

From the above observations, an approximate idea can be formed as to the amount of infection spread daily by an infected flock.

The Action of the Sun on Mature Larvae : In Faeces.—An observation on the exposure of mature larvae in pellets during winter was recorded in table No. 4, in the paragraph "Dryness." From this observation it appears that after a day of exposure, in which the maximum temperature was 42° C, in the sun, about 97 per cent, of the larvae died. The following day the maximum temperature was 35° C. in the morning, and 46° C. in the afternoon, when the living larvae were reduced to 1-2 per cent. This minimum was still found after 4, 6, 14, and 25 days of exposure, when during the last three days there were heavy clouds and rain.

Exposure of mature larvae in droppings was also attempted in some instances during summer. The single pellets were directly exposed to the sun on the bare soil. The larvae were found dead after a day of exposure.

In the field mature larvae in faeces survive longer when protected by grass from the direct sunlight.

On Dry Grass.—Experiment No. 1.—In the evening blades of dry grass were placed on the internal walls of a jar culture ; migration of larvae to the grass then took place. The following morning at 7 a.m. the same blades were exposed to the sun in an upright position, in such a way that one surface was facing the sun. In the evening both surfaces of each blade were washed in separate glasses. After twenty-four hours it was noted, out of some 400-500 larvae, none were living on the surface exposed to the sun. On the opposite side, however, from 20-30 per cent, living larvae were found. The day of exposure was dry, the maximum temperature being 40° C. in the sun.

Experiment No. 2.—On the 22/8/14 pieces of dry open blades of grass, on to which mature larvae had crawled as in the first experiment, were exposed in a room for three days. On the morning of the 4th day 70 per cent, larvae were still living, and a number of pieces of the same grass were exposed to the sun at 7 a.m., under the same conditions as in the first experiment. Every evening a piece of grass was placed in water and was examined next morning. The result was as follows:—

At the end of the —

1st day, at a maximum temperature of 36° C,	20 per cent, were living.
2nd " " "	36° C, 15
3rd " " "	39° C, 5-6
4th " " "	40° C, 3-4

Other observations were made at the end of the 5th, 6th, and 8th days, when all the larvae were found dead.

Experiment No. 3.—On the 16/4/15 larvae fifteen days old were collected on dry open, blades of grass, and exposed to the sun the following day, under similar conditions as in experiment No. 1. The result was as follows:—

At the end of the—

1st day, at a maximum temperature of 40° C,	40-50 per cent, were living.
2nd " " "	40° C, 2
3rd " " "	42° C, all were dead.

Other observations were made after the 4th, 5th, and 6th days when all larvae were found dead. (The maximum temperature in the sun was 43° C.)

Experiment No. 4.—Larvae were exposed on dry, shrivelled up grass. On the 5/5/15 pieces of green grass, on to which numerous larvae had crawled, were exposed to the sun under the same conditions as in experiment No. 1. The day was dry and windy, with a maximum temperature of 35° C. After three hours the pieces of grass had a dry, shrivelled up appearance. The resistance of larvae was recorded as follows :—

At the end of the—

1st day 20 per cent, of larvae were living.
 2nd day 10 per cent, of larvae were living (maximum temperature 39° C).
 3rd day 4 per cent, of larvae were living (maximum temperature 39° C).
 8th day 1-2 per cent, of larvae were living (maximum temperature 41° C).

Experiment No. 4.—On the 26/3/15 a certain amount of infected faeces was placed at the foot of a dry grass plant in a flower pot, covered with a glass bell, and constantly moistened. On the 9/4/15, early in the morning, a large piece of the dry grass was examined and numerous living larvae were detected. The flower pot was then placed in the sunlight, and the blades of grass commenced coiling up. The results of exposure to the sun during the following days were as follows :—

At the end of the—

1st day	at a maximum temperature of 32° C,	84 per cent,	were living.
2nd	"	"	" 43° C,, 6
3rd	"	"	" 40° C, 2
4th	"	"	" 40° C, 1-3 "
5th	"	"	" 40° C, all were dead.

Up to the 5th day only blades of grass were examined ; on the 8th day two pieces of stalk from the same grass plant were cut and examined, and 60 per cent, larvae were found to be dead. On the 9th and 10th days the examination was repeated in the same way, and 50-60 per cent, were found to be dead.

On Green Grass.—Experiment No. 1.—A large number of young mature larvae were spread at the foot of a grass plant growing in a flower pot. The plant was constantly kept moist, and covered with a glass bell. The flower pot was exposed to diffused light. On the morning of the 11/8/14, when large numbers of larvae were found on the grass blades, the flower pot was suddenly exposed to the sun. The three following days were sunny, with an average maximum temperature of 39°-40° C. in the sun, and a minimum relative humidity of 18 per cent. On the 14/8/14, three days later, at 7 a.m., 60 per cent, of larvae were found dead on the blades of grass. From the 14/8/14 to the 22/8/14 the maximum average temperature in the sun was from 35°-40° C. ; the daily minimum humidity was 10 per cent. On the 22/8/14, eleven days later, at 8 a.m., on three open blades of grass, all the larvae were dead. On the 26/8/14, fifteen days later, on three open blades of grass all the larvae were dead. The same result was obtained 17, 21, and 24 days later.

NOTE—The grass was watered every morning, and during the night was sheltered on the veranda from the dew.

Experiment No. 2.—At the foot of a green grass plant growing in a flower pot, infected faeces were placed, constantly kept moist, and covered with a glass bell. On the 22/3/15, when the mature larvae were migrating on to the grass in large numbers, the flower pot was exposed to the sun. The result of successive observations was as follows:—

22/3/15.—At 6 p.m. 5 per cent, of larvae on blades were dead.

23/3/15.—At 6 p.m. 10 per cent, of larvae on blades were dead.

24/3/15.—At 6 p.m. 10 per cent, of larvae on blades were dead.

26/3/15.—60 per cent of larvae on blades were dead.

31/3/15.—80 per cent, of larvae on blades were dead.

1/4/15.—All larvae on blades were dead.

2/4/15.—80 per cent, larvae on blades were dead.

5/4/15.—All larvae on blades dead.

6/4/15.—All larvae on blades dead.

7/4/15.—All larvae on blades dead.

8/4/15.—Two stalks with four blades of grass were cut, and examined; 15 per cent, of larvae were dead.

15/4/15.—The examination of stalks was again undertaken and 60 per cent, of larvae were found dead.

30/4/15.—The blades of the grass were dried up, but the stalks were still green. All larvae were dead.

5/5/15.—On the dry blades of grass 10 per cent, of larvae were found living.

7/8/15.—On two dry stalks of grass, twenty-four living larvae and twenty-one dead larvae were found.

(The last rain fell seventeen days previously).

11/9/15.—On two dry stalks of grass, twelve dead larvae were found. (From the date of the previous observation practically no rain fell.)

14/9/15.—On two dry stalks of grass, three living larvae and six dead larvae were found. (A heavy rain fell in the night between the 12th and 13th of the same month.)

NOTES.—In the second experiment the big mortality of larvae was observed later than in the first experiment, but the weather in the second experiment was not as harmful.

In the examination on the 31/3/15, I expected to find all the larvae dead as in the previous experiment, but, in all probability owing to the thunderstorm on the previous day, a new lot of larvae migrated on to the grass from the faeces. In this way can also be explained the reappearance of living larvae on the 2/4/15, 5/5/15, 7/8/15, and 14/9/15, after negative results were obtained. The high percentage of larvae still living on the stalks of grass after repeated negative results on the open blades illustrates the efficacy of shelter against sun exposure, and indicates further that larvae may survive on the stalks after escaping from the sun. The points mentioned in this note will be dealt with again under "Migration of Larvae."

NOTE.—For further details on the atmospheric conditions during the above experiments, see page 420.

Conclusions on the Experiments made with Mature Larvae on the Grass.—The resistance of the larvae of *Haemonchus contortus* exposed to the sun on dry grass depends on the position of the larvae on the grass and on the condition of the blades, viz., if they are open or shrivelled up. The dry, shriveiled-up grass preserves the larvae for a longer period than the open grass.

From the above observations, it appears that larvae on dry grass in the open veld do not survive for longer than 8-10 days. This period need not, however, be considered to represent the maximum time during which larvae can resist, but, nevertheless, it does not seem probable that the larvae on dry grass are able to resist through a long period of drought in summer or in winter.

On green grass the difference in resistance is comparatively small. A large percentage of larvae die within the first 3-4 days after sun exposure when on the blades. On the stalks the resistance varies within wide limits, according to the nature of the blades and grass stalks. Experiments on a large scale have not so far been made. From experiment No. 2 the period of resistance on the stalks would hardly be a month, although during the time of observation rain fell on several occasions.

It must be noted that in the veld the stalks of grass are frequently collected in a thick tuft, which remains green practically all the year, whilst the plant used in experiment No. 2 had separate stalks. The resistance of the larvae in tufts will receive special attention subsequently.

The experiments with the resistance of the mature larvae on grass are not so important as it was thought before, owing to the fact that during a rainfall a new lot of larvae migrates from the soil to the grass.

MIGRATION OF THE MATURE LARVAE.

Thigmotropism of the Larvae.

During the period of their growth, the larvae are principally engaged in feeding and in finding suitable conditions for their further development.

When the larvae are in a faeces medium, as is the rule in the veld, food is abundant, and the movements of the larvae are chiefly to the outside of the pellets where there is a better supply of air. They return into sheltered layers of the pellets when the conditions of light, moisture, and temperature are not suitable on the surface. This probably occurs when the larvae are undergoing the lethargic stage.

During their growth the larvae show a distinct preference to migrate towards the ground, and this is probably due to the fact that there is frequently more moisture in the lower layers of the pellets and in the pellets touching the ground.

When the larvae reach maturity a new feature appears in their movements, viz., a tendency to leave the medium in which they developed. This fact was observed :—

- (1) In jar cultures with faeces, where the migration of mature larvae on to the walls is usually conspicuous.
- (2) In agar cultures where mature larvae were found on the walls of the Petri dish; and

- (3) In liquid medium in watch glasses, where mature larvae were found coiled up above the level of the liquid.
- (4) In cultures made at the base of a tuft of grass, when mature larvae are found on the grass blades 4-5 days afterward if the conditions of the ambient are favourable.

The same fact was not observed in liquid medium in Petri dishes, as on the vertical glass walls the larvae do not seem to be able to crawl out of the liquid. When, however, mature larvae are placed in liquid or agar medium they remain there. This is due to the cultures containing toxic substances excreted by the larvae.

The mature larvae migrate from the culture medium in all directions, but they prefer crawling on to supports rising vertically over the medium in which they are. Sometimes on the 3rd day, but more frequently on the 4th day, mature larvae were seen in great numbers crawling up the walls of the jars. The colony could then be clearly recognized by the naked eye as a whitish patch, resembling frost on a window-pane, and such patches could be seen to change their position. The distribution of the colony resembles the branches of a tree, the branches being formed by a continuous line of larvae. This continuity of the larvae and the large number of anastomoses is a constant feature of a moving colony. (Fig. 23A.) When a drop of water was placed on a partially dry colony the larvae were seen to start their movements as soon as the water commenced spreading over the slide following the branches of larvae. It appears, consequently, that the continuity of the larvae forming the ramifications plays an important role in the distribution of water for the benefit of the whole colony. This fact appears to be of great importance in the natural migration of larvae when the dew is on the grass. It was observed when larvae were isolated in a drop of water they were not able to leave the drops.

To obtain a rapid migration of larvae on to the walls of the jar, it is advisable to spread the faeces at the foot of the walls of the jar. When the mature larvae are unable to reach the walls of the culture glass, viz., when a heap of faeces is disposed in the middle of a glass dish without contact with the walls, they crawl on to the top of the faeces, and many of them erect their bodies, trying to find a higher support. Sometimes two or three larvae cling together, visible to the naked eye as small white dots. If a stick is fixed perpendicularly into a heap of faeces, numerous larvae will shortly afterwards be found crawling up the stick. The larvae are very persistent in their crawling movements, and I attempted to stop the migration by spreading vaseline along the walls of the jar, but if the colony is a strong one the larvae pass through it very easily. If the jar is closed with a slide cover, the larvae soon find if there is an outlet and then escape. If the conditions are favourable, the larvae travel further and spread on to the outer surface of the jar.

For diagnostic purposes in working with cultures, when a number of test-tubes were corked with plugs of cotton wool and placed in a large specimen jar, it was observed that after a lapse of some days larvae were frequently present on the walls of the jar, having escaped from different test tubes. If the escaped larvae find the external ambient too dry, they collect together along the commissure between the cover and the jar, and then form one or more dark yellowish clusters, some of which are as large

as a maize grain. If such a cluster is immersed in water, the latter becomes turbid with swimming larvae.

The mechanism and velocity of the travelling larvae vary slightly, according to the supporting surface and the influence of external agents.

Agar Plates.—The most efficient support for the movements of the larvae is semi-solid medium, or slightly moistened rough solid surfaces such as a grass blade. The travelling of the larvae, observed on the surface of an agar plate, can be compared with that of a snake.

At 15° C, with the usual reflected light under the binocular microscope, on an agar plate (solution of 1 per cent.) young mature larvae crossed the field of the microscope (3 mm. in diameter) in 8 to 12 seconds. Within the agar jelly (1 per cent. solution) larvae were found travelling with great facility, and presented the same features in their movements as on the surface. They crossed the field of the microscope (3 mm.) in 12 to 15 seconds. The larvae freely passed from the surface into the mass of the gelatine, and vice versa. In agar plates, in which flakes of cotton-wool were embedded, the larvae passed through the flakes with the same speed as through the homogeneous medium.

