the shoot. It is difficult to rear the larvae outside the gall cavity under laboratory conditions. Other larval instars were therefore determined from the collection of a large number of larvae on the basis of size of head sclerites. There appear to be four larval stages. The entire larval period extends between 30 and 40 days, and the pupal duration varies from 10 to 18 days.

The first stage larva burrows into tissues of the tender terminal parts of the stem. A pear-shaped (13mm x 8mm) or fusiform gall develops around the larva (Fig. 3). The larval cavity inside the gall becomes completely shut off from the outside world. The larvae feed on the juicy inner wall of the gall. The excretory pellets of the larva accumulate at the bottom of the gall cavity. The fully grown larva (9 to 10. mm. in length) eats away the wall at the top of the gall and makes an exit hole burrow and finally the exit hole before pupation. Very rarely the exit hole is made at the bottom of the gall near the 'stalk'. The caterpillar may not be a serious pest of the host plant because the gall appears to be a localised reaction of the plant to the presence of the larvae.

When the caterpillar of *D. candida* completes the exit burrow, the apex of the gall becomes thin (306 micra). At this stage the female *Bracon greeni* Ashmead (Braconidae) oviposits into the gall by piercing the thin walled apex of the gall. Vertical sections of the parasitised gall show the course of the ovipositor (Fig. 4). The same method of oviposition is adopted by the other parasites of *D. candida* viz. *Eurytoma* sp., (Eurytomidae), *Bruchocida orientalis* Crawford (Eupelmidae) and *Neanastatus proximus* Ferriere (Eupelmidae). *Brachymeria* sp. and *Antrocephalus* sp. (Chalcididae) are endophagous parasites of the gall-maker. *Goniozus* sp. (Bethyridae) also attacks the caterpillar of *D. candida*. The larvae of *B. greeni* (Fig. 5) and *Goniozus* sp. are ectophagous on the host caterpillar, usually more than one larva parasitising a single host. These larvae secrete membranous cases in which they pupate.

The water content of the tissues of the gall is 16 to 18 per cent. higher than that of the normal stem. The histology of the gall also differs markedly from that of the normal stem. Serial transverse sections through the transitional region between the gall and adjoining normal stem show the transformation of the tissue structure. The gall is a morbid modification of the normal tissues. In the early stages of the gall formation the vascular bundles are widely separated by the parenchymatous cells. At a later stage the tracheids proceed from the vascular regions and reach the zone of nourishment surrounding the gall-maker. Prominent nuclei are found in most of the cells of the young gall tissue. The full grown gall undergoes a great alteration in its tissues by the hypertrophy, and hyperplasia of its cells with the result that three distinct zones are recognized in its wall. The differences in the diameter measurements of normal cells and gall cells are shown in Table. 1.

TABLE 1

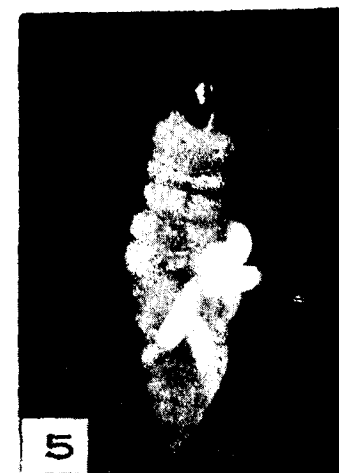
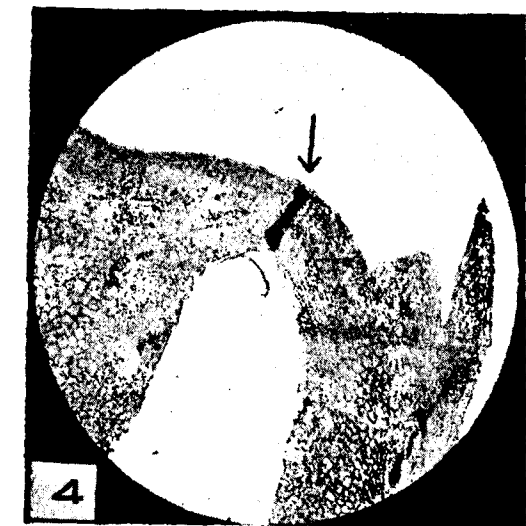
Diameter measurements (in micra) of the normal cells and gall cells of *Tephrosia purpurea*

	Normal Stem	Parasitised gall Vertical Section	Well developed gall Transverse Section	Transitional region Upper level	Transitional region Lower level
Cortical cell	12.37	34.96	30.30	27.61	23.76
Epidermal cell	13.64	19.32	15.92	19.32	18.18

The outermost zone is the cortical region consisting of thin walled parenchymatous cells. The inner zone lining the gall cavity is the nutritive layer comprised by cells rich in cytoplasm. In between these regions is a layer of highly thick walled cells which obviously lend rigidity to the gall. (Fig. 6.)

Discussion

Various theories have been given to explain gall formation. Felt (1936) explained that whereas many insects kill the plant tissues at the point of attack, the successful gall-makers are more subtle in their effects. According to him the histological modification in gall is by diffusion of cell contents, the process evidently originating in reactions between the gall producers and adjacent tissues. The galls which are characterised by definite sizes and shapes are termed by Felt as determinate galls. He holds the view that the gall is a passive reaction of the plant to the stimuli from the gall maker.



Explanation of Figures

Fig. 1. *D. candida*, adult; Fig. 2. Eggs of *D. candida* on the stem of Kolingi. Fig. 3. Stem galls on Kolingi. Fig. 4. Vertical section through the apex of the gall—Arrow indicates the course of ovipositor of *B. greeni*. Fig. 5. Caterpillar of *D. candida* parasitised by the larvae of *B. greeni*. Fig. 6. A portion of the transverse section through the gall.

Studies of elliptical goldenrod gall caused by *Gnorimoschema gallae-solidaginis* (Riley) by Barber (1938) form a relevant reference. Though there are parallel characters between the Goldenrod gall and *Tephrosia* gall in structure and biology, there are certain differences characteristic for these galls.

It is reported that *G. gallaesolidaginis* produces only one generation a year. But *D. candida* is found to breed all through the year. The silk lining of the gall cavity of the Goldenrod gall formed by the gall maker is absent in *Tephrosia* gall. While the exit hole is closed by an ingeniously made plug in Goldenrod gall, it is left open in *Tephrosia* gall. A clean habitation is maintained in the Goldenrod gall by the gall-maker which covers the faecal deposits with silk; but in *Tephrosia* gall the faecal pellets lie uncovered in the bottom of the gall. Parr (1940) studied galls produced by scale insects and showed that the stimuli arise from salivary secretion. He also suggested the presence of enzyme-like substance in the salivary secretion as responsible for tissue proliferation. The Coccid galls studied by Shrot (1947) are caused by the insect's feeding. In this case the rate of growth of gall affects the rate of growth of the insect. Nysserakis (1947) showed that the leaf galls in vines due to *Phylloxera* feeding were the result of injections of indole-3-acetic acid into the plant by the insect. Carter (1952) expresses the view that the toxins secreted by the insect are comparable to plant hormones. Sakimura (1947) concluded from a study of the gall produced by thrips that they are specific to the host plant and to the species of thrips producing them. Imms (1947) says that injuries are probably contributory influences in gall formation, combined with growth promoting secretions produced by the insects. One or both of these causes may influence the production of auxin by the affected part of the plant. The more complex galls according to him result probably from the combined influence of several causes. In the *Tephrosia* gall proliferation of tissue ceases when the gall-making caterpillar is fully grown. The gall formation in this plant is presumably due to the feeding stimulus of the caterpillar.

Summary

Caterpillars of *D. candida* cause stem galls on *Tephrosia purpurea*. The gall affords nourishment and protection to the gall-maker and grows by hypertrophy and hyperplasia of the stem tissues. The stimulus for gall production appears to arise from irritation caused by spreading by the gall insect. Numerous Hymenopterous parasites attack the gall maker, e.g. *Goniozus* (Bethyridae); *Brachymeria* sp. *Antrocephalus* sp. (Chalcididae); *Bracon greeni* (Braconidae); *Eurytoma* sp. (Eurytomidae); *Bruchocida orientalis* Crawford, insect *Neanastatus proximus* Ferriere (Eupelmidae). Species of *Neanastatus*, according to Dr. C. Ferriers (1957; personal communication) attack only Cecidomyids; but here it has been periodically found to parasitise *D. candida* (Galechidae).

Acknowledgments

I have great pleasure in recording my sincere thanks to Dr. P. Govindan, Professor and Head of the Department of Zoology, Annamalai University, for guidance.

References

- BARBER, W. G., 1938.—A study of the Elliptical Goldenrod gall caused by *Gnorischema gallaesolidaginis* Riley. *J. N. Y. ent. Soc., Soc.* **46**: pp. 155-178.
- CARTER, W., 1952.—Injuries to plants caused by insect toxins. *Bot. Rev.* **18**: pp. 680-715.
- FELT, E. P., 1936.—The Relations of Insects and Plants in gall production. *Ann. ent. Soc. Ame.* **29**: pp. 694-700.
- KALYANAM, N. P., 1957.—Some parasites of *Dactylethra candida*, an insect pest of *Tephrosia purpurea*. *Madras agric. J.* **44**: pp. 205-206.
- MANI, M. S., 1948.—Indian Cecidozoa and Zoocidia. *Jour. roy. Asi. Soc. Bengal* **14** No. 2. pp. 130-131.
- NAYAR, K. K., 1948.—Descriptions of plant galls from Travancore. *J. Bombay nat. Hist. Soc.* **47**: pp. 674.
- NYSTERAKIS, F., 1946.—Resistance of American vines to *Phylloxera* and sensitiveness of their cells to Phytohormones. *C.R. Acad. Agric. Fr.*, **10**: pp. 444-446.
- PARR, T. J., 1940.—*Asterolecanium variolosum*, a gallforming Coccid, and its effect upon the host trees. *Yale. Sch. For. Bull.*, **46**:
- SAKIMURA, K., 1947.—Thrips in relation to gall-forming and plant disease transmission. *Proc. Hawaii. ent. Soc.*, **13**: pp. 193-206.
- SHORT, J. R. T., 1947.—Description and life history of a new Western Australian Coccid. *Proc. Linn. Soc. N.S.W.* **71**: pp. 257-269.

Racial Analysis of *Rita chrysea* Day Inhabiting The Mahanadi River

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Introduction

In connection with the author's taxonomic study of the fishes of the family Bagridae, samples of *Rita chrysea* were collected from the River Mahanadi during October-November, 1954. The species is endemic in the Mahanadi river system and has not been so far recorded from elsewhere. Four samples are utilised for purposes of this study:

	Range of Total length in mm.
Sample A from Anicut, Cuttack N = 126	94.0 to 212.0
Sample B from Kamli Bazaar, Sambalpur N = 167	48.5 to 208.0
Sample C from Chandrapur N = 50	63.2 to 146.0
Sample D from Tel River, Belgaon N = 12	56.0 to 154.0

The fourth sample was collected by Chauhan (1947) from Tel River which is a tributary of the Mahanadi (see Fig. 1). The rest of the samples were collected by the author.

The study was undertaken (i) to test whether the stock in the River Mahanadi is homogenous, (ii) to determine the population which diverges

most, (iii) to find whether the four samples are different from each other, and (iv) to find whether they are taxonomically divergent to be named as separate infra-specific categories.

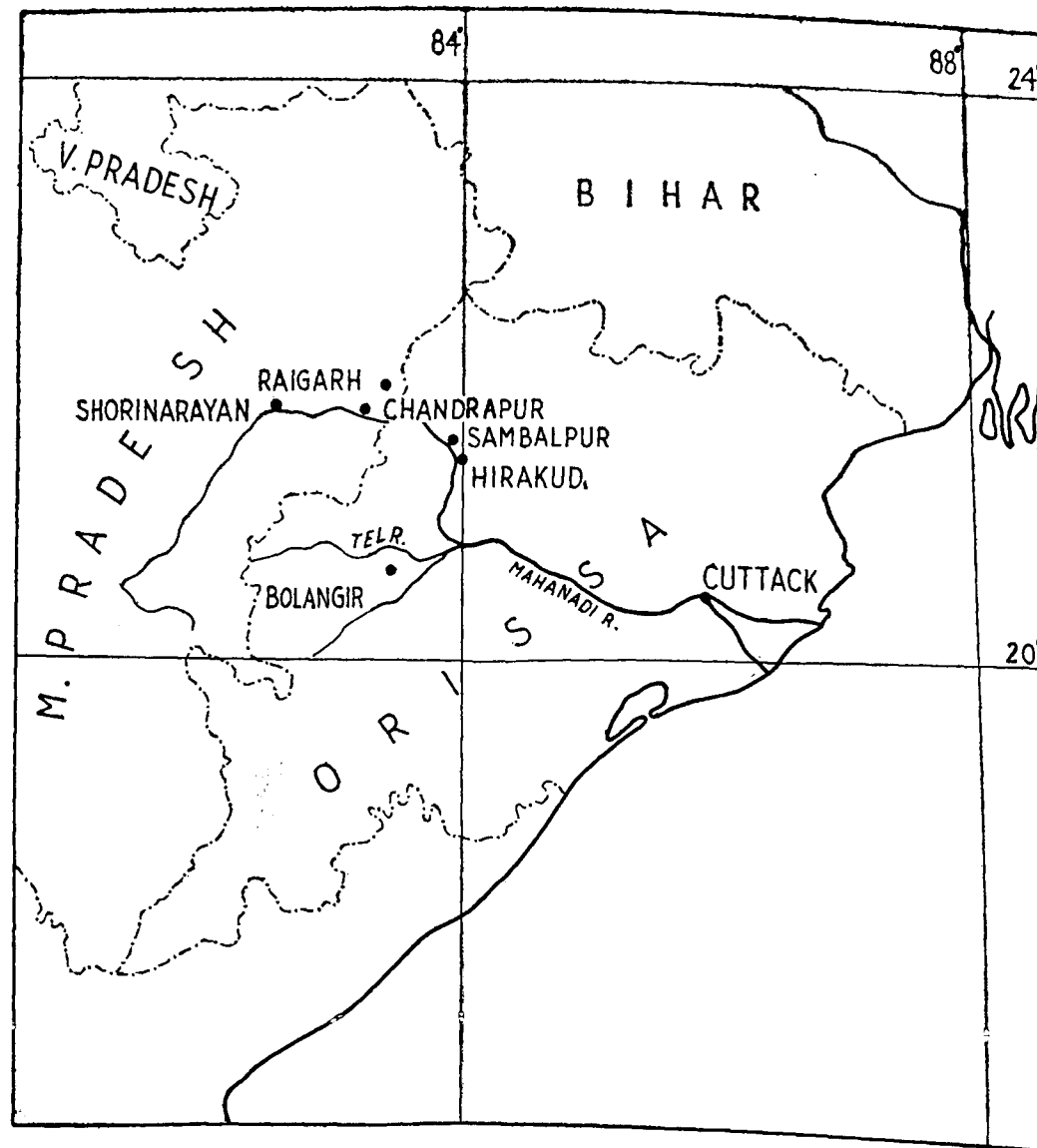


Fig. 1. Map of River Mahanadi showing the localities from where samples of *R. chrysea* were collected.