Faeces in Pellets.—A suitable method for observing the movements of the larvae on faeces, is to place pellets on a glass slide in a moist glass dish exposed to a diffused light. If on the following days the slide is transferred under the binocular microscope, in the same diffused light, and examined with a dark field, numerous larvae will be seen wandering on the surface of the pellets. The immature larvae are very slow, moving the head only. The mature larvae are quicker, but not as fast as on agar, probably owing to the fact that in a dark field the larvae are not disturbed by concentrated light.

Grass.—On moist grass blades, the mature larvae have the same velocity as on the agar plates.

Glass.—On the moist surface of a glass slide, the movements of the larvae are distinctly more of a wriggling nature than on agar plates, and the progress of the larvae is not so fast and easy, owing to the fact that the glass surface does not offer as much support as the agar.

Fluid Medium.—In water the movements of the larvae are of a wriggling nature, and their progress in a horizontal direction is slower and more difficult than on the glass surface.

Larvae from the same cultures as used for the observations on agar, and in the same external ambient, were placed in a layer of water 2 mm. deep. The larvae took 35-40 seconds to cover the distance of 3 mm. of the field of the binocular microscope.

If a watch glass, in which larvae are immersed in a thin layer of water is placed under the binocular microscope, a number of them attempt vertical movements. As a result of vigorous wriggling movements, the larvae succeed in climbing for a distance equal to once or twice the length of their bodies, but they fall to the bottom again in spite of all efforts. These attempts can be observed for a day or two in the same lot of larvae, but if the conditions of light and temperature do not change, the larvae finally remain at the bottom, and only move slightly.

When larvae are placed in deep water they remain suspended for rather a long time before falling to the bottom. In a large graduated tube, containing a column of water 20 cm. high, mature larvae were placed at the bottom by means of a long thin pipette. When removing the pipette, I noticed that the last few larvae to be ejected remained suspended in the water for at least ten minutes. The tube was left motionless until all the larvae were at the bottom, and then was gently placed in the sun, near a window. After a short time several larvae were seen moving and rising through the water to the top, and then slowly descending again. When the sun disappeared the ascending movements of the larvae were no longer noticed. The following morning the tube was exposed to the sun for about two hours, during which period some larvae were again observed ascending and descending, taking about 1½ minutes to ascend, and the same to descend. When the tube was again placed in diffused light, no larvae were observed travelling through the water. After 11-12 days no larvae were observed to be ascending, even when the tube was exposed to sunlight. At this time the larvae were examined, and half were found to be dead, and half were dormant and coiled up, but showing signs of life. Consequently it may be concluded that mature larvae are unable to rise in still water, but can do so when vertical currents occur in the mass of the water.

On the other hand, the ascent and descent of larvae is due not only to changes in the density of the water, but to their activity as well. This view is supported by the fact that in the above experiment no motionless larvae were seen to be carried by the water.

Influence of External Conditions on the Migration of Larvae.—Moisture.—Larvae remain motionless unless a certain amount of moisture is present. In a jar culture the larvae will not crawl on to the wall after it has been dried with cotton wool.

Similarly, to induce migration of mature larvae along *the* blades of grass from infected faeces placed at the foot of the grass kept in a flower pot in a room or on a veranda, it was necessary to cover the plant with a glass bell to preserve the moisture. If larvae in migration are overtaken by dryness, they collect together, or simply coil up. Larvae that were drying up on a slide were seen to collect on the spots where the moisture remained longest. In an experiment undertaken for another purpose on 31/3/15, it was noted that larvae on the walls of a jar retired for a distance of 10-11 cm. towards the faeces after sun exposure. The jar was opened twenty minutes later, and the larvae were observed to have retired further back to the level of, and partly into, the faeces. Some other larvae, apparently too far away when overtaken by dryness, were coiled up and remained on the same spot. This phenomenon was repeatedly observed in jar cultures when the lid was purposely removed to observe the effect of dryness on the migration of the larvae.

Another observation on the same subject is the following:—It frequently happened in jar cultures kept in a room, that the deposit of moisture on the inner walls disappeared from one place and reappeared on another spot. If the larvae had already commenced their ascendant migration, it could be clearly seen that they followed the moist places.

Temperature—A warm ambient is favourable for the migration of larvae. A temperature of 40°-42° C. appears to be the highest point at which the larvae remain active for any considerable length of time. At higher temperatures the larvae still move, but only for a short time, as they soon get exhausted and motionless. Low temperatures retard the migration of larvae. Diagrams drawn from jar cultures kept at 9°-10° C. show that the migration is not stopped, but the speed is reduced.

(1) 18/4/15.—Larvae in a culture in faeces constantly kept in an incubator at 35° C. for four days, had migrated 7 cm. above the level of the faeces.

On the walls of the vessel containing the culture, a line was drawn marking the upper limit of the area covered by the migrating larvae.

The curve shown in Chart No. 1—A is a reproduction of this line, showing the height and form of this upper limit.

It may be stated that during the further course of this paper the word "curve" will frequently occur, and is to be understood as being used in the same sense.

When placed in direct sunlight they descended 2-4 cm. (Chart No. 1—B). The culture was then placed in the cold storage at 9°-10° C. for twenty-four hours. On the 19/4/15 the larvae had descended a further 1-2 cm., appearing in white patches, and had risen in some places 4 cm. above the previous level (Chart No. 1—C).

Placed in the direct sunlight, no alteration was noted in the curve. The culture was then placed in a dark room at 10 p.m., at a temperature of 18°-20° C. At 10 p.m. the larvae rose uniformly around the jar for a distance of 4-10 cm. (Chart No. 1—D. Chart No. 2—A).

20/4/15.—Another exposure to the sunlight caused the larvae to descend 11 cm. (Chart No. 2—B). In the evening the culture was replaced in the cold storage.

21/4/15.—A rise of the colony of larvae was noted all along the curve to a maximum of 7-8 cm. (Chart No. 2—C).

Concerning migration on the grass, it has been mentioned in experiment No. 5 (*Temperature in the Field*) that on the morning of the 8/7/15, after an all-night rain and a minimum temperature of 10° C, living larvae were found moving on to the grass.

(2) On the 26/7/15, at 10 p.m., a jar culture 11 days old showed a strong migration of larvae over a large area, 10 cm. high, the ambient temperature being 15° C. The jar was placed in the open when the temperature was about 1° C. During the night the minimum temperature was -3° C. At sunrise the following morning the temperature was 5° C, but the larvae were still at the same level as the previous evening, and had collected in small oval patches.

On the 29/7/15, at 6 p.m., the jar was placed in the open; the larvae had formed numerous branches rising 8-9 cm. above the level of the faeces. The temperature was 15° C. At 10 p.m. the temperature was 5° C, but no further progress was noted. During the night the minimum temperature was 1° C, and in the morning it was noticed that the larvae had not changed their level, but the larvae in numerous branches of the previous evening had collected into thick oval patches. The following night at 10 p.m., the temperature of the room being 18° C, it

was observed that the same colony of larvae had reached a height of 16-18 cm. above the level of the faeces. It is therefore evident that the larvae stopped their migration when the temperature decreased from 15° to 5° C, and collected together in clusters, remaining at the same level. The conclusion is that larvae discontinue their ascendant movements with a decrease in temperature and when a temperature of 10°-5° C. is reached. With a further decrease in temperature the larvae do not descend, but collect in patches and remain motionless until the temperature rises again.

Phototropism of Mature Larvae.

Night time appears to be favourable for the migration of larvae. When a jar culture was exposed in the open, the highest migratory curve was noticed from 9-10 p.m. till sunrise.

If a culture is kept in constant darkness at the optimum of temperature, the migration begins at the usual time, but the progress of the colony is slow, and often the maximum height is not reached. If the culture is exposed to a diffused or direct sunlight for some hours and then placed back in darkness, an extensive and quick migration of larvae could be noticed.

Diffused Light.—A weak diffused light, observed in heavy cloudy weather, is also favourable for the migration of larvae. They show a gradual progress by day and night. It was also observed that larvae in a dark place were attracted by diffused weak sunlight. In this connection the following facts were observed :—

- (1) If a culture of larvae in the migratory period was placed in a room with bright diffused light, it was noted that from sunset to sunrise the larvae prefer migrating on to the wall of the jar opposite to that facing the window.
- (2) If a culture of larvae in migration is placed on to a window table in heavy cloudy weather, or in the night, the larvae collect on the wall facing the window.
- (3) If a culture of migrating larvae is placed in a cupboard with the door left partly open, the larvae collect on the wall facing the opening.

It was also noticed that larvae are attracted from the darkness towards a weak artificial light. An experiment was carried out in the following way ;—

A jar culture, with mature larvae uniformly distributed over the walls, was placed in a closed box having a narrow opening at one end. In front of the opening a gas-lamp was placed at a distance of 50 cm. The room in which the experiment was made was nearly dark. At the end of an hour the majority of larvae had collected in thick patches on the illuminated area.

From the above observation it can be concluded that larvae of *Haemonchus contortus* are positively phototropic. In comparing the same observations with those on "Bright diffused light," it must be concluded that they possess a limited positive phototropism. They are, in other words, seeking for a suitable intensity of light.

The intensity of light most suitable for the larvae of *Haemonchus contortus* is that observed in the open in rainy weather.

Experiments to Show the Behaviour of the Larvae on the Walls of a Jar placed in a Room in Ordinary Diffused Light.—In a jar culture exposed in the laboratory small branches of larvae were observed on the 4th day spreading from the level of the faeces; by the afternoon some branches were reduced to small patches at the level of the faeces, whilst others had disappeared. On the 5th day, at daybreak, the branches of larvae were 2.5 cm. high; by the afternoon the larvae were observed in patches, sometimes connected with each other by small branches, whilst other larvae were still scattered. On the 6th day, at daybreak, the larvae had risen 6.8 cm. above the faeces; by the afternoon the colony had descended some distance. On the 7th day, at daybreak, the larvae were in full ascendant migration, some reaching the edges of the jar. In the following days the migratory curve showed an oscillation in direct proportion to the intensity of the light until the 20th day, when migration stopped, and the larvae remained dormant on the walls. The above observations were noted in March, 1915, at a temperature of 15°-25° C. The difference in the migratory curve during day and night was constantly observed in numerous other cultures placed under similar conditions.

It was also noted that a culture constantly kept in darkness some days, after the larvae had reached maturity, and then exposed to the open by day and night, did not show at once the same degree of nocturnal ascending migration as that observed when a culture was exposed to the same conditions from the commencement. It appears that a colony of mature larvae want some days of training before they develop constant oscillatory movements day and night.

Bright Diffused Light.—A bright diffused light, as observed on a bright day, is decidedly unfavourable for the ascending movement of larvae, and produces a marked decrease in the height of the migratory curve of the previous night. Chart No. 3, Curve A, shows the level reached by a colony of young larvae on the night of the 28/7/15, with a minimum temperature of 5° C., and curve B the level of the colony at 2 p.m. on the 29/7/15 in a bright diffused light at a temperature of 20° C., when they had descended about 7 cm. Where the curves A and B are closer together, it must be inferred that the larvae did not descend owing to their being overtaken by dryness.

On Chart No. 5 it can be seen that a culture which was placed on a window table on the 30/3/15, containing larvae on the wall facing the window (Chart No. 5—A, two distal portions of the curve), the larvae migrated on to the opposite wall (Chart No. 5—B, medial portion of the curve).

Generally the descending migration of larvae during the day was always observed when a culture was exposed on a veranda during bright weather (see Chart 5-17).

Bright Artificial Light.—If a jar culture showing heavy migration of larvae on the walls is exposed facing a gas or electric lamp at a distance of 30-40 cm., the larvae migrate on to the opposite wall. An hour later

usually only a few larvae can be observed on the illuminated wall, and thick tracts are directed in the opposite direction to the light.

Changes in Diffused Light.—During their migratory movements the larvae are highly sensible to variations of diffused light.

A colony of larvae having reached a certain level while the culture is exposed in a room quickly descends to a lower curve if the culture is transferred to the diffused light of a veranda, and sometimes the larvae collect in patches. Vice versa the migratory curve rises at once if a colony is transferred to a room from the verandah in the day time, and the patches of collected larvae spread at once. Chart No. 3 illustrates the above observation. When the migration traced in curve B was obtained by exposure on the veranda, the culture was transferred to a room with a dim light. Within five minutes at a temperature of 17° C, a marked rise in the curve of the colony was observed (Chart No. 3—C).

If a bright day suddenly becomes cloudy, or rain falls, the ascending migration of larvae in jar cultures is immediately observed. In this connection the following experiments were undertaken :—

20/3/15.—A jar culture, made on the 14/4/15, had, during the previous night, been kept in a room at a temperature of 20° C.

On the following morning a large colony of larvae was seen on the walls of the jar 10-14 cm. above the level of the faeces (Chart No. 4—A). The jar was then exposed to a diffused light on the veranda. After a short time, just as the larvae were commencing to descend, heavy clouds gathered, and it remained cloudy until 11 a.m. The culture was then examined, and it was observed that the larvae had ascended 4-8 cm. from the spot where they were in the morning (Chart No. 4—B) (1).

The rest of the day was sunny. At 2 p.m. the culture was again examined and the larvae were found 10-11 cm. lower (Chart No. 4—C).

As a control, the culture was placed in a diffused light on the veranda the following morning, when the curve of the ascending migration was rather high; four hours later the larvae had descended 12 cm.

From the above observations it can be concluded that in sunny weather larvae descend from the higher to the lower parts of the grass, seeking shelter not only from the sun, as will be seen in the following chapter, but also from bright diffused light, always provided that moisture conditions are favourable.

Heliotropism of Mature Larvae.

On this subject a number of experiments were carried out by exposing mature larvae in jar cultures of varying ages to direct sunlight and when the larvae were either in ascending or descending migration.