Methods

Samples were collected at random, without any bias as regards to gear or fishing effort. The specimens were preserved in formalin and all measure-

ments were taken in the laboratory. The statistical work in this paper is based on formulae and tables found in Simpson & Roe (1939) and Snedecor (1946). The graphical representation of the variations are as proposed by Dice & Lerass (1936), modified by Hubbs and Perlmutter (1942) and Hubbs (1952). Another modification introduced is to arrange the graphs face to face, which facilitates easier comparison of the overlapping standard deviations of the two samples. In all graphs, the base line is the range, the hollow area is one standard deviation and the solid black area is two standard errors on either side of the mean which is represented by the vertical small line.

Analysis

A preliminary study was carried out employing the method of analysis of covariance. The data are presented in tables 1—9. The analysis revealed possible populational divergence. In order to determine whether the population (A) at Cuttack, which is the population from the type-locality, diverged most, it was compared (table 10, figs. 2 & 3 (graphs 1 to 15) with all the remaining populations pooled together (X), employing the *t* test. Ginsburg's method (1938, 1939, 1940) of computing intergradation and divergence was applied to these populations A and X. The results are as below:—

	In per cent	
	Intergradation	Divergence
* SL/Body depth	35.12	64.88
SL/Head width	29.49	70.51
SL/Head depth	37.28	62.72
SL/Length of dorsal spine	31.07	68.93
LH/Snout	33.32	66.68
LH/Eye	31.35	68.65
LH/Width of gape of mouth	38.74	61.26
LCPD/HCPD	16.89	83.11
LH/HCPD	7.93	92.07

The analysis indicates that the populations have diverged to the subspecific or specific levels in respect to characters such as the length and depth of the caudal peduncle.

* Throughout this paper SL = Standard length; LH = Length of head; LCPD = Length of caudal peduncle, and HCPD = Least depth of caudal peduncle.

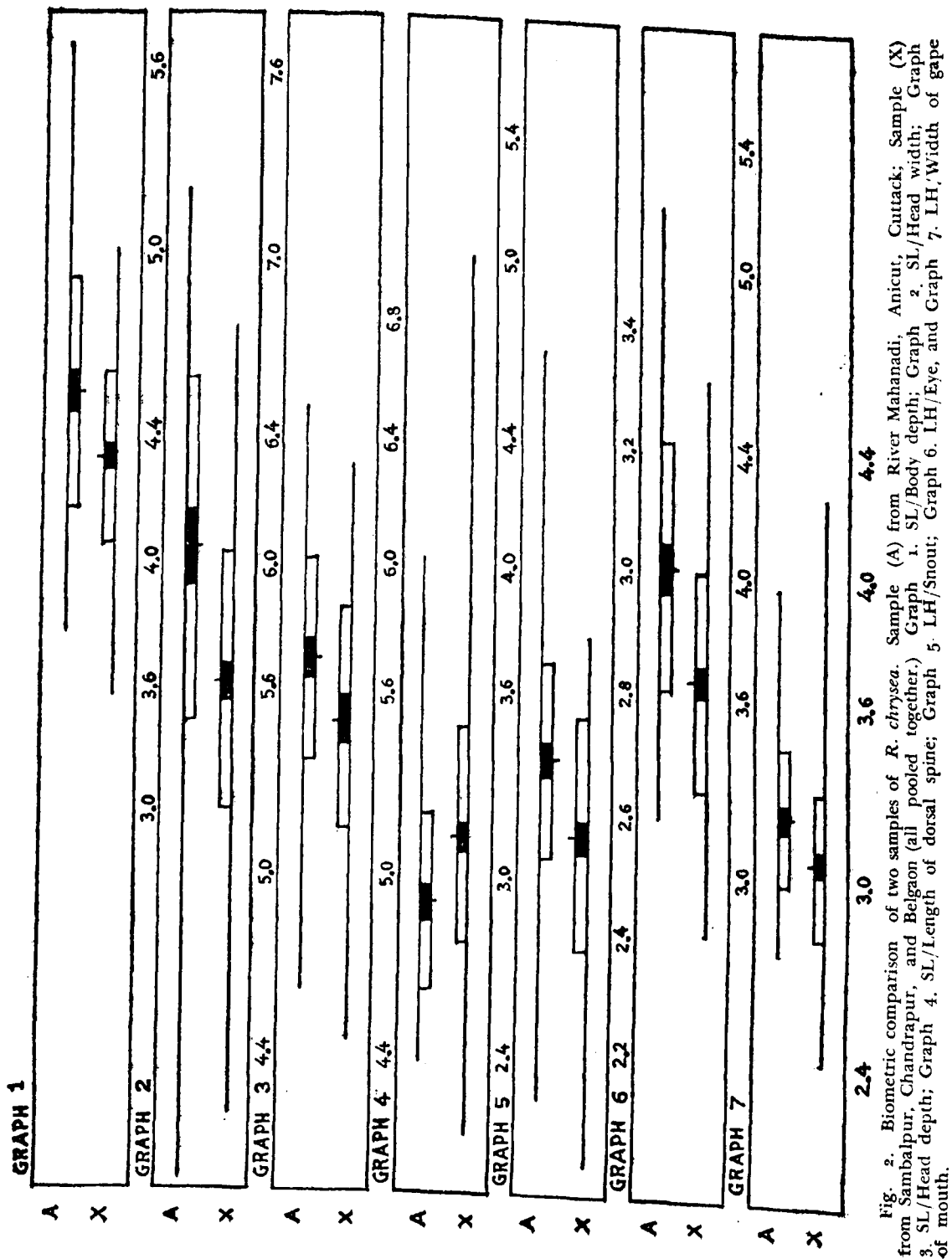


Fig. 2. Biometric comparison of two samples of *R. chrysea*. Sample (A) from River Mahanadi, Anicut, Cuttack; Sample (X) from Sambalpur, Chandrapur, and Belgaon (all pooled together.) Graph 1. SL/Head depth; Graph 2. SL/Length of dorsal spine; Graph 3. SL/Head depth; Graph 4. SL/Length of dorsal spine; Graph 5. SL/Head depth; Graph 6. SL/Length of dorsal spine; Graph 7. SL/Head depth.

Having thus established that the typical population at Cuttack is divergent to the maximum extent from all the other populations pooled together, the Sambalpur population (B) was compared (table 10, figs 4 and 5 (graphs 16 to 26) with the population at Cuttack (A) to determine whether it is statistically different when considered alone. A third comparison was made (table 10, fig. 6 (graphs 27 to 29) to determine whether the Chandrapur population (C) is statistically different from the Sambalpur population (B).

Discussion

As a result of these studies, it is concluded that (i) the stock of *R. chrysea* in the River Mahanadi is heterogenous, (ii) the population at Cuttack diverges most, and (iii) the populations at Sambalpur, Chandrapur are statistically different from each other.

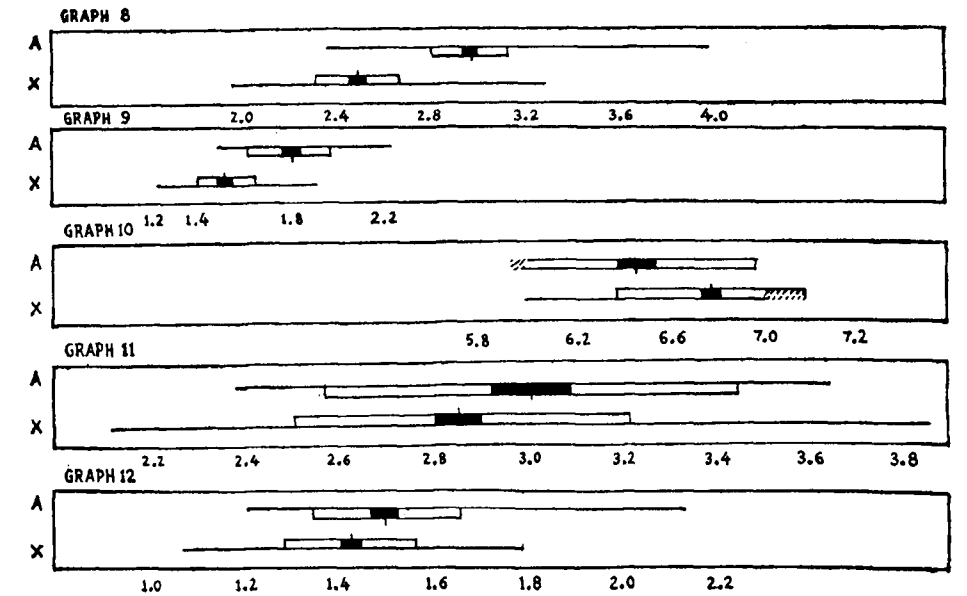


Fig. 3. Biometric comparison of two samples of *R. chrysea*. Sample (A) from River Mahanadi, Anicut, Cuttack; Sample (X) from Sambalpur, Chandrapur, and Belgaon (all pooled together.) Graph 8. LH/HCPD; Graph 9. LH/LCPD; Graph 10. Dorsal fin rays; Graph 11. LH/Int. Orb. Wdh.; Graph 12. Snout/Eye; Graph 13. SL/Head length; Graph 14. LH/LCPD; and Graph 15. Int. Orb. Wdh./Eye.

The taxonomic characters which show the divergence among these populations best are the relative length and depth of the caudal peduncle. Although the divergence approaches high level of differentiation if Ginsburg's method (*loc. cit.*) of designating populations is used, they are not named since these differences are purely statistical and may not represent real, biological differences to separate them taxonomically. Further, the possibility of geographical gradients among the characters selected in the various populations is also not eliminated. As such, these populations are tentatively considered as races.

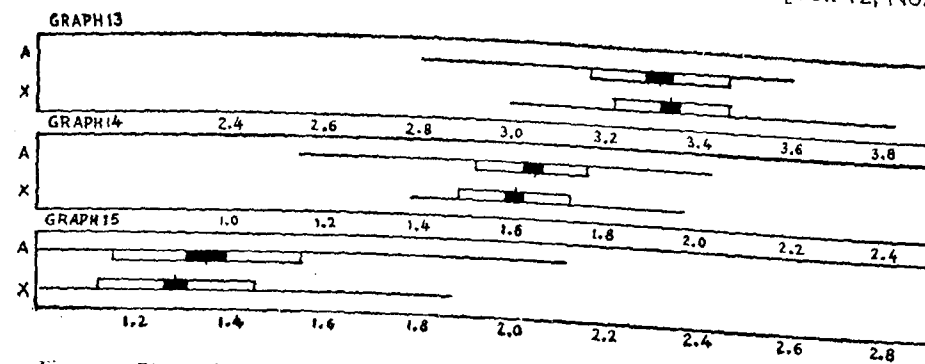
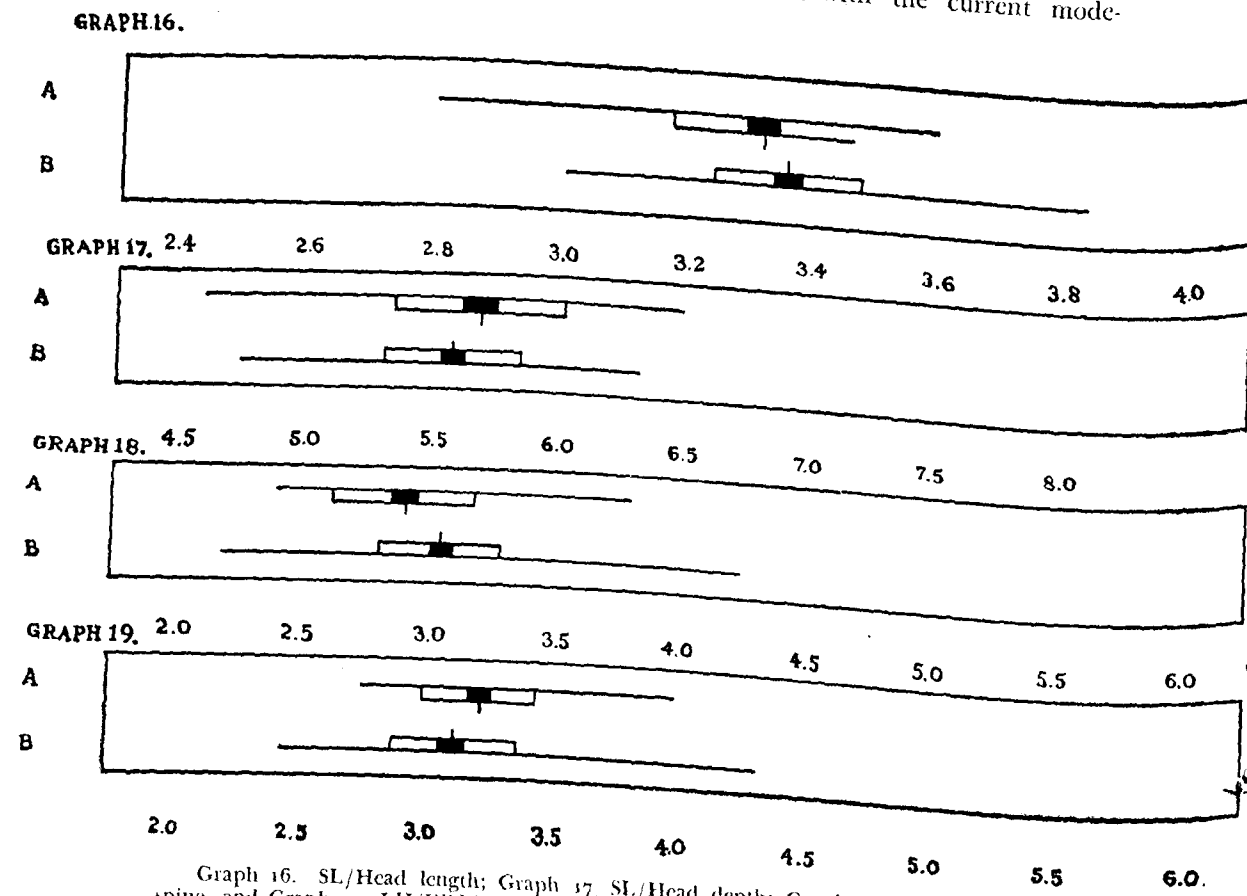


Fig. 4. Biometric comparison of two samples of *R. chrysea*. Sample (A) from River Mahanadi, Anicut, Cuttack; Sample (B) from Sambalpur.

The ecological features of the River Mahanadi at these localities are different. Thus at Cuttack the river bed is composed of soft alluvium typical of deltaic areas. The stream is about a mile wide with the current mode-



Graph 16. SL/Head length; Graph 17. SL/Head depth; Graph 18. SL/Length of dorsal spine, and Graph 19. LH/Width of gape of mouth.

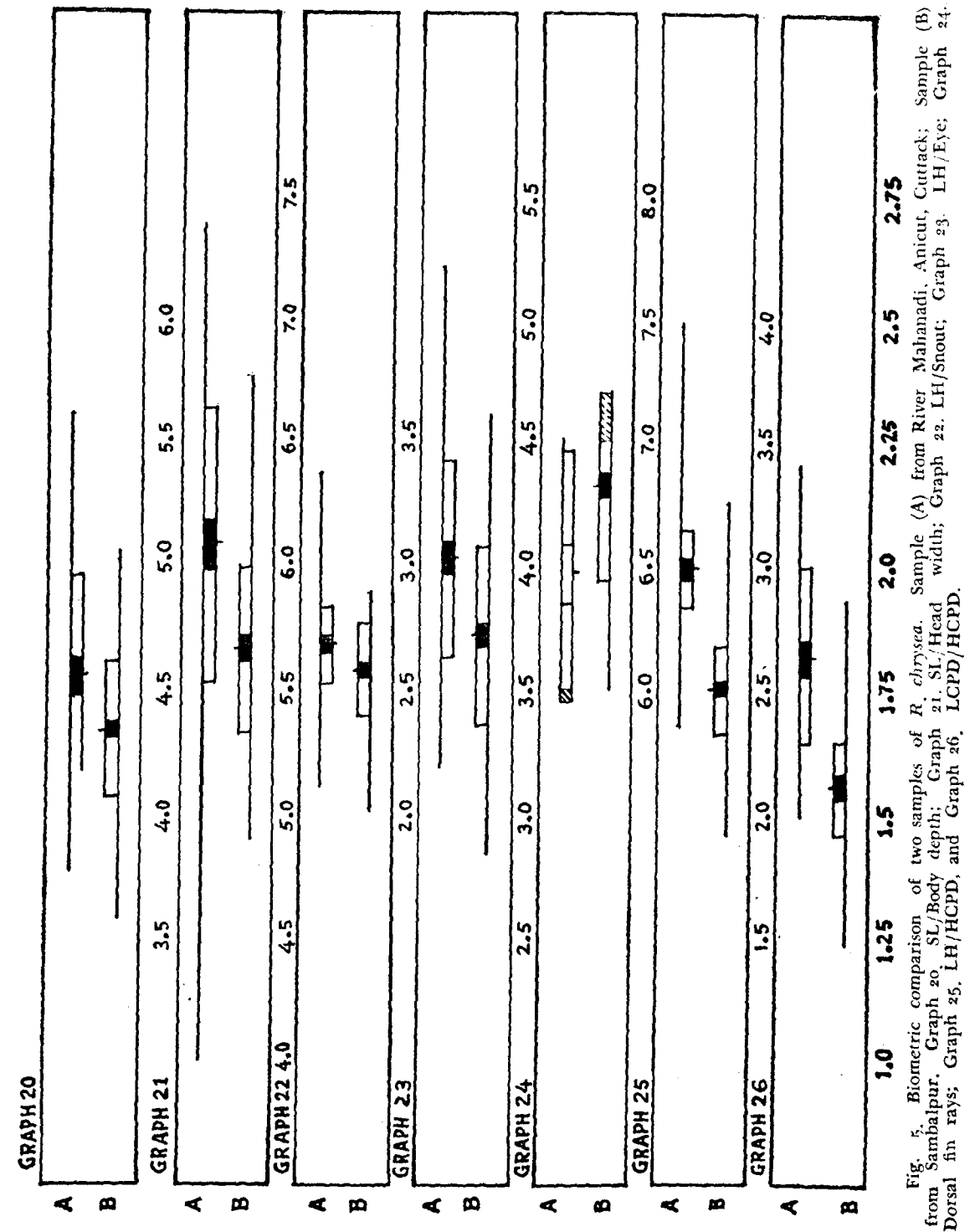


Fig. 5. Biometric comparison of two samples of *R. chrysea*. Sample (A) from River Mahanadi, Anicut, Cuttack; Sample (B) from Sambalpur. Graph 20. SL/Body depth; Graph 21. SL/Head width; Graph 22. LH/Snout; Graph 23. LH/Eye; Graph 24. Dorsal fin rays; Graph 25. LH/HCPD, and Graph 26. LCPD/HCPD.

rate. Above the anicut, which is a stone bridge temporarily planked during the summer months a vast sheet of water of considerable depth is impounded. Only the overflow is released through sluice gates across which fishermen place their trap nets and catch a good deal of fish. The river course at Sambalpur district is surrounded by an undulating hilly terrain. At Sambalpur and Belgaon, the river flows fast through a bed of rocks and boulders with a number of rapids and riffles. The stream is broken up and flows over clear gravel or sandy bed. At Chandrapur the river flows through a shallow bed of sand and fine mud, with a slow current. These different ecological features also seem to corroborate the heterogeneity of the population of *R. chrysea* in the stretch of the River Mahanadi studied.

Acknowledgements

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Summary

Four random samples of *R. chrysea* from Cuttack, Sambalpur, Chandrapur and Belgaon, all of the Mahanadi river system, were studied to test the homogeneity or heterogeneity of the stock in the river; if heterogenous to determine the population diverging most, and the differences, if any, between the four samples. Analysis by the Covariance method revealed possible population divergence. By employing the *t* test it was found that the population at Cuttack diverged most and that others at Sambalpur and Chandrapur are statistically different from each other. Although the divergence is of sub-specific order as per Ginsburg's method (1938) and also corroborated by the different ecological factors at these localities, the populations are not named since they do not seem to represent real biological differences to separate them taxonomically.

TABLE 1

Comparison of the regressions of the total length of four samples of *Rita Chrysea* population from River Mahanadi

Samples	A	B	C	D
D. F.	125	148*	49	11
$S(x-\bar{x})^2$	32394.80	70323.30	10874.76	12167
$S(y-\bar{y})^2$	49690.85	1051.86	17322.33	19892
$S(x-\bar{x})(y-\bar{y})$	38930.72	85257.95	13637	15518.65
b_{yx}	1.202	1.212	1.253	1.276
$b_{yx} S(x-\bar{x})(y-\bar{y})$	46794.73	10332.64	17087	19802
$S(y-\bar{y})^2 - b_{yx} S(x-\bar{x})(y-\bar{y})$	2896.12	1853	235	90

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. 1% F.
Separate Regression	332	5074	15.24	
Common Regression	335	5401		
Deviation	3	327	109	7.15223 4.66

D. F. = Degrees of Freedom b_{yx} = Regression Coefficient

$\bar{x}$ = Standard length $\bar{y}$ = Mean of values of y

Y = The variable S = Summation

$\bar{X}$ = Mean of values of x Obs. F. = Observed F.

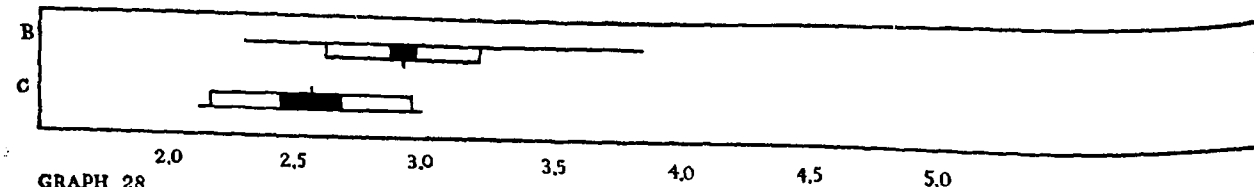
* Out of 167 specimens, 18 had their caudal fin damaged.

TABLE 2

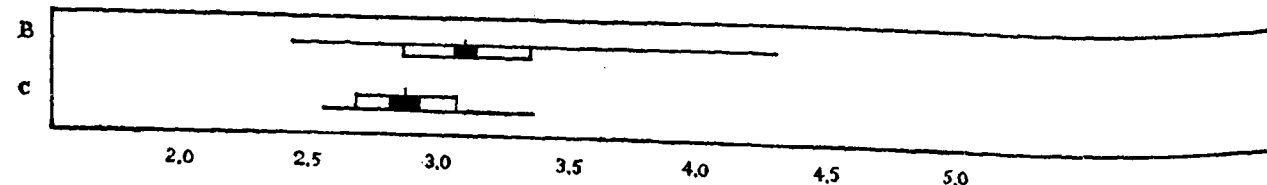
Comparison of the regressions of the length of head of four samples of *Rita Chrysea* population from River Mahanadi

Samples	A	B	C	D
D. F.	125	166	49	11
$S(x-x)^2$	32394.80	74342.18	10874.76	12167
$S(y-y)^2$	3016.12	5779.37	923.6	1029
$S(x-x)(y-y)$	9250.03	20603.36	3129.76	3473
b_{yx}	0.2855	0.2771	0.2878	0.2854
$b_{yx} S(x-x)(y-y)$	2640.88	5709.19	900.74	991.19
$S(y-y)^2 - b_{yx} S(x-x)(y-y)$	375.34	70.18	22.86	38

GRAPH 27



GRAPH 28



GRAPH 29

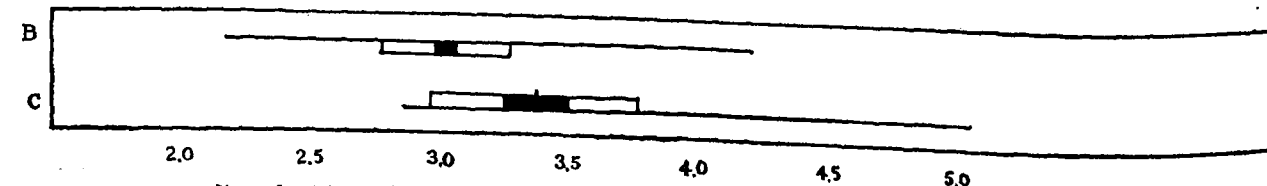


Fig. 6. Biometric comparison of two samples of *R. chrysea*. Sample (B) from Sambalpur; Sample (C) from Chandrapur. Graph 27. LH/Int. Orb. Wdh.; Graph 28. LH/Width of gape of mouth, and Graph 29. SL/Length of dorsal spine.