Some cultures were exposed daily and the migratory curve recorded, of which the following is a typical one :—

On the 26/3/15 a jar culture was made with heavily infected faeces and placed in an incubator at a temperature of 29° C. On the 29/3/15 a small colony of larvae was observed on a wall, forming a curve 1-2 cm. above the faeces. The following day at 9 a.m. the colony had formed a curve 3-6 cm. above the level of the faeces (see Chart No. 5—A), and the culture was then placed on a window table. The wall on

which the larvae were crawling was facing the light. At 5 p.m. tracts of larvae were running towards the opposite wall where a large colony was observed 7-8 cm. above the level of the faeces (Chart No. 5-B). On the 31/3/15 at 7 a.m. the curve of the colony was 7-8 cm. higher than on the previous evening, reaching the edge of the jar (Chart No. 5-C). At 10 a.m. the curve of the colony was 1-4 cm. lower. Thick tracts of larvae were seen converging toward the faeces (Chart No. 5-D). The jar was then exposed to the direct sunlight. At 10 a.m., the colony had descended 10-11 cm. and consisted of a dense collection of larvae 2 cm. above the level of the faeces (Chart No. 5-E). The walls of the jar were still moist, and the jar was then left uncovered. Twenty minutes later the majority of larvae had collected together in thick round patches adhering to the mass of faeces. Scattered larvae were seen 2-3 cm. higher, but were dried up. At 3 p.m. the majority of larvae had disappeared into the faeces; only a few were scattered 1 to 2 cm. above the level of the faeces (Chart No. 6-A). Water was then poured into the faeces and the jar was covered again. The sun shone on the culture till 5.30 p.m. and no migration of larvae was detected, but half an hour later the culture was in the shade and a new migration of larvae was noted 3-6 cm. above the level of the faeces (Chart No. 6-B). At 9 p.m. the curve of the colony was 9-12 cm. above the level of the faeces (Chart No. 6-C). On the 1/4/15 at sunrise (6 a.m.) the curve of the larvae was 12-14 cm. above the level of the faeces at the top of the wall (Chart No. 6-D). The jar was then exposed to the sun. At 8 a.m. the larvae had descended 12-14 cm., and were collected in thick patches on a level with the faeces (Chart No. 6-E). A few larvae formed a curve 1-2 cm. above the level of the faeces, and were stretched out motionless. On examining them under the microscope they were observed to be moving slowly, and the chyle intestinal cells were rich in granulations.

During the five minutes that the jar remained in the room for the drawing of the curve new branches of larvae were observed 1-2 cm. above the level of the faeces. On the 2/4/15 at sunrise the curve of the larvae had reached a height of 7-12 cm. (Chart No. 7-B). The ascending curve was observed to be lower than that of the previous night. Under the supposition that the direct exposure to the sun the previous day had injured the larvae, the jar culture was exposed on the veranda in a bright diffused light. At 3 p.m. the larvae had not reached the level of the faeces as in the previous day (Chart No. 7-C). On the 3/4/15 at 6 a.m. the curve of larvae had reached a height of 14 cm. at two points (Chart No. 8-B). Samples of the faeces in the jar were examined and a fair number of larvae was noticed; 30 per cent, had reached maturity, were rich in granulations, and had not commenced migrating; 70 per cent, were still in the second stage. On the 4/4/15 at 6 a.m. the highest points in the curve were 12 cm. above the level of the faeces (Chart No. 9-B). At 10 a.m. the larvae were descending on the wall facing the light. A large number of larvae had turned towards the opposite wall, slightly ascending (Chart No. 9-C, right half of the curve). The oscillation in the migratory curve from the 5/4/15 to the 15/4/15 is shown in the charts from No. 10 to No. 16. In these charts the curve B represents the level reached by the larvae at 6 a.m., and the curve C represents the

level reached in the previous day. It appears that the difference in the ascent and descent of the curve decreases gradually, but constantly remains above the level of the faeces. On the 15/4/15 at 6 a.m. samples of faeces were examined and numbers of mature larvae, rich in granulations, were found, which apparently had not yet started their migration. The jar was again exposed to direct sunlight. Four hours later the curve had descended 8 cm. on the wall facing the sun, many of the larvae were seen re-entering the faeces, and on the opposite wall they ascended to a height of 4 cm. (Chart No. 16—C). On the 16/4/15 at 6 a.m. the larvae were still at the same level as on the previous day. On examining some under the microscope, the granulations of the intestinal cells were very much reduced, and were slightly yellowish. Some of the larvae were dead, and numerous living larvae without the outer skin were found.

A control culture from the same lot of faeces, dated 2/4/15, and kept in darkness, showed the larvae on the walls of the jar richer in granulations than the larvae in the above culture; practically none of them were without the outer skin. At 3 p.m. the curve of larvae was unchanged, but they had collected in small thick patches and were connected with each other by thin filaments. The larvae in the patches were stretched. On the 18/4/15 the larvae were practically in the same position. Samples of faeces in the higher layers in good condition were examined and numerous living larvae were found coiled up. Faeces from the bottom layers of the jar, moist and decomposed, contained only dead larvae. The medium was then carefully removed without disturbing the larvae on the walls, and black moist earth was substituted. On the 19/4/15 at 6 a.m., the larvae were practically at the same level as the previous day (Chart No. 17—A). The jar was then exposed to the sun for two hours, when the larvae were still practically in the same position, but were collected in thick patches touching the earth (Chart No. 17—B). On the 20/4/15, the curve was unchanged, with the exception of a few isolated branches (Chart No. 17—C). On the 24/4/15 60 per cent, of larvae had migrated into the earth. The jar was exposed to the sun, and after two hours only two or three small patches of larvae were present above the level of the earth; higher up only a few dead larvae were found; the remainder had disappeared into the earth. (Chart No. 18.)

Observations on the above experiment.—The migratory curves recorded during the first two days of exposure at the window confirm the negative phototropism of larvae to bright diffused light. The curves traced during the following days show the decided and marked negative heliotropism of the larvae, and the positive thigmotropism during the night. The curve traced at 6 p.m. on the 31/3/15 shows that the larvae commence their ascending movements immediately after sunset, and by 9 p.m. the curve is nearly at the usual maximum height reached at night. This was also frequently observed in other cultures.

The curves traced daily at sunrise show that the larvae remain at the maximum height until the sun, or a bright diffused light, reaches them.

The successive charts obtained in the above observations show that the mature larvae gradually acquire the maximal migratory instinct in the course of a few days, as the night and day migratory curves are then most widely separated. From this time onwards the oscillations of both curves gradually decrease in amplitude, until the surviving larvae descend into the ground.

The observation that the larvae did not seek shelter in the faeces from a diffused light on the veranda, but only from direct exposure to the sun, again shows that the larvae have a strong reluctance to re-enter the medium, probably owing to the decomposition of the faeces, but they do so when forced.

The observation of the 19/4/15 and following days shows that the larvae prefer to shelter in the earth, as after a certain period of migration they retire into the ground.

The possibility that the migration of larvae might be due to their efforts to evade the drying out effect of the rays of the sun was taken into consideration, but this view cannot be upheld, as it was frequently observed that the walls of a jar, from which the larvae retired, sometimes remained moist for an unlimited period.

In the experiments undertaken on the heliotropism of the larvae of *Haemonchus contortus*, it was found that the best results were obtained:—

- (1) By using jar cultures in which the larvae had just reached maturity.
- (2) By replacing the faeces medium with earth, and this should be done when the larvae are at the maximum height of their migration.
- (3) By exposing the jar culture to the sun at sunrise, or during the early morning, and at sunset when the sun is not strong enough to injure the larvae.

Aberrations in the migratory instinct.—If a jar culture which has been constantly kept in darkness, and in which the larvae are creeping on the walls, is placed in a strong diffused light, or exposed to the direct sunlight, it is observed that the larvae, instead of descending, ascend a few cm. further. This ascending movement, however, does not last long, and the larvae soon commence descending as usual. This fact can be explained by the sudden change of light, with which the larvae are not yet familiar, and as a result they become stupified. In fact, the new curve does not present the fine branches usually observed, and the larvae are scattered in quite an unusual way.

Heliotropism of the Larvae tested on Agar.—Test tubes were filled with an agar medium (5 per cent, solution) 10 cm. high, and allowed to harden. Mature larvae were then placed in the tubes on the surface of the agar jelly, and the tubes were immersed in sand to the level of the jelly and exposed to sunlight or to darkness.

A number of experiments were carried out on the above lines, of which the following is a typical one:—On the 24/4/15 four agar tubes with mature larvae were prepared as mentioned above. Two of them were placed in the sun at a temperature of 35°-40° C, and the other two in a dark cupboard. Two hours later the two exposed to the sun were examined,

and very few larvae were found coiled up on the walls of the tubes 0.5 to 1 cm. above the level of the jelly. 50 per cent, of the remainder were, coiled up, or moving in a well defined zone 2 cm. below the level of the jelly; the other 50 per cent, were at the bottom of the test tube, 10 cm. below the level of the medium.

The two test tubes were afterwards placed in a vertical position outside the sand in a weak diffused light. Five minutes later numerous larvae were seen rising from the zone, 2 cm. below the level of the gelatine. Fifteen minutes later a fairly large patch of larvae were visible to the naked eye, actively moving on the walls of the tubes. The tubes were then immersed in sand as mentioned above, and exposed to the sunlight. Within a very short time the colony of larvae on the walls had retired into the medium, leaving a few slow moving or motionless larvae on the walls. At 5 p.m. no other larvae had crawled on to the walls of the tubes. Four days later at 4 p.m., the two tubes were again examined, when some dead larvae were found on the walls of the tubes; the living larvae were in the jelly. When the culture was placed in a weak diffused light, twenty minutes later a migration of larvae on to the walls, similar to that noticed on the 24th, was observed. The two tubes constantly kept in darkness showed half the larvae on the walls coiled up and alive; the other half was found alive at the bottom of the medium.

Geotropism of Mature Larvae.

Experiment No. 1.—On the 1/9/14 water containing a large number of mature larvae was poured into the soil at the foot of a green tuft of grass growing in a flower-pot; the grass was covered with a glass bell and exposed in the open, in the shade. Ten days later the glass bell was removed, and the pot was exposed to the sun. On the 26/9/14, 12 dead larvae were found on three blades of grass. In a $\frac{1}{2}$ c.c. of earth, taken from under the grass at a depth of 5 cm., 8 living larvae of *Haemonchus contortus* were found. On the 5/10/14, 6 dead larvae were found on the dry grass blades. In a $\frac{1}{2}$ c.c. of earth taken from under the grass at a depth of 10 cm., 5 larvae were found, 4 of which were living. The earth was still moist enough to stick to the spoon used for the operation. On the 3/3/15, at a depth of 5 cm., living larvae of *Haemonchus contortus* were found. On the dry grass only dead larvae were found.

Experiment No. 2.—On the 27/8/14 a culture of infected faeces was made at the foot of a green tuft of grass growing in a flower-pot. The culture was covered with a glass bell and kept moist. After a few days the culture was left uncovered in the open. On the 3/3/15 dead larvae were found on the blades of dry grass. A few pellets of faeces were present, and scattered in the flower-pot on the surface of the ground, contained dead larvae. The ground at a depth of 5 cm. contained a few living larvae of *Haemonchus contortus*.

Experiment No. 3.—On the 28/3/15 a flower-pot was filled up with black ground, and sterilized in an autoclave. Two plants of green grass were thoroughly washed and planted in the flower-pot. A culture of infected faeces was made at the foot of the grass and covered with a glass bell. The flower-pot was constantly kept on the veranda and watered

with sufficient frequency to keep the ground moist. On the 16/4/15 numerous living larvae were found on the green grass. In a $\frac{1}{2}$ c.c. of earth, taken at a depth of 4 cm., 25 living larvae of *Haemonchus contortus* were found.

With the object of finding out if larvae are transferred through the ground by watering, the following experiments were carried out:—

Experiment No. 4.—On the 29/9/14, a flower-pot was filled up with black turf and sterilized. A layer of infected moist faeces was then disposed on the surface of the ground. The pot was immersed in water 5 cm. deep contained in a glass dish, and left on the veranda; the water was kept constantly at about the same level, and no water was poured on to the ground in the flower pot. On the 15/11/14, at a depth of 3 cm. living larvae of *Haemonchus contortus* were found. On the 20/11/14, at a depth of 5 cm., living larvae of *Haemonchus contortus* were found.

Experiment No. 5.—On the 5/7/15 a culture of infected faeces was prepared in a flower-pot under a tuft of grass, as described in the third experiment. The flower-pot was partially immersed in water as described in the fourth experiment. The pot was kept in a room with an average temperature of 11°-15° C, but without any water being poured on the surface of the contained soil. On the 11/7/15 it was placed on the veranda in the sunlight, without the glass bell and without the dish of water underneath. The temperature was frequently at freezing point during the night. On the 20/7/15, on the green grass the larvae were rather numerous, the majority being alive. In the superficial pellets of faeces, nearly all larvae were in the advanced second stage. The pellets in contact with the ground contained twice as many larvae as the superficial pellets, the larvae also being in the advanced second stage. In 1 c.c. of ground at a depth of 2 cm., 50 mature larvae were found. The ground still contained a good amount of moisture. The pot was again immersed in water, placed in the room, and the culture was covered with a glass bell. On the 7/8/15 fairly numerous larvae were found at a depth of 8 cm. Five days later samples of earth were taken at a depth of 10 and 15 cms. respectively, when a fair number of living larvae of *Haemonchus contortus* was found in all samples.