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. F.	1% F.
Separate Regression	350	468.76	1.335		
Common Regression	353	519.53			
Deviation	3	50.77	16.92	12.674	4.66

TABLE 3

Comparison of the regressions of the depth of body of four samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D
D. F.	125	166	49	11
$S(x-x)^2$	32394.80	74342.18	10874.76	12167
$S(y-y)^2$	2186.23	5580.56	813.71	857
$S(x-x)(y-y)$	7489.95	20120.8	2933.20	3202.45
b_{yx}	0.2312	0.2706	0.2697	0.2632
$b_{yx} S(x-x)(y-y)$	1731.68	5444.69	791.08	842.18
$S(y-y)^2 - b_{yx} S(x-x)(y-y)$	454.55	135.87	22.63	14.12

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. F.	1% F.
Separate Regression	350	627.17	1.787		
Common Regression	353	862.46			
Deviation	3	235.29	78.43	43.889	4.66

TABLE 4

Comparison of the regressions of the length of snout of four samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D	
D. F.	125	166	49	11	
$S(x-\bar{x})^2$	32394.80	74342.18	10874.76	12167	
$S(y-\bar{y})^2$	482.239	691.691	111.67	116.77	
$S(x-\bar{x})(y-\bar{y})$	3639.700	7025.10	1018.02	1169.88	
b_{yx}	0.1124	0.0945	0.0936	0.0962	
$b_{yx} S(x-\bar{x})(y-\bar{y})$	409.102	663.872	95.29	112.54	
$S(y-\bar{y})^2 - b_{yx} S(x-\bar{x})(y-\bar{y})$	73.137	27.819	16.38	4.23	
Test of heterogeneity of regressions within the population					
Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. F.	1% F.
Separate Regression	350	121.57	0.3464		
Common Regression	353	129.16			
Deviation	3	7.585	2.528	7.298	4.66

TABLE 5

Comparison of the Regressions of the Diameter of Eye of four samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D	
D. F.	125	166	49	11	
$S (x-\bar{x})^2$	32394.80	74342.18	10874.76	12167	
$S (y-\bar{y})^2$	71.43	209.65	33.02	44	
$S (\bar{x}-\bar{x}) (\bar{y}-\bar{y})$	1025.25	3649.75	564.07	650.10	
b_{yx}	0.0316	0.049	0.0518	0.053	
$b_{yx} S (\bar{x}-\bar{x}) (\bar{y}-\bar{y})$	32.40	178.84	29.22	34.45	
$S (\bar{y}-\bar{y})^2 - b_{yx} S (\bar{x}-\bar{x}) (\bar{y}-\bar{y})$	39.03	30.81	3.80	9.55	
Test of heterogeneity of regressions within the population					
Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs.F.	1% F.
Seperate Regression	350	83.19	0.237		
Common Regression	353	96.404			
Deviation	3	13.21	4.403	18.578	4.66

TABLE 6

Comparison of the regressions of the interorbital space width of four samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D
D. F.	125	166	11	49
$S(x-\bar{x})^2$	32394.80	74342.18	10874.76	12167
$S(y-\bar{y})^2$	642.96	912.418	95.48	168
$S(x-\bar{x})(y-\bar{y})$	4309.62	7807.39	887.86	1340.85
b_{yx}	0.133	0.105	0.0816	0.110
$b_{yx} S(x-\bar{x})(y-\bar{y})$	573.18	819.78	72.45	147.49
$S(y-\bar{y})^2 - b_{yx} S(x-\bar{x})(y-\bar{y})$	69.78	92.64	23.03	20.51

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. F.	1% F.
Separate Regression	350	205.96	0.5868	53.988	
Common Regression	353	301.00			
Deviation	3	95.04	31.68	53.988	4.66

TABLE 7

Comparison of the Regressions of the Length of Dorsal Spine of four Samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D
D. F.	125	166	49	11
$S(x-\bar{x})^2$	32394.80	74342.18	10874.76	12167
$S(y-\bar{y})^2$	4911.48	11321.50	2093.38	1106.56
$S(x-\bar{x})(y-\bar{y})$	11161.55	28509.87	4722.51	3169.53
b_{yx}	0.3445	0.3835	0.4338	0.2605
$b_{yx} S(x-\bar{x})(y-\bar{y})$	384515	10933.54	2048.62	825.77
$S(y-\bar{y})^2 - b_{yx} S(x-\bar{x})(y-\bar{y})$	1066.33	387.96	44.76	280.79

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of squares	Obs. F.	1% F.
Separate Regression	350	1779.84	4.929		
Common Regression	353	2109.31			
Deviation	3	329.47	109.823	22.81	4.66

TABLE 8

Comparison of the Regressions of the Length of Caudal Peduncle of four Samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D
D. F.	125	166	11	49
S (x-x) ²	32394.80	74342.18	10874.76	12167
S (y-y) ²	808.674	2129.737	352.48	423
S (x-x) (y-y)	4711.60	12379.009	1895.770	2200.72
b _{yx}	0.1454	0.1665	0.1742	0.181
b _{yx} S (x-x) (y-y)	685.07	2061.104	330.24	398.33
S (y-y) ² - b _{yx} S (x-x) (y-y)	128.604	68.633	22.24	24.67

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. F.	1% F.
Seperate Regression	350	239.147	0.681		
Common Regression	353	247.901			
Deviation	3	8.754	2.918	4.285	4.66

TABLE 9

Comparison of the Regressions of the Anal Fin Rays Count of four Samples of *Rita Chrysea* from River Mahanadi

Samples	A	B	C	D
D. F.	125	166	49	11
S (x-x) ²	32394.80	74342.18	10874.76	12167
S (y-y) ²	109.64	152.55	51.62	17.6
S (x-x) (y-y)	943.15	2609.82	623.344	374.20
b _{yx}	0.0291	0.0351	0.0573	0.0308
b _{yx} S (x-x) (y-y)	27.466	91.60	35.72	11.53
S (y-y) ² - b _{yx} S (x-x) (y-y)	82.19	60.25	15.90	6.07

Test of heterogeneity of regressions within the population

Source of Variation	D. F.	S. S.	Mean sum of Squares	Obs. F.	1% F.
Separate Regression	350	165.11	0.4704		
Common Regression	353	206.066			
Deviation	3	40.956	13.652	29.022	4.66

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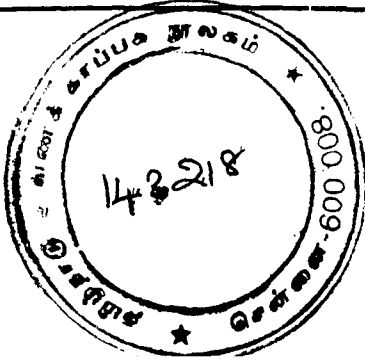


TABLE 10

Biometric Comparison of the Samples of *Rita Chrysea*

Characters	Samples A & X		Samples A & B		Samples B & C	
	t	P	t	P	t	P
SL/Body depth	6.10	Less than 0.01	5.10	Less than 0.01	0.62	Greater than 0.10
SL/Head length	1.90	Greater than 0.05	2.70	Less than 0.01	2.00	0.05
SL/Head width	8.10	Less than 0.01	7.80	Less than 0.01	2.60	Less than 0.02
SL/Head depth	5.30	Less than 0.01	3.30	Less than 0.01	4.30	Less than 0.01
SL/Length of dorsal spine	5.90	Less than 0.01	4.30	Less than 0.01	7.20	Less than 0.01
LH/Snout	6.40	Less than 0.01	5.30	Less than 0.01	4.20	Less than 0.01
LH/Eye	9.10	Less than 0.01	7.20	Less than 0.01	4.10	Less than 0.01
LH/Int. Orb. Wdh.	3.50	Less than 0.01	1.70	Greater than 0.10	7.40	Less than 0.01
LH/Width of gape of mouth	5.60	Less than 0.01	3.60	Less than 0.01	6.00	Less than 0.01
LH/Length of Caud. Peduncle	2.80	0.01	2.30	Less than 0.02	0.21	Greater than 0.10
LH/Least height of Caud. Peduncle	26.8	Less than 0.01	23.5	Less than 0.01	3.20	Less than 0.01
Length of Caud. Ped./Least height of Caud. Ped.	17.90	Less than 0.01	18.6	Less than 0.01	3.20	Less than 0.01
Int. Orb. Wdh./Eye	2.70	Less than 0.01	3.00	Less than 0.01	2.90	Less than 0.01
Snout/Eye	4.50	Less than 0.01	4.50	Less than 0.01	1.40	Greater than 0.10

References

- CHAUHAN, B. S. 1947.—Fish and fisheries of the Patna State, Orissa, *Rec. Indian Mus.*, **45** : 267-282.
- DICE, L. R. and LERAAS, H. J. 1936.—A graphic method for comparing several sets of measurements. *Cont. Lab. Vertebr. Genetics Univ. Mich.*, **3** : pp. 3 (Not seen in original.)
- GINSBURG, I. 1938.—Arithmetical definition of species, subspecies and race concept with a proposal for modified nomenclature, *Zoologica*, **23** : 253-286.
- , 1939.—The measure of population divergence and multiplicity of characters, *J. Wash. Acad. Sci.*, **9** : 317-330.
- , 1940.—Divergence and probability in taxonomy, *Zoologica*, **25** : 15-31.
- HUBBS, CLARK, 1952.—A contribution to the classification of the Blennoid fishes of the family Clinidae, with a partial revision of the eastern Pacific forms, *Stanford Ichthyol. Bull.*, **2** : 41-165.
- HUBBS, C. L. and PERLMUTTER, A. 1942.—Biometric comparison of several samples with particular reference to racial investigations, *Amer. Nat.* **76** : 582-592.
- SIMPSON, G. G. and ROE, A. 1939.—*Quantitative Zoology*, New York and London. pp. 414.
- SNEDECOR, G. W. 1946.—*Statistical methods applied to experiments in agriculture and biology*, Ames. pp. 485.

Observations on the Length-Frequency Distributions
of The Indian Whiting, *Sillago sihama*, (Forsk.)
from the Karwar Waters

BY V. C. PALEKAR AND D. V. BAL,
(Department of Zoology, Institute of Science, Bombay 1)

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Introduction

For the development and scientific management of a fishery, it is essential to know amongst other things size or age composition of its stock from season to season and from year to year. *Sillago sihama*, however, comprises a minor fishery in certain estuarine and inshore waters of the Bombay State (original), and the different stocks generally seem to have a restricted habitat. So far, no studies on the general biology of this delicious food fish of this region have been made, although some observations on the Indian Whiting from the Rameswaram Island (South India) have been recorded by Radhakrishnan (1957). The present paper is a part of the investigation on the biology and fishery of *Sillago sihama* in Karwar waters, conducted over a period of three years and relates to the size distribution of the fish, occurring in the Kali River estuary up to about 3 miles from the river mouth and in the inshore waters of Karwar. An attempt is made here to indicate the distribution of the fish sizes during the course of the year in sea and estuary and also the possible movements of the fish from sea to estuary.

Material and Methods

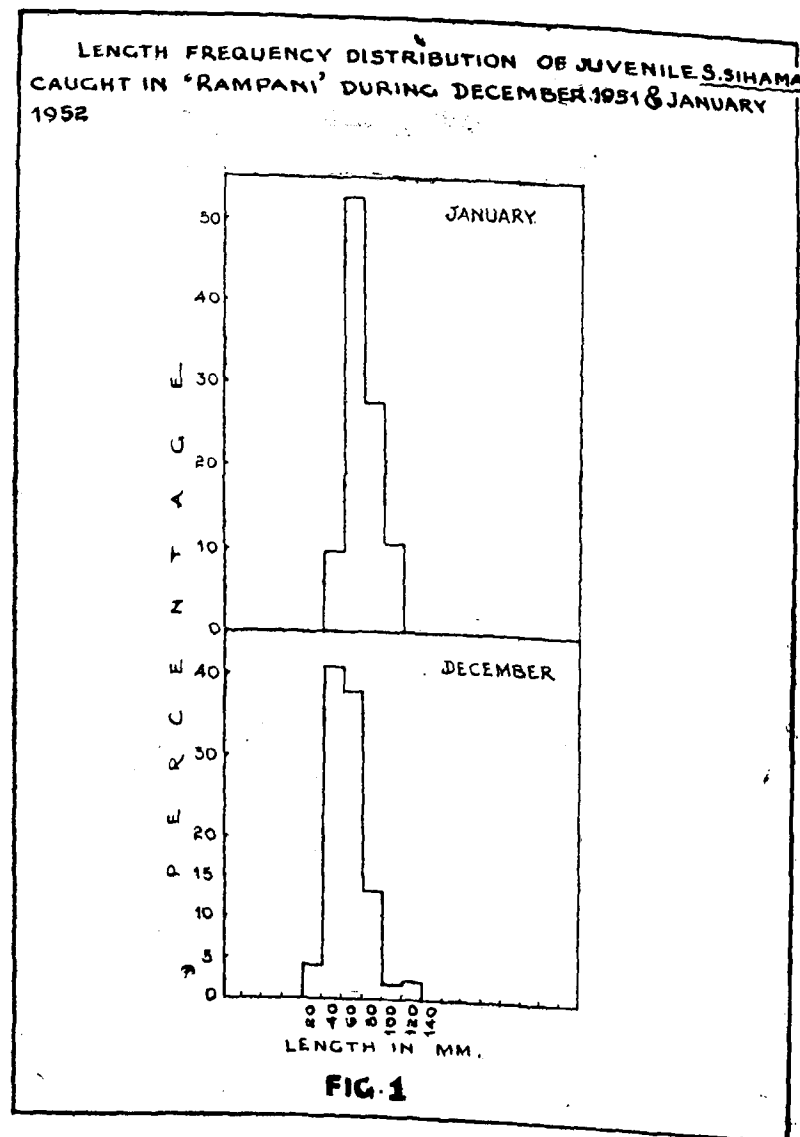
The fish is caught in abundance in the estuary during the season from June to October. During this period fishing is generally made by drift nets in the vicinity of the river mouth, while angling and cast-net fishing is resorted to during the rest of the year. In the coastal inshore waters, the fish is generally caught in shore-seine, locally known as *Yendi* over a major part of the year. Very young juveniles also occur in fairly large numbers in the inshore catches made by large shore-seines, known as *Rampani*, only during December and January.

Since it was not possible to follow a definite method of sampling on account of the difficulty in obtaining regular collections of fish for study, all the samples collected for each month, from different sources were considered to represent at best, the general population restricted to the limited area of distribution of the fish in Karwar waters. To facilitate comparison of figures for different months, the percentages of fish in each 20 mm. size-class have been tabulated, as the total number varied from month to month. The data collected from estuarine and marine habits relate to the year 1951-1952. During the course of this investigation about 7,000 specimens were examined for total length. It may be observed that the samples for some months are rather small for this type of study and no samples could be obtained from the sea during September, October and April. The object of the present investigation is therefore, limited to study broadly the distribution of this common food fish in the two neighbouring surroundings-estuary and sea, during its life-cycle and only to this extent the value of the data may be judged. Each length-class is denoted by the extreme limit of the respective group while discussing the length-frequencies.

New Recruitment

The first indication of new recruitment to the *Sillago* population is the occurrence of post-larval and early juvenile forms caught in the large shore-seines (*Rampani*), in the inshore waters soon after the spawning season viz. August-October. Those young forms further seem to suggest that the eggs and larvae of the fish drift with the fast moving current of the river during the monsoon, into the inshore waters of the Karwar Bay.

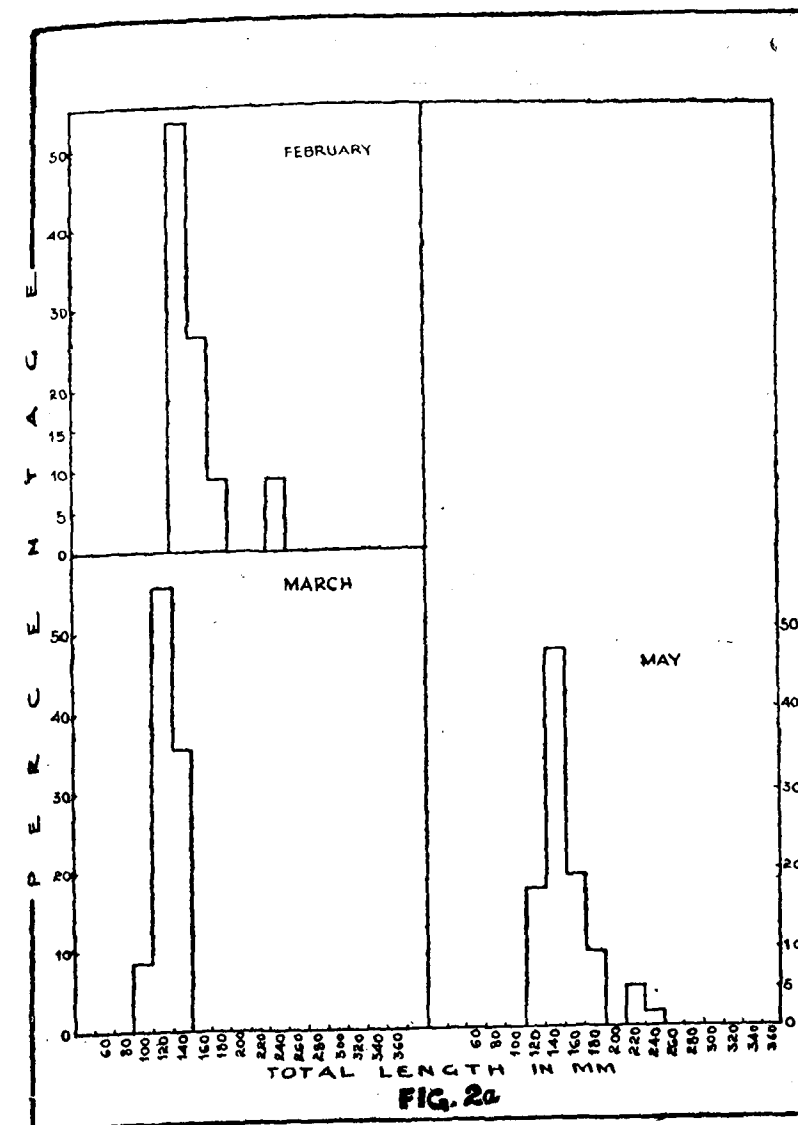
and develop there. As the larvae grow into post-larvae and juvenile forms, they restrict themselves to the inshore waters or to the river bank when it may be possible for them to move up the stream. It may be observed from Fig. 1 that they varied within the range of 20 mm. to 140 mm.



size-groups during December, with a peak at 40 mm. group. During January they were found only within 40-100 mm. size-classes, the highest mode being at 60 mm. group.

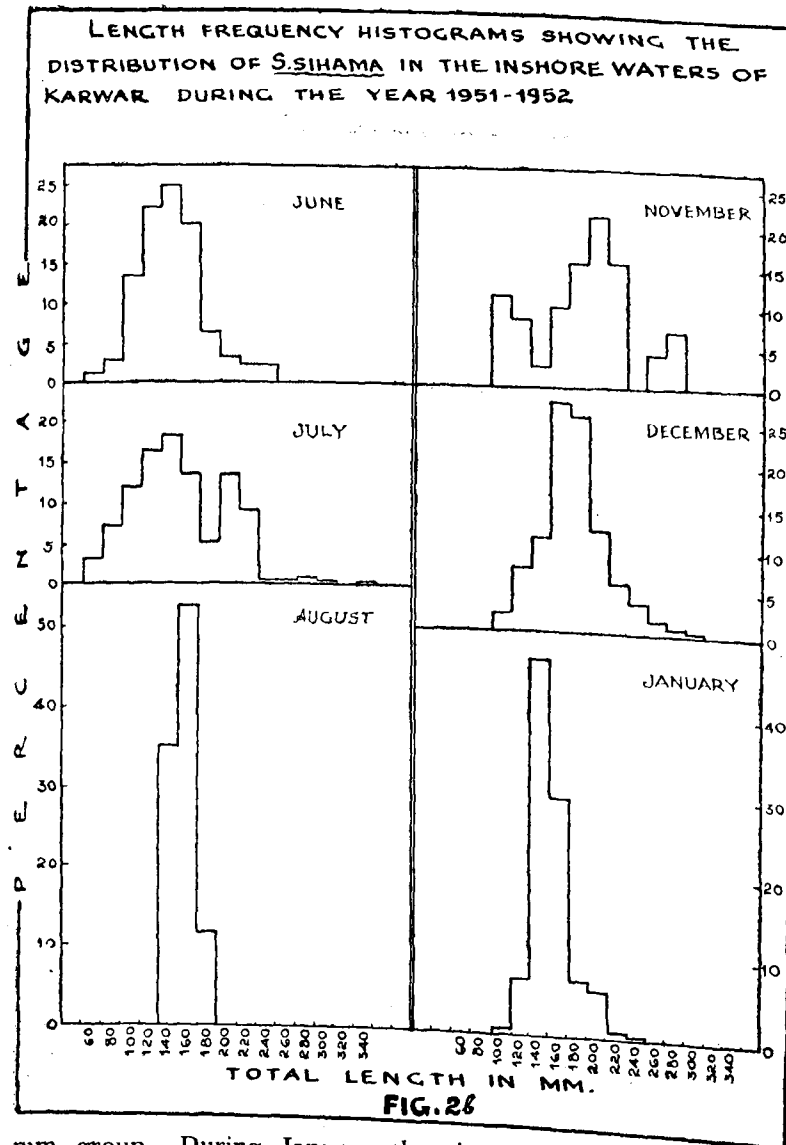
Fish from Inshore Waters

The size-frequency percentage distributions of the marine (inshore) forms during the year 1951-52 are shown in fig. 2. In the month of June, specimens of *Sillago sihama* between 60 mm. and 240 mm. size-groups were recorded with a fair abundance of 120-160 mm. groups, and a peak at 140 mm. group. July



presented a wider range of fish size, varying between 60 mm. and 340 mm. groups, but individuals in length-classes beyond 220 mm. were almost negligible. 140 mm. group continued to show the highest percentage during this month also, with an additional mode at 200 mm. group. The data for

August are represented by a few specimens with 140-180 mm. groups with a peak at 160 mm. group. The fish measured during November fell within 100 mm. and 300 mm. groups, showing three modes at 100 mm., 200 mm. and 280 mm. groups respectively. The same range stood for December with a fair abundance of 160 and 180 mm. groups and a mode



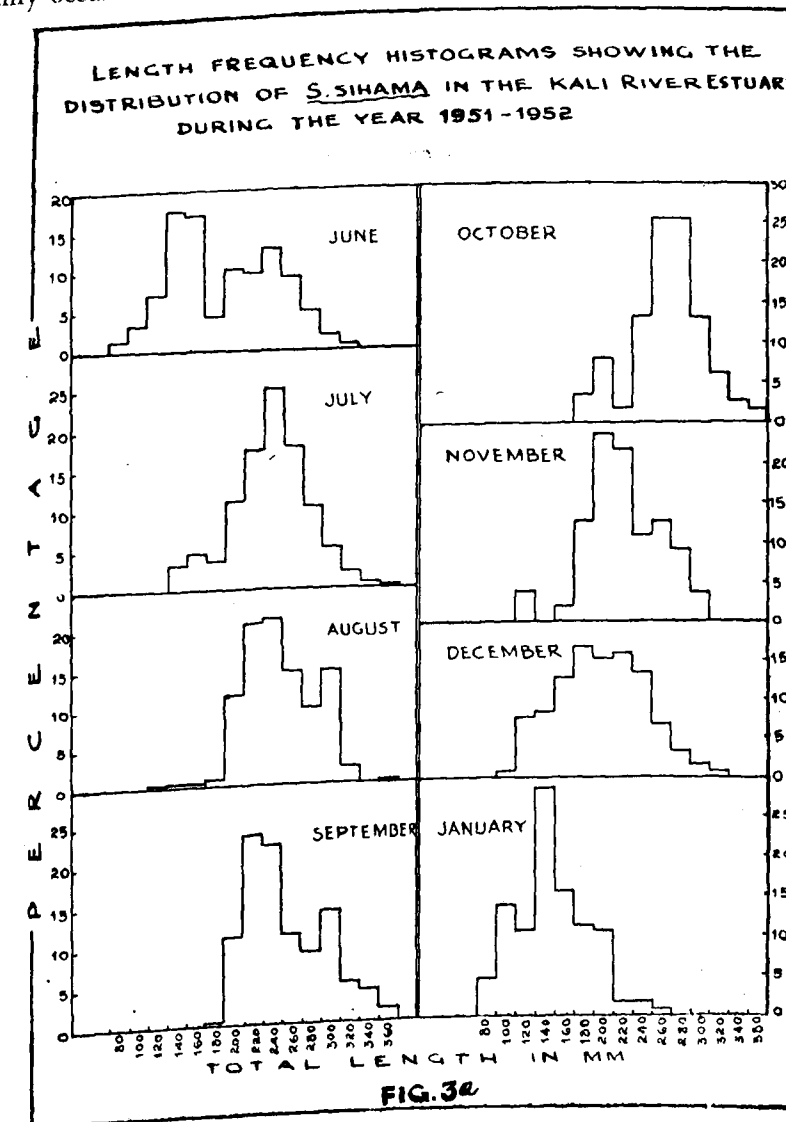
at 160 mm. group. During January, the size-classes ranged from 100 mm. to 240 mm., with a distinct mode at 140 mm. group. In spite of the scanty material available during February, the first mode seems to remain consistently dominant at 140 mm. group, while a small group at 240 mm. is seen isolated. For March, only 100 mm. to 140 mm. groups were represented with

a mode at 120 mm. class. The size-frequencies for May range within 120-180 mm. and 220-240 mm. groups, the first set of the population showing a definite mode at 140 mm. group.

It appears from the above that the major population of *S. sihama* in the coastal waters mainly comprised 140 mm. and 160 mm. length-classes during the course of the year under investigation.