Experiment No. 6.—In the second experiment reported in connection with "Sun Exposure of Larvae on Green Grass," it was mentioned that on the 7/8/15, 4½ months after the larvae had reached maturity, 24 living and 21 dead larvae were found on two dry stalks of grass. Presumably these larvae had crawled on to the grass seventeen days previously, during the last rainfall. On the same day a sample of ground from the same flower-pot was taken at a depth of 4 cm. and examined, and in $\frac{1}{2}$ c.c. ground 10 living larvae were found with the outer skin, and still containing a good store of granulations. Living larvae were also found in ground taken at a depth of 2 cm. The ground was half black turf and half sand, and at the time was dry.

The fact that all the larvae were found alive in the ground, whilst on the grass half of the larvae, which had been exposed for only seventeen days, were dead, proves that larvae resisted better in the ground than on the grass.

Conclusions.—From the above observations on the migration of larvae it can be concluded, that—

- (1) The mature larvae of *Haemonchus contortus* crawl on to the grass under favourable conditions of moisture, light, and temperature.
- (2) The larvae withdraw to the lower part of the grass, or into the ground, when the surrounding conditions are unfavourable, and reappear on the grass with the return of favourable conditions.
- (3) The succession of night and day produces a nocturnal ascent, and a diurnal descent of larvae on the grass, provided the conditions of moisture are favourable.
- (4) The period during which a colony of larvae, when not interrupted, performs the ascending and descending migration, was found under artificial conditions to last from 20-30 days. It varies within rather wide limits according to a difference of ambient.
- (5) In the field at the end of the migratory period part of the larvae are found dead or alive on the grass; the majority are found sheltered in the tuft of grass, or at various depths in the ground.
- (6) It was repeatedly observed that the larvae in the ground were the richest in food granulations, and in a better condition of preservation than those on the grass. It appears, consequently, that the "migratory period" results in a natural selection of the species, by which weak specimens will soon die by exposure, and the stronger are able to find shelter and to resist exhaustion.
- (7) The mature larvae stored in the ground are able to pass the winter season without heavy mortality.
- (8) The presence of larvae in the soil cannot be explained by the penetration of the superficial water alone, but is due to "geotropism of the larvae."

The larvae in the ground represent a reservoir, from which a new migration on to the grass is made under suitable conditions.

Observations on the Weather.

March, 1915.

- | | |
|-------|---|
| 22nd | Bright; maximum temperature in the sun, 40° C. |
| 23rd. | Bright; maximum temperature in the sun, 42° C. |
| 24th. | Bright; maximum temperature in the sun, 45° C. |
| 25th. | Cloudy; maximum temperature in the open, 30° C |
| 26th. | Bright in the afternoon; dry wind; maximum temperature in the sun, 37° C.; <i>night</i> , minimum temperature, 12.5° C. |
| 27th. | Dull; maximum temperature, 26° C.; <i>night</i> , cloudy, damp. |
| 28th. | Dull, damp; sharp thunderstorm; maximum temperature, 24° C.; <i>night</i> , rain; minimum temperature, 13° C. |
| 29th. | Dull, shower; maximum temperature, 25° C.; <i>night</i> , rain; minimum temperature, 14° C. |
| 30th. | Dull, sharp thunderstorm; maximum temperature, 25° C.; <i>night</i> , cloudy; deposit from mist. |
| 31st. | Cloudy and bright weather; temperature, 26° C.; <i>night</i> , heavy dew; minimum temperature, 12.5° C. |

April, 1915.

- 1st. Alternately bright and cloudy weather; maximum temperature in the sun, 40° C.; *night*, heavy dew; minimum temperature, 12.3° C.
- 2nd. Bright in the morning; maximum temperature in the sun, 39° C.; shower in the afternoon; *night*, minimum temperature, 12.5° C.
- 3rd. Alternately bright and cloudy; *night*, heavy dew; minimum temperature, 12.3° C.
- 4th. Bright, warm, genial day; maximum temperature, 50° C.; *night*, heavy dew; minimum temperature, 12.5° C.
- 5th. Bright, warm, moderate wind; *night*, minimum temperature, 12° C.
- 6th. Bright, dry; maximum temperature in the sun, 41° C.; *night*, dry, slight wind; minimum temperature, 7° C.
- 7th. Bright, dry; maximum temperature in the sun, 39° C.; *night*, damp, shower; minimum temperature, 10° C.
- 8th. Cloudy in the morning; bright in the afternoon; maximum temperature in the sun, 30° C.; *night*, minimum temperature, 10° C.
- 9th. Bright, dry; maximum temperature in the sun, 32° C.; *night*, minimum temperature, 11° C.
- 10th. Bright, dry; maximum temperature in the sun, 43° C.
- 11th. Bright, dry; maximum temperature in the sun, 40° C.
- 12th. } Bright, dry; maximum temperature in the sun, 38° – 40° C.; *night*,
 13th. } minimum temperature, 11° – 12° C.
 14th. }
- 15th. Bright, dry; maximum temperature in the sun, 40° C.; *night*, minimum temperature, 8.5° C.
- 16th. Bright, dry; maximum temperature in the sun, 42° C.; *night*, minimum temperature, 8.5° C.
- 17th. Bright, dry; maximum temperature of the air, 26° C.; *night*, dry; minimum temperature, 8° C.
- 18th. } Bright, dry; maximum temperature in the sun, 40° C.; maximum
 19th. } temperature of the air 26° C.; *night*, minimum temperature,
 20th. } 8.5° C.
- 20th. Dull; damp in the morning; bright in the afternoon; maximum temperature of the air, 25° C.; *night*, minimum temperature, 8.5° C.
- 21st. } Bright, dry; maximum temperature in the sun, 40° C.; *night*,
 22nd. } minimum temperature, 8.9° C.
 23rd. }
- 24th. } Bright; dry strong wind; maximum temperature in the sun,
 25th. } 40° C.
- 26th. } Bright; dry strong wind; maximum temperature in the sun,
 27th. } 26° C.; *night*, minimum temperature, 4° – 6° C.
 28th. }
- 29th. } Bright, dry; maximum temperature in the sun, 35° C.; maximum
 30th. } temperature of the air, 22° C.

May, 1915.

- 1st. Bright; maximum temperature in the sun, 35° C.; maximum temperature of the room, 21° C.; *night*, rainy; maximum temperature of the room, 19° C.
- 2nd. Dull; maximum temperature of the room, 20° C.
- 3rd. } Bright; maximum temperature in the sun, 30°–35° C.; maximum
4th. } temperature of the room, 19° C.; *night*, minimum tempera-
5th. } ture, 7° C.
- 6th. } Bright; dry wind; maximum temperature in the sun, 39°–41° C.;
7th. } maximum temperature of the air, 19° C.
8th. }
- 9th. Bright; dry wind; maximum temperature in the sun, 35° C.; maximum temperature of the air, 19° C.; *night*, frost, minimum temperature, -2° C.
- 10th. } Bright; maximum temperature in the sun, 38°–40° C.; maximum
11th. } temperature of the room, 18°–20° C.; *night*, minimum tem-
12th. } perature, -2° to -3° C.
21st. }
- 22nd. } Night, minimum temperature, -1° to -3° C.
28th. }

June, 1915.

- 11th. }
to } Night, minimum temperature, -7° C.
15th. }
- 16th. *Night*, minimum temperature, -5° C.
- 17th. Bright; maximum temperature in the sun, 28° C.
- 18th. *Night*, minimum temperature, -5·5° C.
- 19th. *Night*, minimum temperature, -6·5° C.
- 20th. *Night*, minimum temperature, -8° C.
- 21st. *Night*, minimum temperature, -5° C.
- 22nd. *Night*, minimum temperature, -6° C.
- 23rd. *Night*, minimum temperature, -6° C.
- 24th. Bright, dry; maximum temperature in the sun in the morning, 30° C.; in the afternoon, 40° C.; *night*, minimum temperature, -7° C.
- 25th. Bright; maximum temperature in the sun, 42° C.; maximum temperature of the room, 13° C.; *night*, minimum temperature, -8° C.
- 26th. Maximum temperature in the sun in the morning, 35° C.; in the afternoon, 46° C.; *night*, minimum temperature, -6° C.
- 27th. Maximum temperature in the sun in the morning, 30° C.; in the afternoon, 42° C.; maximum temperature of the room, 12° C.; *night*, minimum temperature, -8·5° C.
- 28th. As recorded on the 27th; *night*, minimum temperature, -7° C.
- 29th. As recorded on the 27th; *night*, minimum temperature, -7° C.
- 30th. In the morning dull; maximum temperature of the air, 20° C.; in the afternoon, bright; maximum temperature in the sun, 39° C.; *night*, minimum temperature, -5° C.

July, 1915.

- 1st. Bright; maximum temperature in the sun, 40° C.; *night*, minimum temperature, -6° C.
- 2nd. As recorded on the previous day; *night*, 9 p.m., temperature, 0° C.
- 3rd. Morning, 6 a.m., temperature, -10° C.; day, warm, genial; *night*, minimum temperature, -6° C.
- 4th. Warm, genial; *night*, minimum temperature, -6° C.
- 5th. As recorded on the previous day.
- 6th. Alternately bright and cloudy; fairly dry; *night*, minimum temperature, -3° C.
- 7th. Dull, rainy; maximum temperature of the air, 12° C.
- 8th. Dull, rainy; maximum temperature of the air, 10° C.; *night*, minimum temperature, 10° C.
- 9th. Dull, damp; maximum temperature of the air, 10° C.
- 10th. Dull, damp; maximum temperature of the air, 10° C.; *night*, clearing up; heavy dew; minimum temperature, -0.5° C.
- 11th. } Bright; damp in the morning; maximum temperature of the
14th. } room 15°-18° C.; *nights*, damp; minimum temperature, 0° C.
- 15th. Dull; maximum temperature of the air, 14° C.
- 16th. Heavy rain; maximum temperature of the air, 16° C.; *night*, minimum temperature, 0.5° C.
- 17th. Alternately bright and cloudy; bright in the afternoon; maximum temperature of the air, 15° C.; *night*, cloudy; minimum temperature, 0.5° C.
- 18th. Dull and rainy; maximum temperature of the air, 11° C.; *night*, rain; minimum temperature, 0.5° C.
- 19th. Dull and rainy; *night*, rain; minimum temperature, 3.5° C.
- 20th. }
21st. } Dull and raining.
- 22nd. Bright in the morning, dull in the afternoon; maximum temperature in the sun, 36° C.
- 23rd. Bright; maximum temperature in the sun, 36° C.; *night*, minimum temperature, -8° C.
- 24th. }
25th. } Bright; maximum temperature in the sun, 40° C.
- 26th. Bright; *night*, 10 p.m., temperature, -2° C.
- 27th. 8 a.m., temperature, 4.5° C.; bright; *night*, minimum temperature, -3° C.
- 29th. Bright; *night*, minimum temperature, 1° C.
- 30th. }
31st. } Bright; *night*, minimum temperature, -2° C.

INFECTION.

Infection through the Mouth.

The direct introduction of mature larvae through the mouth of sheep is always followed by the presence of parasites in the stomach.

During the present work numerous lambs and sheep were infected with mature larvae of *Haemonchus contortus* either by giving the larvae

In water or with food, and invariably, in the examination of droppings or on post-mortem, an infection was found proportionate to the number of larvae administered.

Frequently mature living larvae were found in the droppings the day following the administration. A number of experiments were carried out by infecting lambs with eggs or larvae in the first and second stages, but the result was always negative.

Infection through the Skin.

A number of experiments were carried out, different methods being employed. Some of them were as follows :—

Experiment No. 1.—On the 7/10/14 a three-month-old lamb was selected, and the hair on the abdominal wall was cut very short over a patch the size of a hand. The patch was washed and dried, and was then kept moist for about 15 minutes with water containing a large number of mature larvae eight days old; the patch was then allowed to dry in the shade. After two hours the infected skin was well washed with a concentrated solution of lysol. During the two following days a slight reddening of the skin was observed, apparently produced by the lysol solution. From the 27/10/14 cultures of droppings were made from time to time, but with negative results. The lamb was killed on the 28/11/14, **and** no *Haemonchus contortus* were found in the digestive canal.

Experiment No. 2.—On the 8/10/14 a four-month-old lamb was selected, a patch was shaved on the abdomen, and a paste, made from black turf to which a great number of mature larvae had been added, was applied to the patch. The lamb was muzzled for six hours, and then treated with lysol as stated in Experiment No. 1. The lamb was killed on the 24/10/14, and no worms were found in the intestinal tract.

Experiment No. 3.—(a) On the 29/1/15 cultures were made from droppings of lamb No. 7161, four months old, which did not show the presence of larvae. The skin of the abdomen was shaved over an area 10 cm. square. On the skin so prepared a piece of calico soaked in water containing numerous larvae of *Haemonchus contortus*, mixed with larvae of *Strongyloides papillosus*, was applied. Over the calico a sheet of gutta-percha and a thick layer of cotton-wool were placed, and the whole was fixed to the shaved patch by a bandage. The lamb was isolated in a disinfected box. The following day the piece of calico was again soaked in water infected with larvae, and replaced on the lamb for twenty-four hours. The next day the shaved patch was washed with absolute alcohol and the lamb with an appropriate lysol solution. The lamb was then left in the box, and fed with food passed through an autoclave.

(6) On the 5th/12/15 lamb No. 7162, eight months old, was found to be free of larvae and was treated in the same way as No. 7161. The larvae were applied for three consecutive days.

Cultures from droppings were made every day, with the result that, nine days after infection, in both lambs larvae of *Strongyloides papillosus* were found. Larvae of the same species were very numerous in cultures made about 15 days after infection.

On the 3/3/15, 33 days after infection, lamb No. 7161 was killed, and in the stomach were found six *Haemonchus contortus*, which from their development appeared to be of a date anterior to the artificial infection.