Fish from the Estuary

An analysis of the data represented in fig. 3, showing the monthly occurrence of *S. sihama* in the Kali river within about three miles



from the river mouth, brings out relatively wider fluctuations in the occurrence of the major size-groups of the fish, captured during the course of the year. The June population presents two modes, first at 140 mm. group and the second at 240 mm. group. During the succeeding three months, which mark the breeding period, the first mode (140 mm) seems to disappear, so

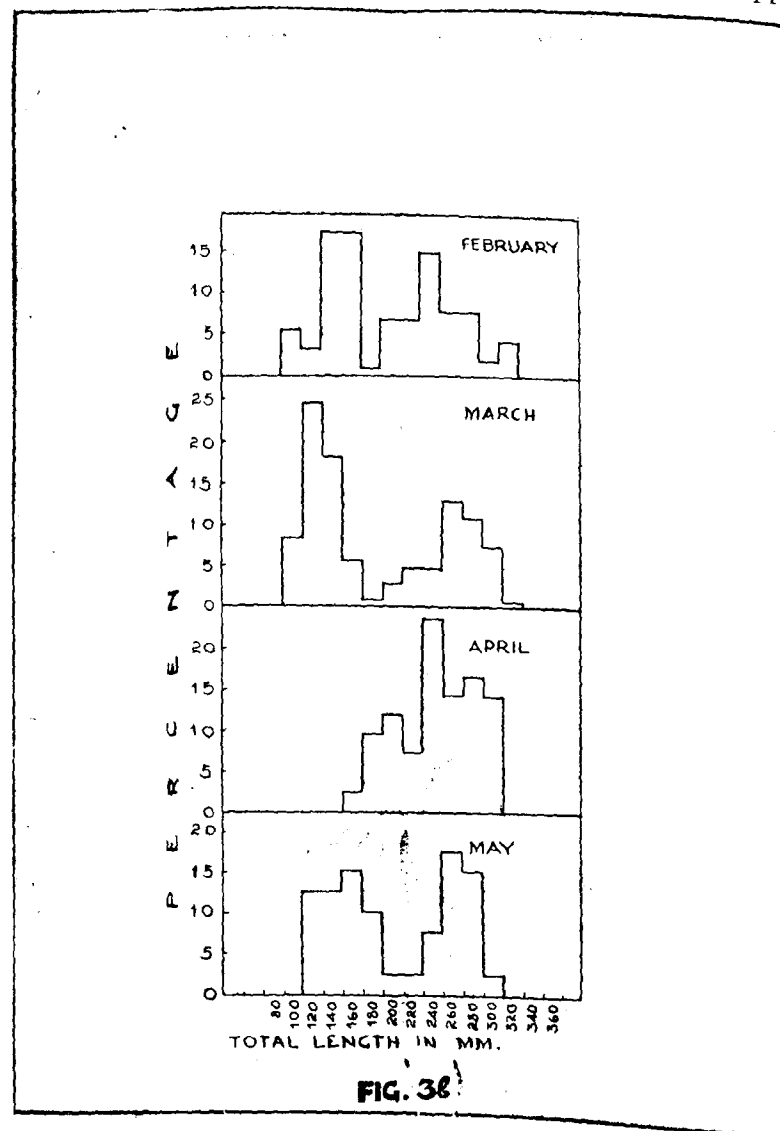


FIG. 36

that in July, the mode at 240 mm. group is dominant. In August and September the first mode lies at 240 mm. and 220 mm. classes respectively, with an additional mode at 300 mm. group. During July-August, the size limit ranges between 120 and 360 mm. groups and between 180-360 mm. groups in September. Of the two modes noted during October, the

first one at 200 mm. group is relatively smaller than the prominent second mode, commonly located at 260 mm. and 280 mm. groups. With the close of the breeding season, i.e. from November onwards, the modes seem to move towards the smaller size-groups presumably on account of the disappearance of the larger individuals from this area. The mode at 200 mm. group becomes dominant during November, showing an additional isolated group at 120 mm. This mode (200 mm.) seems to shift towards smaller groups, till in January it comes to stay at 140 mm. group. The histogram for February shows four modes: two of them at 140-160 mm. and 240 mm. groups are prominent, while the first at 100 mm. and the last at 320 mm. group are negligibly small. Two populations become marked out during March, with the first mode at 120 mm. group and the second at 260 mm. group. During April, the first population of smaller individuals does not seem to be properly represented though its presence is indicated by the mode at 200 mm. group, while the second is marked by the mode at 240 mm. group. The two populations are again distinctly shown by the histogram for May, the mode at 160 mm. group representing the first, and that at 260 mm. the second.

Thus the variations in the occurrence of the different size-classes tend to bring out the following important points:—

1. Large fish with modes fluctuating between 220-300 mm. groups predominate during July to October, i.e. during the breeding season or the monsoon period.
2. Smaller fish with the mode gradually shifting back from 200 mm. group to 100 mm. group, predominate from November to January.
3. Two distinct populations of the smaller and larger groups are found to exist from February to June, the smaller being represented by the modes fluctuating between 120 mm. and 160 mm. groups, while the larger with modes between 240 mm. and 260 mm. groups.

The above points further seem to maintain a close harmony with the phases of life-cycle of the fish, during the course of the year. The first one tends to show the congregation of larger forms, above 200 mm. group, for the purpose of breeding during the monsoon period, thus giving a picture of the breeding population of *Sillago*. The studies on sexual maturity of the fish have shown that the whiting attains sexual maturity at an average minimum size of 240 mm. in total length. It may also be noted here that the larger fish migrating to the estuary take to bottom feeding, subsisting mainly on polychaete worms, the common bivalves and to some extent on crustaceans like prawns and crabs. This tends to show that the fish may be moving to the estuary primarily for food. With the close of the breeding season, new populations are added, as indicated by major prevalence of smaller groups between 100 mm. and 200 mm. during the period November to March which

has been noted by us as the 'resting period' from the studies on sexual maturity.

General Remarks

A close scrutiny of the above observations suggests some interesting features, with regard to the growth and movements of the fish in the locality under investigation:

1. *S. sihama* generally occurs in all phases of the life cycle in the river during the course of the year, the large-sized fish being well represented only during the breeding period.

2. Small and medium sized fish are generally found in the inshore waters in all the months.

3. The fish larger than 220 mm. group generally seem to move to the river, first for food and then for breeding.

It may be observed here that some earlier workers have indicated the possibility of migration of the fish to the deep sea after spawning. However, to our knowledge, not even a single stray specimen of *Sillago* has been known to be caught by fishermen going for offshore fishing. Likewise, in the trawl fishing experiments in offshore waters of Karwar, organised by Government of India during December to March, *Sillago*, though a bottom feeder, was never reported, while many other fishes like small pomfrets, sole fishes, *Synagris* sp. etc. were noted. The large adults of *Sillago* therefore, do not seem to return to the sea after spawning in the estuary.

4. New recruitment takes place during December and January, as shown by the sudden appearance of post-larvae and juvenile forms in these months.

5. An attempt to broadly classify the general fish stock, in the sea and estuary during the course of the year, tends to show the following three groups:—

Group	Range of size	Habits
I	Upto 140 mm.	Sea
II	140-240 mm.	Sea and Estuary
III	240 mm-360 mm.	Estuary

6. The larger fish above 220 mm. from group II, seem to move gradually from sea to the river, during December to March. This can be inferred from their meagre presence or total absence in the histograms (Fig. 2)

for the marine fish during these months, and their distinct appearance in the histograms (Fig. 3) for the estuarine fish.

It may be observed from the preliminary remarks made above that the whereabouts of the large-sized fish which congregate in the estuary during the breeding season, are rather confounding as they are neither reported from the sea nor from the estuary after the close of the spawning. Their recurrence during the succeeding season, however, needs further study for elucidation of this point.

The observations made above do not seem to agree with those of Radhakrishnan (1957), on the Indian Sand Whiting of the Rameshwaram Island. According to him the fish occurs there in sizes ranging from 2-29 cm. in total length, the commercial size being 16-23 cm. It is also reported that the species attains sexual maturity at a length as small as 13-14 cm. However, the observations made in the present investigation, indicate that the size at first maturity is at about 240 mm. In view of these differences, a further comparative study of the Indian whiting from the two coasts, will be worth while.

References

1. ANONYM, 1883.—*Gazetteer of Bombay Presidency N. Kanara District and Ratnagiri Dist.*
2. CHAUDHURI, B. L., 1923.—'Fauna of the Chilka Lake—Fish' Vol. 5, Part IV, PP. 711.
3. PALEKAR, V. C., 1958.—'Studies on the Biology and fishery of *S. sihama*, in Karwar waters'—Thesis submitted for Ph.D. degree of Bombay University.
4. SESHAPPA, G. AND BHIMACHAR, B. S., 1954.—'Studies of the age and growth of the Malabar sole, *Cyanoglossus semifasciatus*, Day, *Indian J. fish*, Vol. 1 (1-2).
5. SESHAPPA, G. AND BHIMACHAR, B. S., 1954.—'Studies on the fishery and biology of the Malabar Sole *Cyanoglossus semifasciatus*, Day *Indian J. Fish*, 2, 180.
6. SORLEY, H. T., 1933.—'The marine fisheries of the Bombay Presidency', Government Central Press.
7. RADHAKRISHNAN, N., 1954.—'Occurrence of growth rings on otoliths of the Indian Whiting, *Sillago sihama* (Forsk.)', *Curr. Sci.* XVIII (6) pp. 196-197.
8. RADHAKRISHNAN, N., 1957.—'A contribution to the biology of the Indian Sand Whiting, *Sillago sihama* (Forsk.) *Indian, Fish*, Vol. 4, No. 2, pp. 254-283.

On the Asphyxiation and Influence of CO_2 on Respiration of Air-Breathing Fish, *Heteropneustes fossilis* Bloch and *Clarias batrachus* (Linn.)

By

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(With 5 Text-figures).

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Introduction

In order that any organism occupy a particular habitat, it is essential that it be properly adjusted, mainly in reproduction nutrition and respiration, to that environment. The adjustment to respiration is continuous, while habitats may be changed for purpose of food gathering or for reproduction.

There are at least three types of aquatic environment in which aerial respiration is of advantage to the fish:

- (1) In which the water is periodically removed for a short time or for a longer time, as in many shallow freshwaters of India during the hot and dry summer (April to June) months,

- (2) shallow freshwaters with lack of oxygen; in these conditions also it will be of advantage for a fish to meet its respiratory needs either by an increase of the respiratory surface for aquatic respiration and direct contact with the air afterwards, or by coming to the surface and then taking in occasional gulps of air and passing it over the gills,

- (3) the stagnant and foul waters, in which excess of carbon-di-oxide and other harmful gases, caused by the decaying organic matter are present.

In gill-breathing the potent factors are oxygen and carbon-di-oxide tensions of the water bathing the gills, as the gill breathers are not able to control the carbon-di-oxide and oxygen tensions of the water bathing the gills, since it is more of an open system. The one essential difference in the physiology of respiration of terrestrial and aquatic animals is that terrestrial animals are able within limits to control the oxygen and carbon-di-oxide partial pressures of their external environment by the rate and depth of respiration, while aquatic animals have very little at least far less control of the oxygen and carbon-di-oxide tensions of the water bathing their gills.

The experiments to be described in the following pages were devised to obtain information on asphyxiation of air-breathing fishes by preventing access to air and also concerning the influence of carbon-di-oxide on these fishes in the presence of sufficient oxygen. To my knowledge no attention has been paid to CO_2 asphyxiation of these fishes in India.

Historical

In recent years several useful reviews on respiration of fishes have appeared by Powers *et al* (1932) on the relationship of fishes to the environment, Dam ('38) on the utilization of oxygen and regulation of breathing in aquatic animals, Korph (41) on the comparative physiology of respiratory mechanisms and Hoar *et al* ('51) on some aspects of the physiology of fish respiration.

The response of some fishes to changes in environment mainly in the oxygen and also the carbon-di-oxide contents of the inspiratory water, has been discussed by many workers, but on searching through the literature it becomes evident that very little attention has been paid in India to the different aspects of the physiology of fish respiration. In the past quarter of a century much literature has accumulated. Das ('27) performed drowning experiments with the air-breathing fishes of India; Ghosh ('33) made certain observations on the asphyxiation of some air-breathing fishes of Bengal; Basu ('49) on oxygen requirements of Indian fishes; Black and Black ('51) worked on the carbon-di-oxide asphyxiation of some British Columbia freshwater fishes; Saxena ('59) on the influence of CO_2 on the respiratory movement of *Heteropneustes fossilis*.

Material

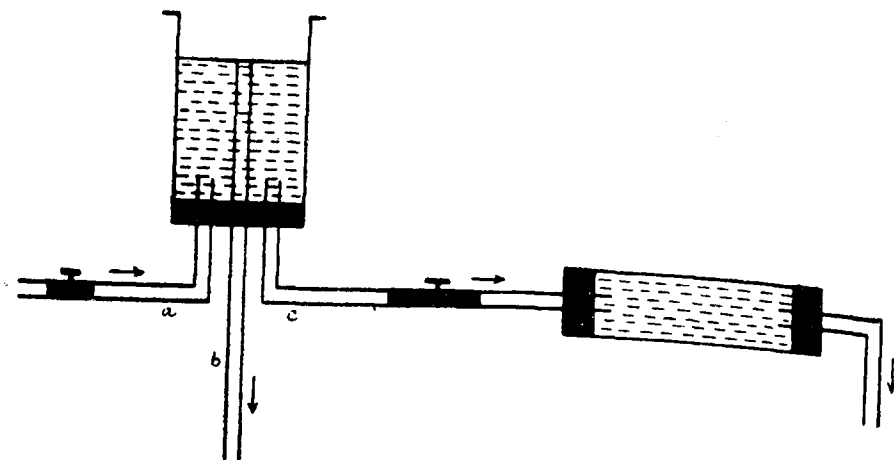
Living fishes were procured through the fishermen at Kanpur and Lucknow. Only *Clarias batrachus* and *Heteropneustes fossilis*, the common air-breathing fishes, were used. All the fishes were kept under Laboratory conditions for at least seventy two hours before they were subjected to experimental conditions and data collected in the following experiments are given in the tables and appropriate graphs also drawn.

Experiments

(i) Preventing access to air.

A. With the fishes in closed jar with continuous flow of water.

The air breathing fishes *H. fossilis* and *C. batrachus* are kept in a closed jar in which a continuous current of water is maintained. To ensure that water runs at a constant pressure and speed, a constant level cylinder (Fig. 1) is introduced in between the tap and the experimental jar. The constant level cylinder was $2\frac{1}{2}$ inches in diameter open at both ends and provided with a rubber cork at one end with three apertures and open at the other end.



Text-fig. 1. Apparatus to provide a continuous flow of water through a jar.

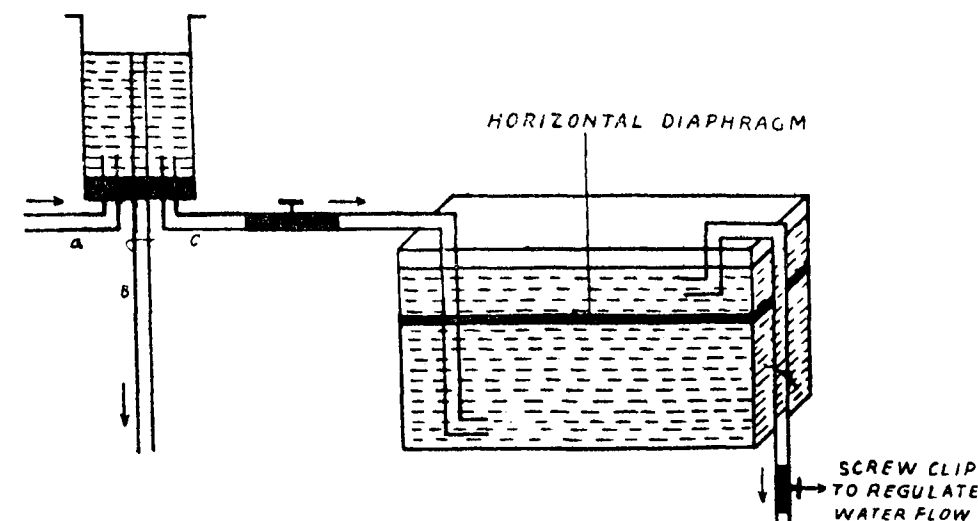
Each aperture is provided with a glass tube (a) from the tap (b) an over flow tube and (c) connected to the experimental jar. Precautions are taken so that there may be no leakage of air bubbles in the jars from any place and to ensure this all the joints were sealed with wax and tested. After the introduction of the fish in the experimental jars, the flow of water current through them was maintained from 250 to 300 c.c. per minute, in all the experiments. The temperature varied between 21° and 23°C . The period taken by each species to stop all the respiratory movements was noted. The oxygen content of the water flowing through the jars varied from 3.8 ppm. to 4.5

ppm. and the CO_2 contents varied from 70 to 85 ppm. through out the experiments.

Results:—It was observed that *H. fossilis* and *C. batrachus* remained active even after ten to fifteen days without showing any visible effect on this activity.

B. With the fishes in an aquarium with a horizontal diaphragm near water surface.

The fishes were placed in aquaria (one specimen of each species in one aquarium) filled with fresh-water from the tap. The aquaria used were of large size ($4' \times 2' \times 1'6''$) (Fig 2). A slow but continuous stream of water was allowed to flow through. The constant current of water caused no dis-



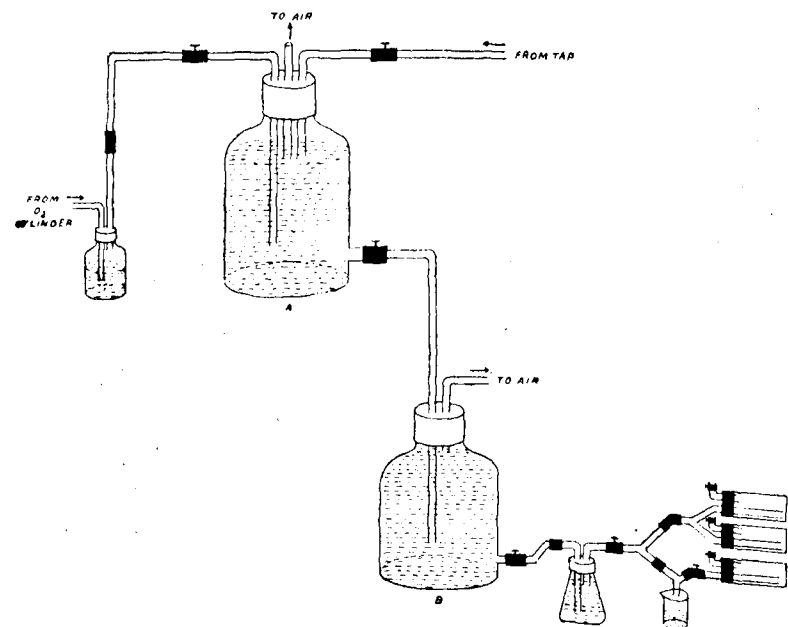
Text-fig. 2. Aquarium with horizontal diaphragm and continuous flow of water.

turbance whatsoever. The fish were kept in the aquaria for 36 hours before a diaphragm made of wire netting was immersed under surface of water to prevent the fish from coming to the surface. The level of the water was never allowed to fall to the level of the diaphragm and throughout the experiments the fishes had no access to atmospheric air. The oxygen content of the water in different aquaria varied from 4 to 4.8 ppm. and CO_2 content varied from 75 to 90 ppm. The temperature through out the experiments varied from 21° to 23°C .

Results:—Surprisingly the results obtained were similar to those in the other set of experiments. Fishes remained alive and active even after twelve to fifteen days without showing any visible effect on their activity.

(ii) With fishes in air-tight water filled jar.

The weight of the fishes used varied in *H. fossilis* between 36.5 gms. and 38 gms. and in *C. batrachus* between 51.5 and 53.5 gms. only. Individual fishes (*H. fossilis* and *C. batrachus*) were placed in bottles filled with water containing adequate quantities of oxygen for respiration. The experimental bottles were sealed and care was taken to ensure that they were free from entrapped air bubbles. This was achieved by using a jar fitted with rubber cork provided with two holes through which (Fig. 3) glass tubings were passed, one of the tubes reaching the bottom of the jar. The tube which does not reach the bottom was connected with the aspirator bottle. Screw-clips were provided on both the tubes. The jar was filled with water and the fish placed in it and the rubber cork was replaced tightly. The screw clip was opened



Text-fig. 3. Apparatus for experiment B.

and the water was allowed to flow freely through the jar and passing out through the glass tube. The samples of water were collected for analysis of CO_2 and O_2 contents before the experiments. When there was no air-bubble in the jar the screw clip on the tube leading to the jar from aspirator bottle was closed and later the other clip was also closed. The CO_2 content of the water was increased due to the respiration of fish. When all the respiratory movements had ceased the jars were opened and two samples of water were carefully siphoned into appropriate bottles for analysis of dissolved CO_2 and O_2 .

Free CO_2 was analysed by titrating 100 c.c sample of water with N/44 sodium hydroxide, using phenolphthalin as indicator. Dissolved Oxygen was determined by the unmodified Winkler method. The temperature throughout the experiments showed variation only of 1°C .

The Oxygen and CO_2 contents of the water at the beginning and at the end of each experiment, when the fish stopped all the respiratory movements are given in Tables I & II.

TABLE I

Showing oxygen and carbon-di-oxide dissolved in water in the beginning and end of the experiments on *H. fossilis*

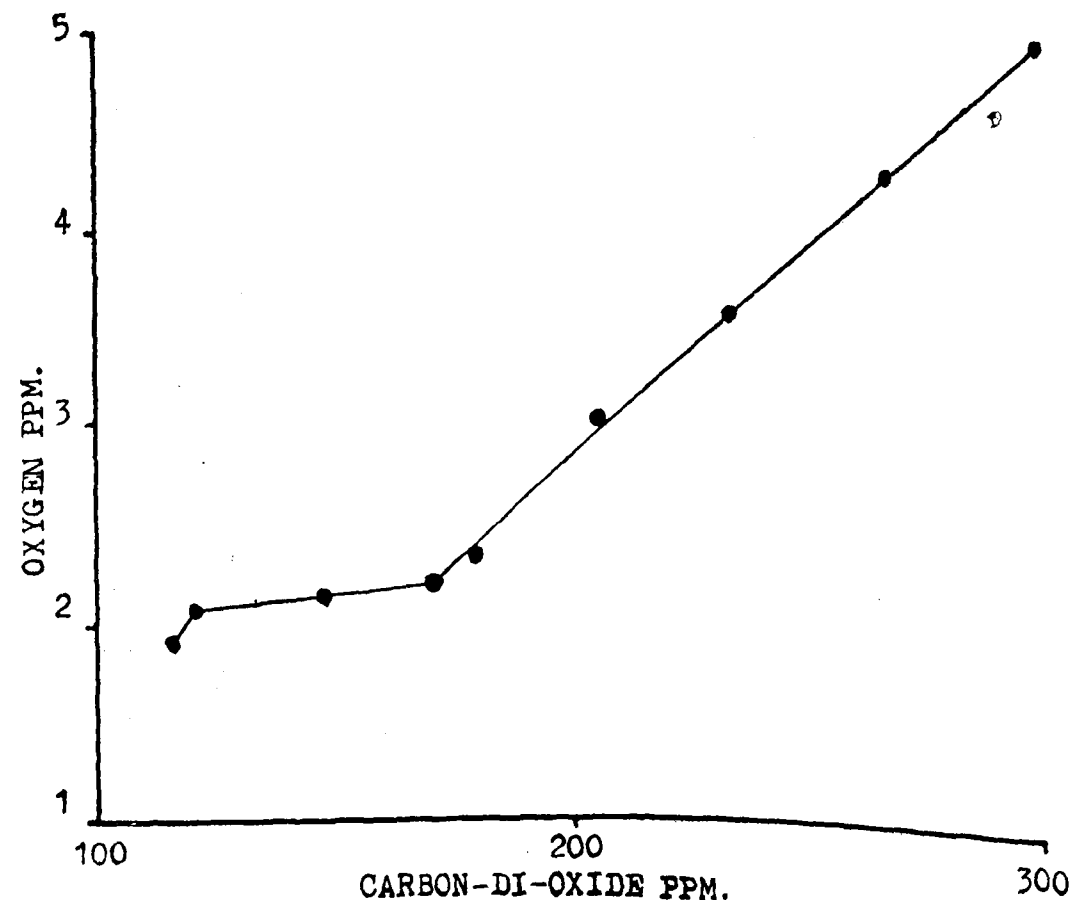
	A	B	C	D	E	F	G	H	I	J	
O_2 ppm.	4.2	3.38	2.7	2.8	6.1	4.7	6.6	3.29	3.4	5.7	Beginning of experiments.
CO_2 ppm.	90	69	80	85	104	90	105	70	70	100	
O_2 ppm.	2.35	2.15	1.94	2.04	4.6	3.55	5.0	2.1	2.3	4.25	When all the respiratory movements stopped
CO_2 ppm.	206	170	116	120	290	232	300	148	180	266	

TABLE II

Showing oxygen and Carbon-dioxide dissolved in water in the beginning and end of the experiments on *C. batrachus*

	A	B	C	D	E	F	G	H	I	
O_2 ppm.	3.0	3.2	3.6	4.1	5.35	5.9	3.9	4.8	6.5	Beginning of experiments.
CO_2 ppm.	80	69	80	100	85	90	100	102	104	
O_2 ppm.	2.45	2.65	2.7	2.8	3.8	4.25	2.75	3.4	4.8	When all the respiratory movements stopped.
CO_2 ppm.	150	156	164	185	208	216	174	198	230	

Results:—These are presented in graphical form in Figs. 4 & 5. The inflected part of the curve indicates the interference of CO_2 in limiting and fully preventing the utilization of O_2 despite the O_2 content being other-



Text-fig. 4. Influence of CO_2 on the utilization of O_2 by *H. fossilis*.

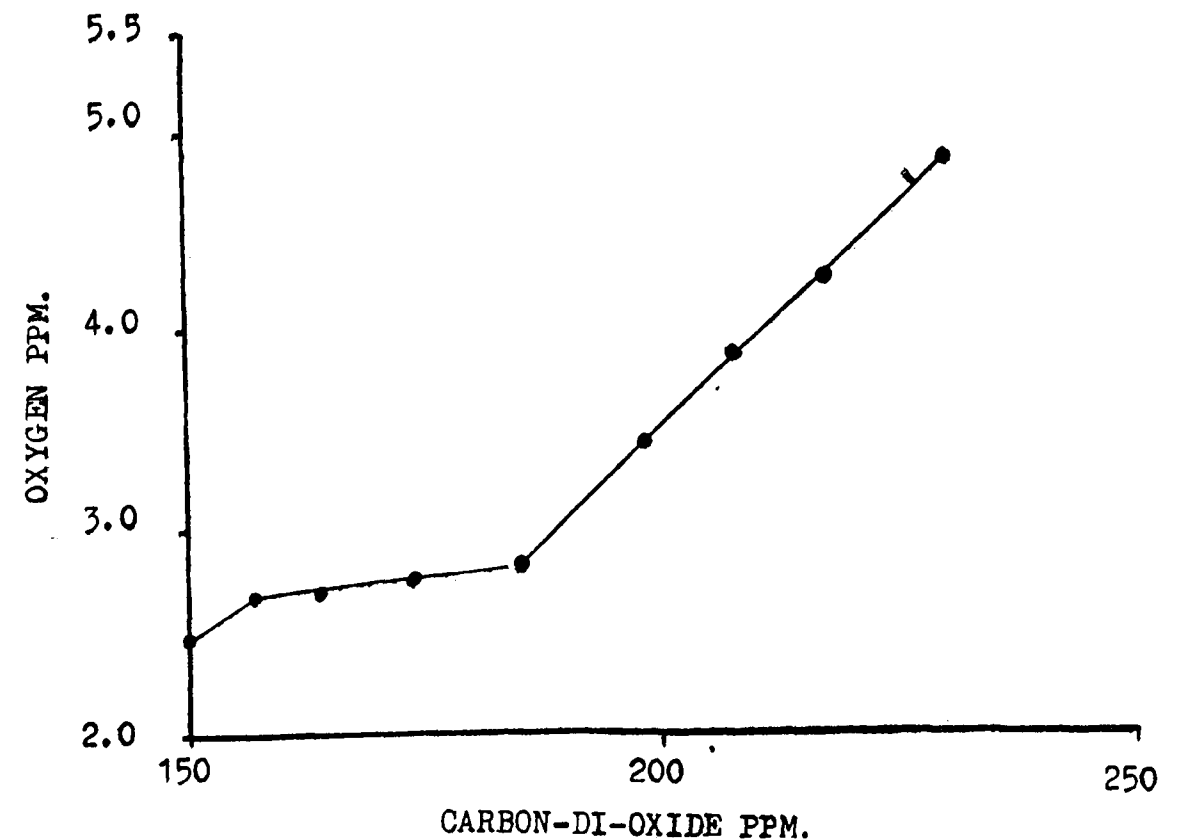
wise adequate for respiration. The first or flat part of the curve indicates the ability of the fish to utilize O_2 in CO_2 content which does not appear to interfere with respiration and the death of the fish is from O_2 shortage.