Lamb No. 7162 died 21 days after infection. Five *Haemonchus contortus* were found in the stomach, apparently due to previous infection.

(c) On the 6/3/15 lamb No. 6415, eight months old, was infected by a similar method as mentioned above with larvae of *Strongyloides papillosus*. The larvae were taken from cultures of No. 7162. About 9 days later the culture from droppings showed larvae of *Strongyloides papillosus* rather frequent.

(d) On the 27/3/15 two other lambs were infected in the same way as mentioned above with larvae of *Haemonchus contortus*. The lambs were killed, one 20 days and the other 30 days after infection, and on post-mortem only a few old *Haemonchus contortus* were found in the abomasum, which appeared to be of a date anterior to the artificial infection.

Experiment No. 4.—Lamb No. 6421, four months old, had been treated with Cooper's dip and bluestone to clean it from wire-worms. On the 21/7/14 30 c.c. of water containing numerous larvae of *Haemonchus contortus* was injected in three different places subcutaneously. On the 29/7/14 water containing larvae of *Haemonchus contortus* was applied to the inguinal region, and allowed to evaporate, and the lamb was killed an hour later. In order to ascertain the result of the first infection, the three last stomachs, and the mucosa of the trachea and bronchi were examined, and no larvae were found. In the three places of injection a small caseous-purulent centre, surrounded by serous infiltration, was present in the subcutaneous tissue. In the centre numerous larvae were present with or without the outer skin. Some of them were alive.

In order to ascertain the result of the second infection, the infected, skin was washed thoroughly and cut out. No larvae were found in the skin. No larvae were found in the corresponding subcutaneous tissue, or in the inguinal lymphatic glands.

Conclusions.—The above experiments show that it was not possible to infect lambs through the skin, although the method used proved to be effective for other species of larvae.

PARASITIC LIFE.

The subject of the following notes is the life of the larva after its entrance into the host. The period of time required for development, from the moment when the larva enters the stomach of the host until it reaches the adult stage, seems to be liable to variations, owing to influences not yet properly understood, but the average, however, can be estimated to be 15 days. Indeed it was not uncommon to find eggs in the faeces of the host even on the 15th day, thus indicating that the adult stage was reached earlier. On the other hand, however, it was noticed that notwithstanding the fact that some worms had reached the adult stage, oviposition was retarded for 10 days or more. The shorter period required by the parasite to reach sexual maturity was noted in a hot season, and the longer period in a cold season. From the morphological and biological point of view, the evolution of *Haemonchus contortus* within:

the host can be divided into three stages, viz., the parasitic part of the third larval stage, or the first parasitic stage of the larva; the fourth larval stage, or the second parasitic stage of the larva; and the stage of the "adult" worm, or the third parasitic stage. During the parasitic development, three ecdyses are noted; the second ecdysis between the free and the parasitic part of the third stage, the third ecdysis at the beginning of the fourth stage, and the fourth ecdysis at the beginning of the fifth stage.

First Parasitic Stage (Parasitic Part of the Third Stage).

Biological notes (second ecdysis).—The mature, non-parasitic larva possesses a skin, which is very fragile, in the anterior portion of the body, and which can easily be removed in the shape of a hood. Under favourable conditions of moisture and heat as verified in the host, the larva shows a marked motility which assists a rapid ecdysis. Larvae introduced into sheep by means of water reach the abomasum, and undergo here the second ecdysis. The majority of the moulted larvae then take shelter in the stomach mucosa. Only a few are washed into the intestines. I was able to notice this fact in lambs, which, when slaughtered two days after drenching, showed a large number of larvae adherent to the mucosa, whereas only a small number were found in the faeces, some being dead. Taking into consideration the great number of larvae remaining, as compared with the small number washed down into the intestines, it is safe to conclude that the larvae possess a distinct biotactism for the mucosa of the fourth stomach. This peculiarity does not seem to hold good for the mucosa of the first three stomachs. In lambs infected with larvae reared on solid media, very few were found in the contents of the rumen between the 24th and 36th hours, and none at all were detected after a lapse of 48 hours, at which time the mucosa of the stomach was swarming with them. Further, no lesions were seen in the first three stomachs. Larvae introduced into sheep with solid food start at once the second ecdysis. The mouths of lambs, after feeding with grass on to which a culture of larvae had migrated, were rinsed out, and the water examined for larvae. Larvae with cast skins were found, thus indicating that the second ecdysis had taken place as soon as they entered the mouth of the host. As soon as the mature larvae have shed their skins they begin to feed. When the fourth stomach is reached they lodge between the minute epithelial processes of the mucosa, where they shelter without actually piercing the mucosa. This can be demonstrated in the following ways:—

- (1) When an animal is killed some time after it has been drenched with larvae, it can be seen, on manipulating the stomach, that the larvae drop off. When the mucosa is examined under the microscope the larvae still adhering can be seen moving between the minute epithelial processes of the mucosa.
- (2) Examination of the intestines of the larvae does not reveal the presence of any red corpuscles, nor of particles of the mucosa.
- (3) The buccal armature of the larvae is still cylindrical and unarmed.

Structure of the Larvae after the Second Ecdysis. Size.—It appears that in the parasitic part of the third stage the larvae do not increase in length

when compared with mature larvae of the free living stage. The following tables give some measurements to illustrate this :—

Measurements of free mature larvae, two months after hatching, during which time they were kept on the walls of a culture tube.

Length.	Thickness.	Tail.
μ	μ .	μ
728	26·2	140
760	26·5	140
740	26·5	142
820	26·5	142
799	26·4	140
784	26·5	141

Measurements of larvae of the first parasitic stage, collected from the stomach of a lamb two days after infection.

Length.	Thickness.	Tail.
μ	μ	μ
655	22·4	75·6
666	21	76
760	21	78
756	22	70
784	22	75
792	22	78
840	22·4	75·8

A striking change that has taken place is the shortening of the tail' the tip being 5-6 μ thick (Fig. 25). The shape of the worm is still cylindrical. The anterior end tapers slightly towards the mouth (Fig. 24). The skin is transversely striated. The lateral lines are 3 μ . broad and slightly concave, ending anteriorly a few microns away from the tip of the head and posteriorly passing the anus.

Alimentary Canal.—The opening of the mouth is bounded by the anterior end of the skin (Fig. 24, cut. head). It is surrounded by six points, representing the cephalic papillae (Fig. 24, pap. dors.). The aperture of the mouth is triangular, and the lip is either open or closed. The lip measures 2-3 μ in thickness. The mouth cavity is still cylindrical and about 5-7 μ in length (Fig. 24, m. cav.). The walls are not rigid as in the free-living stage; when the larva is not feeding the walls are collapsed and the lumen is reduced to a line. In examining larvae in profile the head of the body has the shape of a pair of nippers, between which the mouth cavity lies longitudinally (Fig. 24, m. cav.). The space between the walls of the mouth and the branches of the nipper is occupied by a mass of granular tissue (Fig. 24, gr. tiss.). The substance of the two branches represents the primordium of the future mouth capsule (Fig. 24, m. cap.).

The (Oesophagus.—The oesophagus measures 180-195 μ in length by 8-10 μ in thickness in the posterior portion. A very slight constriction is still noted in the middle portion, but the general shape recalls a claviform body. The walls of the oesophagus are transversely striated and the lumen

is linear (Fig. 24). The anterior end in the dorsal part shows a slight protuberance where the buccal lancet will appear in the fourth stage. (Fig. 24, buc. Ian.). There is no change in the two circular valves behind the oesophagus.

The Intestines—The intestine is still composed of 16 triangular cells filled with granulations and with nuclei slightly visible through the mass of the granules. The lumen is zig-zag shaped. The rectum is thin, situated obliquely to the main axis of the body and measures about 40 μ m length (Fig. 25, rect.).

The Nervous System.—The nervous system does not show any remarkable changes other than an increase in number of the nuclei of the ganglia.

Excretory Apparatus.—Two large cells are now seen ventrally in the coelomic cavity, extending posteriorly to the oesophagus, and connected with the excretory pore by a long peduncle. These cells represent the cervical glands. On transverse section the excretory canal in the lateral bands is also detected. The excretory pore is situated about 140 μ m from the tip of the head.

The Genital Primordium.—The genital primordium is situated about 350 μ m from the tip of the tail, lying slightly obliquely to the longitudinal axis of the body and consisting of two fairly uniform masses of cells, each measuring 5 μ m length.

The appearance of the larvae in the third stage is quite distinct from that of the larvae of the fourth stage, the tail now being straight and symmetrical (compare Figs. 25 and 28), and the mouth having a cylindrical shape (compare Figs. 24 and 27). They are easily recognizable, even under a low power, from the free-living mature larvae, chiefly by reason of the bluntness of the tip of the tail (compare Figs. 21 and 25-26).

Third Lethargus.—Whilst the larva is in the active parasitic period of the third stage it produces a slight mucous deposit on the mucosa of the fourth stomach, which covers and secures the larvae amongst the epithelial processes. It is in this condition of shelter that the larvae are found in the third lethargus. The commencement of the third lethargus cannot be so clearly defined as in the free stages. Nevertheless, I came to the conclusion that it is reached from the 30th to the 36th hour after the larva has gained access to the host, and lasts about 12 hours; in making post-mortem of recently infected lambs 24 hours after infection I could not yet find larvae in the lethargic stage. In other cases, within about 30-36 hours from infestation, about 50 per cent, of larvae were found in lethargus. In another instance at the 48th hour 70 per cent, were already in the fourth stage. The larvae in the third lethargus are more or less curved, completely immobile, and hard to waken; even under the strong reflected light from the microscope, they can remain immobile for ten minutes or more. In a piece of mucosa from an infected sheep kept for seven days at about 0.5° C. (the specimen was slightly putrefactive), the larvae of the third lethargus were still alive while active of the same stage were dead and partly decomposed. Some of the lethargic larvae of the specimen just referred to above kept in tap water between a slide

and cover glass at 20°-25° C. were still alive after two days; they were subsequently killed for further observations. Larvae in the active parasitic period of the third stage are easily distinguished from larvae in the third lethargus by the following peculiarities: The former are much more lively and there are no changes in the structure. Larvae of the latter kind are motionless, slightly curved, and show more confused structural outlines, occasional differentiation of the old skin, loops of the oesophagus or intestinal lumen, appearance of the new mouth capsule, and an asymmetrical outline of the new tail.

Second Parasitic Stage (Fourth Larval Stage).

Completion of the Third Ecdysis.—As stated above, the third lethargus lasts for about twelve hours, after which the larvae get rid of the outer skin. In observing some larvae undergoing moulting, I noticed that a longitudinal rupture of the old skin occurred at the bulb of the oesophagus through which the larvae gradually protruded sideways, withdrawing the head from the anterior end of the skin, and in doing so invaginating it like a finger of a glove. It is not uncommon to see a larva carrying the invaginated piece of skin about whilst it wriggles out of the posterior end of the skin (Fig. 26, out. sk.). I am not quite certain whether this is the normal mechanism of the third ecdysis, although the structures which are present in the mouth at this stage would indicate that this is so. The cast skin frequently shows a long cuticular film, hinged internally to the mouth opening. This represents the inner wall of the mouth cavity and a small piece of the lining of the oesophageal lumen (Fig. 26, cut. oes.). Other larvae are seen free from the old skin, but show remnants of the buccal tube and its cellular surroundings still adherent to the new mouth capsule. This fact might be taken to indicate that it is somewhat difficult for the anterior parts of the skin to separate from the new mouth cavity.

Larvae in the third ecdysis, or just after completion, were found to be from 750-850 μ in length by 22-25 μ in thickness. It appears consequently that but little or no growth is noted in the third stage. The object of this period of life seems to be the formation of a mouth apparatus adapted to piercing the mucosa of the stomach and thus to enable the larva to resume its parasitic life as a blood sucker.

Structure of the Larvae in the Fourth Stage.—The growth of the larvae in this stage appears to be very rapid, as shortly after the third ecdysis many larvae are found to reach 950 μ in length, and a few measure 1 mm.

External Appearance.—The only peculiarity worthy of note is that the tail is asymmetrical smooth at the tip and constantly curved dorsally. (Figs. 26-28.)

Digestive System.—The mouth now shows a provisional capsule which lasts until the appearance of the mouth proper. The cavity has the form of a truncated cone with the bottom of the mouth as the base, measuring 3.5 μ in diameter, and the top measuring about 2 μ formed by the mouth opening (Fig. 27, m. cav.). The internal wall of the mouth observed from the lateral side appears more refrangent, indicating a thickening of the cuticular layer.

The (Esophagus.—The oesophagus measures 160-200 μ in length, about 13 μ in width anteriorly and 20-23 μ posteriorly, the general shape being claviform. The lumen of the oesophagus is narrow and regular, the walls are thick and transversely striated. The intestinal valves form two rings with a combined thickness of about 3-4 μ . The intestine is 700-800 μ long, 20-25 μ thick at the anterior end, decreasing gradually until the posterior end where it is 5—8 μ thick. The intestinal cells still number sixteen, are triangular in shape with granular protoplasm frequently showing two nuclei. The lumen is still of a zig-zag shape, but slightly funnel-shaped anteriorly and uniform in diameter in the rest of its course, funnel-shaped anteriorly and uniform in diameter in the rest of its course.

The Nervous System.—The nervous system shows no changes.

The Genital Primordium.—The genital primordium is situated about 250—300 μ from the tip of the tail. It forms an oval mass of 18-25 μ in length, containing twelve nuclei and makes a marked dent into the intestines. No other changes worthy of note could be detected.

Biology of the Fourth Stage : Further Structural Changes.—The larva in the fourth stage attaches itself to the mucosa by means of the buccal aperture and produces a small haemorrhage ; a coagulum is produced which surrounds the worm. The coagulum is mixed with mucus and food particles. This phenomenon is observed about three days after drenching with mature larvae. The coagula are frequent and measure about 1-2 mm. When placing a piece of mucosa under the microscope and dissecting the coagulum, the larvae can be found on the surface of the mucosa covered by the coagulum. They are coiled up and remain in this position for three or four days when the blood coagulum appears to have increased in size. Together with larvae of the fourth stage, numbers of larvae of the third stage are still found on the mucosa about the 3rd day, but very rare. The body of the normal larva has now appreciably grown. Moreover, it appears that there is a difference in size co-ordinating with some constant structural changes. In larvae of the fourth stage, two distinct positions of the genital primordium can be found, i.e. shorter larvae with a longer primordium and more distant from the anus (Fig. 29), or longer larvae with a shorter primordium situated near to the anus (Fig. 30). This probably indicates the first differentiation of sex, the former being the males and the latter the females. At this stage of development, which is usually noticed on the 4th day after infection, the majority of larvae exceed 1 mm. in length and a few may even reach 1½ mm., with a thickness of 27.5 μ . The mouth is well developed, the lumen of the intestine has a wavy appearance, the cells are well-defined and filled with granulations. Between the 4th and 6th days the coagulum increases in size, thus probably indicating further irritation by the larvae. They are now frequent in the coagulum itself. The tail is bent like a hook, and the larva is apparently anchored to the coagulum.

4th to 6th Day.—Between the 4th and 6th days the male can be recognized by the thick posterior end, the tail being short, conical, smooth, and slightly curved posteriorly (Fig. 31). No details of the bursa can yet be detected. The genital primordium is transformed into a tube situated on the ventral side of the coelomic cavity (Fig. 31, gn. pr.).

In the female the spindle shaped genital primordium produces at the level of its middle section a slight swelling in the ventral side of the body (Fig. 32). Its medial portion consists of cells grouped in pairs, and both distal portions consist of a file of single cells (Fig. 32, gn. pr.). The tail is longer than in the male, tapers slightly and is bent dorsally (Fig. 32).

6th Day.—On the 6th day a distinction between the two sexes can easily be recognized under a low power.

Size.—In the male the length is from 2.7 to 3 mm., with a thickness of from 55-60 μ ; the tail is 50-70 μ long. In the female the corresponding measurements are 3.7 to 4 mm. long, 70-73 μ thick, and a tail length of 132 μ .

The Cuticle.—The cuticle is well developed, measuring about 3.5 μ , to 5 μ in thickness, but it is not yet possible to detect detachment from the body, and only in rare cases are there any signs of the commencing separation of the tail of the male. The distance between the transverse striations of the skin is about 2.5 μ . The buccal cavity has a globular appearance, and the walls appear thicker than previously. The oesophagus does not show anything of interest. The intestinal walls have a finely granular appearance, and border a wide lumen. In the male sexual organs, one can now follow the length of the testes for a distance of about 800 μ , but only reaching within about 100 μ of the rectal sphincter. The primordium of the pulvillus postanalis, the spicules, and the gubernaculum appear among the other structures of the posterior end as cellular masses with distinct outlines. The thick posterior end of the body has a transverse dorso-ventral sulcus bordered laterally by two protuberances 80 μ wide laterally, containing the primordium of the lateral lobes of the bursa. The tail commences at the dorsal commissure of the sulcus, and has a wavy appearance; it is roughly triangular in shape, measuring 70 μ in length (Fig. 33). In the female, at the level of the ventral protuberance previously described, a line of demarcation is noticed separating the linguiform process from the wall of the body. In the sexual primordium a differentiation can be made between the vagina, uterus, and ovary.

1th Day.—By this time the female has reached a length of 4.5 to 5 mm., with a thickness of 92-95 μ . The male measures 3.5 to 4.1 mm. in length, and 80-85 μ in thickness. The principal changes are—

- (1) A more marked appearance of the canalis testicularis; throughout its length two distinct rows of cells are seen, without any apparent differentiation; the anterior end is blind, and the posterior end joins the rectal ligament (Fig. 33, gn. pr.).
- (2) Of the two spicules the posterior end is distinct, whilst the anterior end verges into a long transparent baglike body (Fig. 33, spic).
- (3) The lateral lobes of the bursa are now clearly seen through the old skin, appearing like two fans, but the rays cannot yet be definitely recognized (Fig. 33, burs.). In the medial lobe the bifurcation of the ray can be recognized.
- (4) In the female the ovaries are about 320 μ long, ending in a blind sac.

- (5) The primordium of the uterus is already recognizable by the transverse disposition of the cells of the internal lining, and is about 2 μ long (Fig. 34, ut.).
- (6) The ovijector is represented by a distinct group of large cells (Fig. 34, ovij.).
- (7) It is also possible to detect the site of the opening of the vulva (Fig. 34, vulv.).

The stomach of a sheep examined at this stage does not reveal the presence of any free worms. The coagula are still present and may reach 5 mm. in diameter.

9th Day: Aspect of the Stomach.—The coagula have not increased in size or number, but are rather more flat, contracted, and darker in colour, the absence of haemorrhage indicating that the parasite no longer irritates the mucosa. The larvae are as a general rule still within the coagulum, and three kinds of larvae can be distinguished, namely, those in the fourth lethargus (70 per cent.), fourth ecdysis (15 per cent.), and the adult stage (15 per cent.).

Fourth Lethargus: Aspect of the Worm.—The larvae are coiled up in the substance of the coagulum, either isolated from one another or in some cases attached longitudinally in twos or threes, and in the latter case it is difficult to separate them from one another without breaking. Movements of larvae in this stage are not shown, and even under the microscope the larvae do not move at all unless roughly handled. When they are undisturbed, many hours can pass without any movements being detected. This is in striking contrast to other individuals in the same stomach, which have not reached the lethargic stage, or which have passed it, when they are seen to move about actively, and react sharply to the light of the microscope. The larvae found in the above conditions are evidently in the fourth lethargus. In fact, on examining their structure they are found to be undergoing important changes, although the new outlines of the different organs are not yet definite.

With regard to the provisional mouth capsule, the fundamental structure is unchanged, but the cavity is more globular (Fig. 35, or. cav.). The thickening of the walls is quite conspicuous (Fig. 35, kit.), and the mouth opening is funnel shaped (Fig. 35, marg. or.).

Adult Worm (Fifth Stage).

Completion of the Fourth Ecdysis.—The mechanism of this process does not differ in any essential from that of the previous stages. During the process of casting the skin, the larvae are usually found attached by the hooked tail to their surroundings. It can also be seen that the ecdysis of the female occurs a day or two later than that of the male. Considering that on the 7th day only a few larvae are in lethargus, that on the 9th day some are in the fifth stage, and that by the 12th day all have reached the fifth stage, it can be concluded that larvae of *Haemonchus contortus* undergo their fourth ecdysis between the 9th and 11th days, and that this ecdysis is preceded by a period of lethargus lasting for about twenty-four hours.

Male : Size.—The length of the body is usually over 5 mm., but rarely reaches 5½ mm. ; the thickness is about 90μ.

Skin.—The cuticle is about 1.5μ thick; the transverse striations are again very fine, measuring about 1μ, and extend from the head to the base of the tail. Longitudinal furrows can be found crossing the transverse striations. Special attention to the description of the skin surface will be given when the structure of the full-grown worm is under consideration. The cervical papillae are now situated at about 714μ from the anterior end, still adhering by the free portion to the body lines, and measuring about 35-40μ in length.

Digestive System.—The mouth cavity corresponds in every particular to the mouth of the full-grown worm, although it is not yet completely developed (Fig. 36). It will consequently be described in the full-grown worm. It is about 12μ broad, with a buccal lancet measuring 11μ in length.

The (Esophagus.—The oesophagus is club-shaped, and has a length of 750μ, and a width of 96μ at the base, and 24μ at the top. In the whole specimen the lumen appears linear, but rather irregularly shaped in the last part. The intestine is about 96 μ wide in the first portion, and about 65 μ wide in the posterior part. The chyle intestine walls are uniformly finely granular. The lumen appears to be irregularly shaped, owing to the pressure of the neighbouring organs.

In the male the rectum is about 15μ long, and is connected with the chyle intestine by a strong ligament slanting backwards on to the walls of the cloaca. The cloaca is about 40-50μ long, being wider at the base and narrower at the apex (Fig. 39, clo.). The ventral walls are supported by the substance of the ventral bands. At the bottom of the cloaca the rectum, the spicular canal, and the ejaculatory duct are distinct. The genital cone is 50μ long by 37μ broad, and is covered by a thick cuticular layer (Fig. 39, ge. co.). The spicules are 320μ long, 16μ wide at the base and 4μ at the tip, with a knob-shaped head. The tip of the spicule does not project outside the cloaca, but is protected by a well-marked, hook-shaped protuberance of the dorsal wall of the cloaca (Fig. 39, spic.). The testes, the seminal vesicle, and the cement gland together form a long tube, commencing at about 1.5 mm. in front of the anus, about 32μ broad, lying ventrally to the chyle intestine and running straight to the cloaca. From the external appearance it is possible to distinguish an anterior part about 500μ long, containing two rows of large cells, which are probably the testes. For the following 50μ the tube is slightly enlarged, with uniform contents, representing the seminal vesicle; the remainder represents the cement glands, and shows two rows of cells arranged like the barbules of a feather (Fig. 39, gl. cem.). The bursa is structurally well-developed, with the rays quite distinct, but more bunched together than in the later stages of the worm. The lateral lobes are 130μ long by 260μ broad, and the dorsal one is 88μ long by 32μ broad (Fig. 39, burs. 1. lob., burs. d. lob.).

The Female : Size.—Just after the fourth ecdysis, the female measures between 6.5 to 7.9 mm. in length, although this maximum figure is very rarely reached. The thickness varies from 90μ to 130μ.

The skin and digestive canal do not show any marked structural differences from those of the male.

The Genital Organs.—In a female worm 7.9 mm. in length, the vulva is situated about 1.5 mm. from the tip of the tail. Externally the vulva opening is protected by a linguiform process, which measures $92\mu\text{L}$ in length and is 34μ broad at the base, with the tip removed about 60μ from the body walls. The vagina is a funnel shaped tube about 70μ long, directed forward with an opening into the unpaired part of the genital tube. The lining of its walls is folded. The opening of the vulva is surrounded by a slight protuberance of the cuticular mantle of the body, which will be described under the full-grown worm. The genital tube of the female consists of two portions. One portion is situated anteriorly to the vulva, and the other one is mainly situated posteriorly. Each portion consists of a uterus and of an ovary. Consequently, in the following pages, they will be spoken of as the *anterior genital and posterior genital tubes*. The paired called the *unpaired genital tube or canal*. The anterior genital tube is at this stage frequently distended, and runs ventrally between the chyle intestine and the wall of the body. The end of this anterior tube is situated about 1.3 mm. from the vulva, and the following divisions may be noted in it, from the anterior end backwards.

Ovary.—The anterior portion of the ovarian tube is about 170μ long and 24μ thick; it contains cells regularly arranged, resembling the cones of a fir tree. The succeeding tract of the ovary is about 400μ long. The lumen is large and uniform in diameter; the inner lining is composed of six longitudinal rows of cells, appearing trapezoidal in lateral projection.

The Uterus.—The uterus follows the ovarian tube, and is composed of a first portion, which is the uterus proper, and a second portion or muscular appendage called the ovijector. The uterus measures 220μ in length, the first half is 22μ thick and is homogeneous; the second half is funnel-shaped, with the base towards the ovijector, where it measures 430μ in thickness. The walls of the uterus show a peculiar arrangement of the epithelial cells of the internal lining (Fig. 37, ut.).

Ovijector.—Two portions structurally distinct can be recognized in the ovijector, viz., Pars haustrix and Pars ejectrix.

Pars haustrix.—This is the portion following the uterus and is roughly bottle shaped, with the base anteriorly situated. It measures 132μ in length, with a diameter of 44μ at the base, and $20\text{--}22\mu$ at the neck. The internal lining and the external muscular layer are not yet completely distinct. Of the internal lining four large nuclei are seen in the anterior portion.

Pars ejectrix.—The second portion of the ovijector is about 198μ long. The anterior diameter is 64μ and the posterior one is 36μ . The muscular walls are stronger than in the pars haustrix, particularly anteriorly where they are twice as thick as in the rest of the organ. The internal walls show large irregular folds, and at the posterior end the folds become longitudinal, forming a kind of plug, which protrudes into the unpaired genital tube.

Unpaired genital canal.—This portion is already distinct from the two uteri. The structural composition is not yet complete in all details, but a cuticular wall, an internal folded lining and a granular external layer are formed.

Posterior genital tube.—This differs but slightly from the anterior one. The ovary commences at a distance of about 256μ from the anus, proceeds ventrally and then diverges to the lateral side, where after making a few coils, it returns to the ventral side. When stretched out the ovary measures about 1 mm. Of this distance the germinative portion occupies 160μ , a similar length to that seen in the anterior one. The remaining 940μ is of the same structure as the anterior corresponding part. The uterus and the ovjector are of the same size and of a similar structure to the anterior one.

Nervous System.—Apart from the growth of the body resulting in increased numbers of nuclei, no other details worth mentioning were detected.

The Excretory System.—No further changes have to be recorded.

12th Day.—In examining the stomach of a sheep twelve days after infection, numerous coagula are present, but they are now more contracted and of a black colour adhering to the mucosa, whilst petechiae of recent origin are usually found under the coagula. These petechiae are caused by the piercing of the mucosa by the new mouth apparatus of the larvae, and differ from the one described previously, because they are punctures without any escape of blood. All worms are now found in the fifth stage, and are either in the coagulum, or between the coagulum and the mucosa. It is rare to find worms outside the coagula.