Discussion

There are two groups of air-breathing fishes in India (a) fishes that habitually breathe air, but are capable of aquatic respiration for a shorter or longer period, and (b) fishes that habitually respire through water, but can adapt themselves to aerial respiration for a shorter or longer period.

Fishes of the first category have developed complicated devices for aerial respiration, and Das ('27) showed that some air-breathing fishes in India

drown and die if they are not allowed to breathe air. Carter and Beadle ('31) conducting asphyxiation experiments on tropical air-breathing fishes have proved that however well oxygenated the water may be, the fish die of asphyxiation, if prevented from coming to the surface for breathing air. Hora ('35) observed that fishes with complicated accessory respiratory organs, even



Text-fig. 5. Influence of CO_2 on the utilization of O_2 by *C. batrachus*.

when kept in oxygenated water always come to the surface to breathe air. Dubale ('51) confirmed the results of Hora and Das and maintained that "What ever may be the differences in the nature of the results obtained by these authors, the fact that the air-breathing fishes get asphyxiated if prevented from coming to the surface to breathe air is established."

On the other hand my observations show that if fishes are kept submerged in well oxygenated running water, they can survive for considerable periods (upto two weeks) without having recourse to aerial respiration.

My observations show that when *H. fossilis* and *C. batrachus* are placed in jars completely filled with water (without any air-bubbles and closed air tight), through which a continuous stream of water is maintained and also

in the aquarium with a horizontal diaphragm, the fish remains alive and active even after ten to fifteen days.

Contrary to the observations of the previous workers, I have observed that these fishes do not get asphyxiated if prevented from coming to the surface to breathe air provided the CO_2 and O_2 contents of the water remain above the asphyxial levels as was done by passing a continuous stream of fully oxygenated fresh-water through the containers, without any air-bubbles or air-pockets coming into the picture. Therefore, in these air-breathing fishes aquatic respiration can go on almost indefinitely as effectively as in true aquatic forms.

The experimental work that has been reported on the effects of CO_2 on O_2 consumption is on the whole fragmentary. It has been observed that at first, with the increase of CO_2 content the rate of respiratory movements go on increasing, as happens in all water-breathing fishes. Van Dam ('38) showed that initially an increase in oxygen consumption is caused by increase in ventilation; with increase in CO_2 content of the respiratory water the rate of respiratory movements went on decreasing leading to the ultimate death of the fish; Hall ('31) Meyer ('35), Van Dam ('38) and Basu ('59) all agree that increasing partial pressure of CO_2 lead to a decrease in the percentage of oxygen utilized.

The susceptibility of different species of fish to the lethal action of free CO_2 varies greatly. Sensitive fresh-water species may succumb rapidly at free CO_2 concentration between 100 and 200 ppm. in the presence of much dissolved oxygen. Lower concentrations of 100 to 50 ppm. may be lethal after prolonged exposure or may interfere with the utilization of oxygen.

My experiments go to establish that if we consider dissolved water CO_2 as a limiting factor in respiration, then below 170 ppm. CO_2 in *H. fossilis* and 185 ppm. CO_2 in *C. batrachus*, the ability to utilize O_2 is unaffected. For *H. fossilis* the asphyxial level of O_2 pressure is of the order of 2 ppm. whereas for *C. batrachus* it is between 2.5 and 3 ppm. below 170 ppm. CO_2 ; and between 170 and 185 ppm. of CO_2 it is 2.3 ppm. for *H. fossilis* and 2.8 ppm. for *C. batrachus*.

Summary

1. *H. fossilis* and *C. batrachus* do not die due to asphyxiation, if access to air is prevented, provided the oxygen remains sufficient and CO_2 does not show much variations.
2. These two fishes can survive in higher concentrations of CO_2 .
3. Influence of CO_2 on the utilization of O_2 has been worked out.

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References

- BASU, S. P., 1949.—Some experimental data regarding the oxygen requirements of Indian fishes, *Catla catla*, *Labeo rohita*, *Labeo bata* and *Cirrhina mrigala*. *Proc. nat. Inst. Sci. India*, **15** : 283-86.
- * ———, 1959.—*J. Fish. Res. Bd. Can.*, **16**(2).
- BLACK, E. C. & V. S. BLACK., 1951.—Carbon-di-oxide asphyxiation of some British Columbia fresh-water fishes. *Proc. 1st meeting of the associate committee on research in aquatic Biology, Ottawa, Canada*, pp. 18.
- BROWN, M. (Editor), 1957.—The physiology of fishes. Vol. I, Academic Press, New York.
- CARTER, G. S. & L. C. BEADLE., 1931.—II. Respiratory adaptations in fishes. *J. Linn. Soc. (Zool.)*, **37**(252) : 327-68.
- DAM, L. Van., 1938.—Utilization of oxygen and regulation of breathing in aquatic animals. *Dissertation*, Groningen, 13, pp. 138.
- DAS, B. K., 1927.—The bionomics of certain air-breathing fishes of India, together with an account of the development of their air-breathing organs. *Phil. Trans. Ser. B*, **216** (433) : 183-219.
- DAY, F., 1868.—Observations on some fresh-water fishes of India. *Proc. Zool. Soc. Lond* : 274-88.
- DOBSON, G. E., 1874.—Notes on the respiration of some species of Indian fresh-water fishes *Ibid* : 312-21.*
- DUBALE, M. S., 1951.—A comparative study of the extent of gill-surface in some representative Indian fishes, and its bearing on the origin of air-breathing habit. *J. Univ. Bombay, N. S.*, **19**(5) : B: 6-13
- GHOSH, E., 1933.—An experimental study of the asphyxiation of some air-breathing fishes of Bengal. *J. Asiat. Soc. Beng.*, N. S. **29** : 327-32.
- HALL, F. G., 1931.—The respiration of puffer fish. *Biol. Bull.*, **61** : 457-67.
- HOAR, W. S., V. S. BLACK & E. C. BLACK., 1951.—Some aspects of the physiology of fish. III. Respiration in fishes. *Univ. Toronto. Stud. biol. Ser. no.* **59** : 91-111.
- HORA, S. L., 1935.—Physiology, bionomics and evolution of air-breathing fishes of India. *Trans. nat. Inst. Sci. India*, **1** : 1-16.
- HOWELL, G. C. L., 1915.—Notes on the respiration of the Murrel (Ophicephalidae). *J. Bombay nat. Hist. Soc.*, **24** : 195-96.
- JOB, S. V., 1955.—The oxygen consumption of *Salvelinus fontinalis*. *Univ. Toronto Stud. biol. Ser. no.* **61** : 1-39.
- JONES, J. R. E., 1952.—The relation of fish to low oxygen concentration. *British. J. exp. Biol.*, **23** : 298-311.

* Reference could not be consulted in original.

- KROGH, A., 1941.—A comparative physiology of respiratory mechanism. Univ. Pennsylvania Press.
- POWERS, E. B., F. G. HOPKINS, T. A. HICKMAN & L. M. SHIPE, 1932.—The relation of respiration of fishes to environments. *Ecol. Monogr.*, **2**(4); 385-473.
- SAXENA, D. B., 1959.—On the influence of Carbon-di-oxide on the respiratory movements of the fish *Heteropneustes fossilis*. *Sci. & Cult.* **24**: 483-85.
- SHEPARD, M. P., 1955.—Resistance and tolerance of young speckled trout (*Salvelinus fontinalis*) to oxygen lack, with special reference to low oxygen acclimatation. *J. Fish. Res. Bd. Canada*, **12**(3); 388-446.
- VISWANATHAN, R. & P. R. S. Tampi., 1952.—Oxygen consumption and viability of *Chanos chanos* Forskal in relation to size. *Proc. Indian. Acad. Sci.*, **6**(4). B; 148-57.
- WOLVEKAMP, H. P. & A. G. VLASBLOM., 1952.—Simultaneous determination of oxygen uptake from water and air by air-water breathers. *Acta. physiol. pharmacol. neer.* **2**(2); 214-28.

ERRATA TO Vol. 11. No. 2.

Roonwal, M. L. and Chhotani, O. B. 1960. The apical tibial spur formula in the termite genus *Coptotermes* — *J. zool. Soc. India*, Calcutta, **11** (2) (Dec. 1959). pp. 125-132.

- p. 125, line 16. — For “132”, read “130”.
- p. 125, line 8 from below. — For “fore - middle - and”, read “fore - middle - and”.
- p. 126, line 10. — For “3:3, (“ , read” 3 : 3 : 3”.
- p. 129, line 4 from below. — Add bracket, “)”, after Coptotermitinae.
- p. 131, line 1. — For “hiene”, read “heimi”.
- p. 131, line 3 from below. — For “6 + 43 - 86”, read “37-86”.
- p. 132, line 7. — For “regional”, read “regioni.”

Sengupta and Behura — “On the insect pests of paddy in Orissa”

- p. 139, last line : for “winter” read “autumn”.
- p. 141, line 10 : for “turn yellow” read “show dead hearts”.
- p. 141, line 11 : for “yellow” read “white”.
- p. 141, line 18 : for “autumn” read “winter”.
- p. 146, line 14 : for “1954” read “1953”.
- p. 148, line 10 : put to comma (,) between the words “Kahalia” and “tuturi”.
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The inauguration and the scientific meetings were held in the splendid buildings of the Mahakoshal Mahavidyalaya. Both the Government of India and the Government of Madhya Pradesh gave their valuable patronage. The President of India sent a gracious message. The Minister for Scientific Research and Cultural Affairs, Professor Humayun Kabir, inaugurated the Congress on the 24th October, and the Deputy Minister for Scientific Research, Dr. Mono Mohan Das was also present. Dr. S. D. Sharma, the Education Minister in the Government of Madhya Pradesh, opened the Exhibition.

In his Inaugural Address, Professor Kabir laid stress on the popularisation of zoology. Dr. M. L. Roonwal, in his Presidential Address, emphasised the need for work on field ecology and taxonomy and the importance of the protection of wild life.

Nearly 120 papers were received, abstracts of which were printed and issued in advance in two booklets called *Abstracts of Papers* and *Abstracts of Contributions to Symposia*. The papers were classified into eleven Sections, each with its Chairman and Recorder as follows :—

List of Sectional Chairmen & Recorders

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Three symposia were held as follows, each with its own Chairman and Recorder as follows :—

List of Chairmen and Recorders of Symposia

Symposium	Chairman	Recorder
(A) Re-orientation of teaching of zoology in India	Prof. R. V. Seshaiya	Dr. H. S. Chaudhuri
(B) Marine zoology and fisheries in the Indian Ocean	Dr. B. Sundara Raj	Dr. H. Swarup
(C) Recent evolutionary studies in India	Dr. M. A. Moghe	Dr. B. K. Behura

A little over 100 members and delegates attended the Congress, and several Universities, Government Departments and Institutions had sent delegations.

The First Plenary Session of the Congress was held on the 24th October. The Final Plenary Session, was held on the 27th October, and passed a number of resolutions dealing with a variety of subjects. It was also decided to hold the Congress every three years, the next Congress to be held in 1962.

The Proceedings of the Congress, which will include the official reports, the full papers together with illustrations, and the full contributions made to the symposia, are under active preparation and are expected to be issued in the next few months.

During the Congress, a Zoological Exhibition was also organised in which several institutions and private enterprises took part. The Exhibition consisted of three principal items, namely; (i) an exhibition of new discoveries; (ii) a general exhibition on zoological matters; and (iii) an exhibition of recent zoological publications.



Further particulars may be obtained from :—

DR. B. S. CHAUHAN, General Secretary

First All-India Congress of Zoology; C/o. Zoological Survey of India,
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The Allahabad Agricultural Institute, a pioneer institution in the field of agricultural education, research and extension, is commemorating its 50 years of service to Indian agriculture by a week of celebrations, October 23-30, 1960. The theme of the celebrations will be centered round an historical presentation of the past and the planning of the future.

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