Male.—The length varies from 7 to 8 mm. by 100μ to 130μ in thickness. With the exception of a proportionate increase in size, the organs of the body do not show any new peculiarities. The genital canal is usually distended, measuring about 3.2 mm. in length by 30μ in width. The spicules are about 356μ in length. The genital cone is well developed, protruding for about 60μ from the floor of the bursa. The maximum length of the lateral lobes is about 165μ .

Female : Size.—The length varies from 9 to 10 mm. by 100μ to 150μ , with a tail length of about 250μ . The tip of the anterior genital tube is situated about 2.244 mm. in front of the vulva; the tip of the posterior tube is 1.192 mm. behind the vulva, but the tube itself when stretched is 2.8 mm. long. There are no points of interest in the development of the other organs.

15th Day.—The stomach of a lamb infected fifteen days previously still shows in some cases dark red coagula adhering to the mucosa, whilst in other cases the coagula consist of a residue of yellowish fibrine and ingesta mixed together. In all cases the worms are found in between the coagula, or distributed on the surface of the mucosa itself. Some worms are now found in copulation.

Male.—The male worm measures from 9 to 10 mm. in length with a thickness of 118μ to 140μ . The genital tube is 3.5 mm. long. The vesicula

seminalis mentioned above as a simple dilatation between the testes and the cement gland is now well defined at both ends, and frequently contains a mass of spermatozoa. The spicules are 396μ , long and the gubernaculum is distinct.

Female.—The female varies from 12 to 14 mm. in length, with a thickness of 150 to 180μ , the tail length is about 720μ , and the vulva is situated at a distance of 3.1 mm. from the tip of the tail. A fact which immediately strikes the observer is that the two ovarian tubes have grown considerably in length. This is especially the case with the posterior one, which has turned round and now proceeds anteriorly to the vulva, nearly reaching the tip of the anterior tube at a distance of 5.180 mm. from the vulva. The several sections of the genital tube can now be distinguished definitely, and will be described under the heading of the full-grown worm. The second point of importance is that eggs have now passed through the genital tube, some of them having reached the ovjector. From these notes it is evident that the worms have commenced to lay eggs; in fact, it is sometimes possible to find eggs in the stomach contents.

18th Day.—When examining the stomach of a sheep 18 days after infection, all the coagula and fibrine deposits have practically disappeared. In a heavy infestation the mucosa is swarming with adult worms. The petechiae are numerous and small, but without any fresh blood coagulum. Numerous worms are in copulation, and numbers of females have laid eggs.

Male.—The male measures from 12 to 13 mm. in length. The thickness at the base of the oesophagus is 132μ , and at the base of the spicules is 198μ , gradually decreasing in diameter from the posterior to the anterior end. The genital tube is about 9.6 mm. long, ending anteriorly at a distance of about 4.15 mm. from the head.

Female.—The female is about 17 mm. in length, with a thickness of 150μ at the base of the oesophagus, and 257μ in front of the vulva. Behind the vulva the body is about 145μ thick, increasing slightly until the maximum of 231μ is reached, and then decreasing until the minimum is reached at the tip of the tail. The vulva is situated at about 2.5 mm. and the anus at about 390μ from the tip of the tail. The anterior portion of the rectum is markedly enlarged, showing an internal lining with transversal folds. The striking change of the genital organs is the increased size of the ovary and its spiral shaped disposition around the chyle intestine. The anterior ovarian tube runs for a distance of 7.9 mm., and ends at a point 4.2 mm. from the head. The posterior ovary ends at 16 mm. behind the anterior one and extends for a distance of 8.1 mm. The posterior ovarian tube, considered from the point of connection with the posterior uterus, turns forward and runs parallel to the left side of the chyle intestine until it meets the pars haustrix of the anterior uterus; from this point it turns dorsally and then laterally to the anterior part of the uterus, and on the ventral side meets the commencement of the anterior ovarian tube. From here the two ovarian tubes run round the intestines, making about nine spirals. The uterus is distended by eggs,

which are also present in the unpaired part up to the vagina. In older parasites no other essential structural changes were observed, except normal development.

ANATOMY OF THE ADULT WORM.

Method of preparing Specimens for Examination.

Living specimens were used to observe the functions of the organs. Fresh specimens were used in studying some details of the skin, nervous and excretory systems, which were changed by the fixing process. Specimens cleared in glycerine, according to the method of Looss, proved to be more satisfactory for the study of the internal structure. Transverse sections by the paraffin method were attempted, chiefly for the study of the mouth. The process was found to be delicate, and the result was not always satisfactory. Transverse sections of specimens cleared in glycerine proved to be simple and useful. The method used first of all was as follows:—The portion of the worm to be examined was separated from the body and fixed in vertical position on a thin cube of animal tissue. This operation can be easily performed under the binocular microscope; the preparation was then placed on the freezing microtome. A few drops of water were placed on the preparation during the process of freezing, until the portion of worm was enclosed in ice. In later investigations, the use of animal tissue was discontinued and the portion of worm was fixed vertically in a drop of water which was freezing on the microtome. The specimen was then enclosed in ice in the above way. When cutting the frozen mass a drop of water can be seen to appear on the blade of the razor. This drop of water was then taken up with a pipette and poured on a drop of glycerine on to a glass slide. A cover glass was placed on the glycerine and the preparation was examined.

If the above sections are embedded in gelatine and sealed with asphaltum they can be preserved for years. In this way a series of sections can be prepared. The sections must be about 15μ thick. A number of sections is always broken, but many of them are quite suitable for examination; sections of the anterior portions of the body along the oesophagus and the portion where the internal organs are pressed together proved more suitable than the posterior. For a quick examination fresh specimens can also be used for sections with the freezing microtome.

Size.—Variations in size of the specimens, due to the method of preservation and age of the worm must be expected. The following experiments with different methods of preservation were undertaken with a view to obtaining accurate figures:—

Wire-worms were collected in the beginning of spring, at a time when parasites were supposed to have been present in the stomach since the previous summer. The worms were collected from the stomach immediately after the sheep was killed, were measured and each pair of male and female worms was kept in a watch glass with water at a temperature of 24° to 25° C. They were measured again ten minutes later when they were found motionless, and to all appearances dead. Measurements were again taken forty hours later, when post-mortem changes were evident.

The following table indicates the various measurements recorded :—

EXPERIMENT No.	SIZE.						REMARKS.
	WHEN COLLECTED.		AFTER DEATH.		48 HOURS AFTER COLLECTION.		
	Female.	Male.	Female.	Male.	Female.	Male.	
	mm.	mm.	mm.	mm.	mm.	mm.	
1	25	17	30	21	Broken	19	After 48 hours the females were swollen and the internal organs disintegrated. The males were still in a fair state of preservation.
2	25	15	31	18	23	17	
3	26	16	30	19	24	17·5	
4	25	18	25	21	Broken	19·5	
5	25	17	(Broken) 29	20	26	18	
6	29	16	(Broken) 30	19	27 (Broken)	17·5	

In the above table the following observations can be noted :—

- (1) The maximum length of *Haemonchus contortus* is recorded within a few hours after collection at a time when the worms appear motionless or dead, owing to the collapse of the body tissues.
- (2) When post-mortem changes have advanced the worms are again shorter, owing to swelling of the body.

The apparent discrepancy in the length of the male worm 48 hours after collection, compared with that shown immediately after collection, must be explained by the fact that males remain in a state of good condition, for a longer period than females. Worms left in the dead body of the host are seen to die very quickly, especially in cases of toxæmic diseases; consequently their size is affected very soon after death of the host. The variations in the size of the worms under such conditions are more marked during the summer months, and especially when the carcass of the host is allowed to lie in a warm place. In sheep that died during the night, on which post-mortem examinations were made about ten to twelve hours later, the worms were generally found to be dead. They all had a collapsed appearance, and in full-grown specimens the minimum length of the female was 27 mm. and the maximum 33 mm. In sheep that died on the veld, and had been exposed to the sun, I frequently found the female worms with a length of 31 mm., although more often the specimens even had a maximum length of 33·5 mm., whilst the males measured 19 to 20 mm.

The following table gives certain measurements concerning the size of *Haemonchus contortus* when fixed and preserved :—

NO. OF EXPERIMENT.	SIZE.					
	WHEN COLLECTED AND STILL ALIVE.		24 HOURS AFTER FIXING.		A MONTH AFTER CLEAR- ING BY GLYCERINE.	
	Female.	Male.	Female.	Male.	Female.	Male.
	mm.	mm.	mm.	mm.	mm.	mm.
1	25	16	25	17	26	17
2	27	16	27	17	27	18
3	26	15	26	16	27	16
4	27	17	27	17	29	18
5	28	15	29	16	29	16
6	27	16	28	16	28	17

The worms were all collected from the same sheep as mentioned in Table No. 1, and immediately after collection they were fixed in 70 per cent, alcohol, subsequently being cleared with glycerine according to the method of Looss. The following conclusions, which can be drawn from the above table, are also supported by numerous other observations made on fixed and preserved worms :—

- (1) When a living worm is placed on a slide for the purpose of being measured, the longitudinal contraction of the body is conspicuous, and can be explained by reflex action against the unfavourable ambient.
- (2) Killing the worms in 70 per cent, hot alcohol fixes the size practically at normal, as it prevents the post-mortem muscular relaxation.
- (3) The size shown by worms embedded in glycerine is probably the most correct, and it appears that glycerine is the best preservative for correct measurements of small worms.

The second factor to be taken into consideration for establishing the average size of *Haemonchus contortus* is the age of the parasite. The average size of the young adult worm is not the average size of the fully-grown worm. There is a difference in the two sizes, and the former cannot be taken as the size of normal specimens. *Haemonchus contortus* reach the adult stage after the completion of the fourth ecdysis, when the average length is 5 mm. in the male and 7 mm. in the female. These figures correspond to the initial stage of development in the adult worms, and represent practically one-third of the length of the fully-grown worm. The average sizes given later are taken from adult specimens in which development was complete. The difference between young and fully-grown *Haemonchus contortus* is easily recognizable under low magnifications by the more pronounced pinkish colour of the young worm, by the marked pigment deposit on the intestinal walls of the fully-grown worm, and by the difference in development of the genital organs. By taking the above factors into consideration, the date of infection of a host can be ascertained with a fair degree of certainty. The following notes are taken from one particular case, and illustrate the points I have referred to. In a sheep that died after a short death struggle, during the first part of the summer, numerous wire-worms were found in the fourth stomach in good condition. The worms were then separated into two lots, according to their external appearances. In the first lot the females measured 15 to 18 mm. in length, the males from 12 to 14 mm. Both sexes were pink in colour, and the ovarian tubes showed only a few coils round the intestine, thus indicating an incomplete development in length. In the second lot about 15 other specimens were collected. These were chiefly females, 27 to 28 mm. in length, with a brownish colour, a large store of pigment granules, and with the genital tubes conspicuous by their number of coils and thickness. The conclusion was that the first batch of worms had obtained access to the host in the spring just ended, and that the second batch were of a much earlier infection, which probably occurred before the previous winter.

The material I examined during the three years in which these observations were recorded, came exclusively from South Africa, and the majority of the specimens were collected by me personally from animals at

the Onderstepoort Laboratory. In forty cases the wire-worms were measured as soon as collected, being still in good condition, and they were measured again when preserved in glycerine. The average size of full-grown males was in this way established to be 15 to 18 mm., with a thickness of 164μ at the base of the oesophagus and 270μ near the base of the bursa. The average length of the full-grown female was established as 25 to 29 mm., the thickness at 171μ to 178μ at the base of the oesophagus, and 375μ to 382μ near the base of the linguiform process. The measurements of the thickness were made from worms either with or without a cover glass placed over them, whilst floating in the media. A large number of other cases were recorded in which the wire-worms were collected when dead or relaxed, but in a good state of preservation. From these specimens the length of the female was found to be 29 to 33 mm., and in many cases even 35 mm., but in the case of the male the increase was not so marked, the average length being 17 to 21 mm. Presumably worms in the above condition are frequently collected for identification, but such material would not be suitable for determining the size of the species. Assuming that the size of *Haemonchus contortus* is the same in the different continents, then the length of 10 mm. in the male, and 18 mm. in the female, reported by Stiles and Perroncito, and 13 mm. by Lewis in the male, probably apply to worms collected in the early days following infection. Females measuring 30 mm. in length, as reported by Railliet and Stiles, were never found by me under the above conditions, but worms of this length were frequently noted in specimens that had deteriorated.

Form of the Body.—The body of the male decreases in diameter slightly from the base of the bursa to the anterior end (Fig. 40). On cross section the periphery is not completely circular, but is slightly compressed dorso-ventrally (Fig. 44). In Figs. 46 and 47 the periphery seems to be deformed by the tension of the muscles along the lateral bands. In the female the body decreases in size from the base of the linguiform process to the head. Posteriorly the diameter of the body is largest midway between the vulva and the anus, and decreases in thickness on either side. From the anus, the tail is conical in shape, with the tip fairly pointed (Fig. 41). In transverse section the body is usually slightly compressed dorsoventrally, as is noted in the male (Figs. 51-53).

General Appearance of the Worm.—The main part of the body of young living specimens has a pale, transparent appearance. In the female there are two spirals within the body, one whitish and the other pinkish in colour; when the worms become older, the colour of the latter spiral changes to a slight brownish hue, and becomes more distinct. At the time of death the worms have a whitish or greenish appearance, and are more opaque. Specimens preserved in alcohol are quite white and opaque, whilst those preserved in glycerine are yellowish and markedly transparent.

Body Walls: Cuticle.—The cuticular layer varies from 11μ to 16μ in thickness. In the male, at the level of the cervical papillae, the cuticle is 13μ thick dorso-ventrally and 28μ laterally. In the female the thickness of the cuticle reaches 70μ in the dorsal part of the linguiform process of the vulva (Fig. 52) and 7μ at the tip of the tail. The external surface of the

cuticle is transversely striated, each striation being between 1.5μ and 3μ broad, slightly narrower and less marked towards the two ends of the body, but remaining visible until the level of the buccal capsule (Fig. 42). A number of longitudinal furrows divide the cuticular surface into bands, measuring 25μ to 33μ broad, and slightly convex medially. These furrows are not constant in breadth, but vary according to the movements of the worm. In transverse sections examined either in fresh worms or in those cleared in glycerine, the appearance of the cuticular surface is seen to be quite different to the above description. Figures 43 to 47 were drawn without correction by the Abbe apparatus. The difference is due to the fact that, in the unavoidable deformation of the cuticle during the fixing and clearing operations, the skin became wrinkled, taking the peculiar disposition seen in the figures referred to above, where the cross section of the longitudinal furrow is represented by the external angles, and the width of each band is represented by the concave tracts. This deformation is so constant in section that it could easily be mistaken for the natural configuration of the skin. In Figs. 51, 53, and 56, the external appearance of the cuticle was corrected according to the appearance seen in the live worm.

Chitinous Rod.—The chitinous rods mentioned by Leukart and Schultness and described by Looss in the *Ankylostoma* are conspicuous in *Haemonchus contortus*. In whole specimens they appear as narrow more transparent strips running in the middle line of the lateral bands from the pre-cerebral portion of the oesophagus to the base of the bursa in the male and posteriorly to the anus in the female. In cross section the chitinous rods appear as small discs about 8μ in diameter and situated between the cuticle and the base of the lateral bands (Figs. 43-46, kit.).

Subcuticle.—The subcuticle is represented by a thin granular layer, lying between the cuticle and the muscular cells (Fig. 46, cut. int.), protruding between the muscular quadrants into the coelomic cavity, where it forms the longitudinal bands. In this way are formed one dorsal, two lateral, and one ventral bands.

Dorsal and Ventral Bands.—The dorsal band commences in the dorsal tip of the mouth. At the level of the connection of the oesophagus with the mouth the dorsal band reaches the wall of the oesophagus (Fig. 42, b. dors), where it diverges laterally and forms a thick granular layer around the dorsal part of the oesophagus (Fig. 43, b. dors.). The ventral band commences at the commissure of the two subventral lips of the mouth. At the level of the connection of the oesophagus with the mouth it is broader than the dorsal band (8μ), reaching the ventral walls of the oesophagus, to which it seems to act as a kind of support (Fig. 43, b. vent.). In its substance, nuclei are present, which are sometimes quite distinct. At the level of the nerve ring the two bands are seen in transverse sections to be narrower at their base (Fig. 44), the dorsal one touching the nerve ring from where it diverges on both sides. Between the two bridges of the dorsal band, the dorsal cephalic ganglion is seen (Fig. 44, gl. dors.). The ventral band supports the nerve ring. On both sides are two nucleated cells, apparently representing the "Ventral adventitious cells of the nerve

ring" (Fig. 44, c. adv. ven.). At the level of the cervical papillae the dorsal band is still connected with the oesophagus, and the ventral one appears connected with the vesicle of the excretory system (Fig. 45, b. ventr.). At the level of the posterior end of the oesophagus the median bands are still rather wide, but are compressed dorso-ventrally by the oesophageal bulb. Posteriorly to the oesophagus their breadth is reduced to 3μ or 4μ , apparently due to the pressure of the muscular cells of the body walls (Fig. 46). Within the body cavity they reach the level of the muscular cells. Posteriorly no further peculiarities can be detected in the medial bands, except; in the ventral one, which in the female just anteriorly to the vulva gives origin to the granular internal portion of the linguiform process (Fig. 52). In the posterior part of the body the median bands very much resemble the disposition of similar bands in *Ankylostoma duodenale* described by Looss. In the female, just posteriorly to the vulval opening, the ventral band again appears considerably increased in breadth and thickness, reaching the opening of the anus. In the same region a granular oval-shaped mass, showing nuclei, is found protruding dorsally from the rectum into the coelomic cavity, forming the so-called *pulvillus post analis*, which posteriorly decreases in size until it reaches the tip of the tail (Fig. 58, pulv. p.a.). In the male the ventral band is again increased in thickness at the posterior end of the body. At the level of the curvature of the ventral wall of the body into the floor of the bursa the ventral band encircles the cloaca and joins dorsally, forming the *Pulvillus post analis*. The dorsal bands gradually decrease in thickness towards the posterior part of the body without any peculiarity.

Lateral Bands.—The lateral bands take their origin in the sublateral lips of the mouth capsule. Posteriorly to the mouth they appear in cross section as broad as the dorsal band. They protrude into the body cavity, dividing into a dorsal and ventral bridge. The dorsal bridge supports the cephalic gland and is connected with the bridge of the dorsal band (Fig. 43, gl. ceph.). In the sections under observation it appeared that the bridges of the four longitudinal bands were fused together at the same level, forming the cephalo-oesophageal ligament as observed in other nematodes (Fig. 43). The ventral bridge of the lateral bands is thicker and contains the anterior portion of the excretory canal. At the level of the nerve ring the lateral bands are broader than the two medial ones. The bifurcation surrounding the cephalic glands is well marked. The dorsal bridge is connected with adventitious lateral cells that have been described in other nematodes (Fig. 44, c. adv. lat.). Slightly behind the nerve ring, the dorsal bridge of the lateral bands is very much compressed by the cephalic glands (Fig. 45). The ventral bridge supports the termination of the excretory apparatus (Fig. 45). At about the same level the lateral bands give origin to the granular cone of the cervical papillae (Fig. 45). At the level of the posterior end of the oesophagus the lateral bands are reduced to a thin granular layer by the compression of the cephalic glands. Proceeding backwards, in the male the lateral bands are reduced in breadth (Fig. 46). At the level of the spicules they are again broader and appear in cross section as a granular pedunculated mass (Fig. 47, b. lat.). At the base of the bursa the same bands make a dorsal and a

ventral diversion and contribute to the formation of the pulp of the bursa. In the female the lateral bands as seen between the posterior end of the oesophagus and the anus are broader than in the male (Figs. 51, 53, and 56). Posteriorly to the rectum they form the main substance of the tail on both sides—as far as the tip (Fig. 59).

Sub-Lateral Bands.—The sub-lateral bands are inconspicuous in the precerebral portion. At the level of the cervical papillae the four sub-lateral bands are easily detected (Fig. 45, sub. 1.), but are small in size. From the posterior end of the oesophagus they are constantly seen in cross section between the large and small muscular cells running along the lateral bands (Figs. 46, 51, 53). On cross section in the male at the level of the spicules the sub-lateral bands are much increased in size (Fig. 47, b. sub.). Posteriorly they take part in the formation of the pulp of the bursa.

Musculature.—The somatic musculature of *Haemonchus contortus* is of polymyarian type, the usual number of cells in each quadrant being 8 to 9 (Figs. 46-47). The muscle cell is of coelomyarian structure, except the cell between the lateral and sub-lateral bands, which appears distinct from the other cells of the same quadrant, showing some platymyarian characters (Figs. 47-51). The muscle cell of the first type has an average length of 1.5 mm. It is narrow, gradually decreasing in breadth towards the two ends (Fig. 41A, coel. 1, coel. 2), and protrudes conspicuously into the coelomic cavity (Figs. 46-47, coel.). The fibrillar striation is perpendicular where the cell adheres to the walls of the body and transverse on the two sides. The little protoplasm present is on the internal margin of the cell (Fig. 46-47). Frequent sarcoplasmic processes are present between two or more cells. The cell of the second type is broad at the base, occupying in certain parts of the body all the space between the lateral and sub-lateral bands (Fig. 41A, plat. 1, plat. 2). The fibrillar striation is vertical to the base. The granular part is abundant on the centre of the cell, showing a large nucleus (Figs. 47-51). The length of the cell is sometimes 4 mm. In transverse section frequently two muscular cells are seen in pairs between the lateral and sub-lateral bands, but are unequal in size. They represent the ends of two consecutive cells as represented in Fig. 41A, plat. 1, plat. 2. The somatic muscular cells adhere to the sub-cuticular layer of the body walls and are disposed longitudinally, pressing against each other. Throughout the length of the worm, the muscular coat can be divided into a series of segments or rings with saw-shaped edges. Each ring is formed by muscular cells of similar lengths, ending at the same level. As a result of the protrusion of the longitudinal bands, the muscular coat is divided into quadrants. The transverse section of a muscular ring is represented in Fig. 46. A longitudinal projection of one of the muscular quadrants is given in Fig. 41A. Each ring fits in with the adjoining one in such a way that the pointed ends of the muscular cells lie between the ends of corresponding cells of the adjoining ring. Fig. 41A shows the manner in which the cells of a quadrant fix into the ends of the corresponding cells. In Fig. 47 the two dorsal quadrants show the transverse section of the two muscular rings, in which the posterior end of the anterior cells can just be recognized. At the base of the lips in the male, one muscular cell is seen in each quadrant and

on cross section appears triangular. A few microns behind a second cell is found in each quadrant between the previous one and the lateral band. The eight resulting cells were recognized to correspond to the cephalo oesophageal cells already described by Looss. in the *Aukylostoma duodenale*. In fact, their shape shows a tendency to be cylindrical, as in cross section the fibrillar layer completely surrounds the sarcoplasm (Fig. 43, m. ceph. oes. a. and p). The above cells end on the oesophageal walls below the nerve ring. Very soon after the anterior insertion of the cephalo oesophageal cells some more cells are found in each quadrant, and at the posterior end of the oesophagus seven of them can be counted. More posteriorly there are seven to eight in each quadrant. In cross section the cells are frequently more numerous in a quadrant, the cells of two consecutive rings being cut (Figs. 47-51). The number of the rings of muscular cells was counted, and their lengths measured. In a male, of 17 mm. in length the arrangement was as follows:—1st cell appearing after the anterior origin of the cephalo oesophageal cells 499 μ in length. 2nd cell appearing after the anterior origin of the cephalo oesophageal cells 520 μ in length. The 3rd cell appearing after the anterior origin of the cephalo oesophageal cells 650 μ in length. The next cells commence at the level of the posterior end of the oesophagus. The following figures give the length of the nineteen rings counted between the posterior end of the oesophagus and the base of the bursa:—1st, 715 μ ; 2nd, 928 μ ; 3rd, 1.071 mm.; 4th, 1.213mm.; 5th, 1.428 mm.; 6th, 4.570 mm.; 7th, 1.785 mm.; 8th, 1.785 mm.; 9th, 1.785 mm.; 10th, 1.785 mm.; 11th, 1.785 mm.; 12th, 1.785 mm.; 13th, 1.785 mm.; 14th, 1.785 mm.; 15th, 1.428 mm.; 16th, 1.428 mm.; 17th, 1.071 mm.; 18th, 714 μ ; and 19th, 714 μ .

Counting from the posterior end of the oesophagus to the tail, ten platymyarian cells were found between a lateral and a sub-lateral band. The maximum length was 4 mm. in the middle of the body, two consecutive cells lying along side each other for a distance of 1.7 mm. The two posterior ones were one-third of the length of the anterior ones and indistinguishable from the bursal muscles. Figure 47 shows in cross section the change of the ventral muscular quadrants at the level of the genital organs. In a female 25 mm. long, the muscular cells along the oesophageal portion of the body were similar to those of the male. From the posterior end of the oesophagus until at the vulva, 25 consecutive muscular rings were counted, the longer cells measuring 2.2 mm. From the vulva backwards five to six rings of cells were counted, the cells being short and narrow. Figure 56 shows in cross section that the muscles of the two ventral quadrants, situated at the level of the vulva have nearly disappeared. It was further noted in cross sections of the female that posteriorly to the vulva the two ventral quadrants are again complete, although the muscular cells are smaller in size. Behind the posterior uterus the cells in each, ventral quadrant number four, and further back only two, the rest of the quadrant being occupied by the lateral and ventral bands. At the level of the rectum only one muscular cell appears dorsally, and two cells, ventrally, all of which are reduced to the fibrillar part. The above somatic muscles disappear in the tail.

Digestive System

Mouth: Mouth Aperture.—The oral opening is triangular, each side of the triangle representing a lip. One lip is dorsally situated, and the other two are sub-ventral. The three lips are separated by an incision which extends as far as the cephalic papillae, of which each lip supports two. Between each pair of papillae is a groove, running along the medial axis of the lip to the edge. The edge of each lip is formed by the medial axis of the lip until the edge. The edge of each lip is formed by external cuticle of the head, which projects with a sharp fold towards the mouth cavity. In Fig. 42 the above fold is seen in the dorsal lip in lateral projection, and in the left sub-ventral lip in frontal projection. The incision separating the lips enables the oral opening to expand. In examining a number of specimens under high magnification, the lips are found in different degrees of inclination toward the mouth cavity. In Fig. 42 the lips are slightly distended.

Mouth Capsule.—The mouth capsule is formed by a thick layer of chitin. It takes origin anteriorly just behind the edge of the lips, where a slight sulcus (not reproduced in Fig. 42) is formed. From here the mouth capsule reaches the anterior tip of the oesophagus. The mouth cavity has the form of a truncated triangular pyramid, with a dorsal and two sub-ventral sides. The base of the pyramid corresponds to the bottom of the mouth. The space between the sub-ventral walls of the mouth capsule and the cuticle of the head is divided into two by a transverse chitinous bridge (Fig. 42, right sub-median wall chit. br.). Each sub-ventral wall of the mouth capsule has a transverse furrow running through the middle of its length, and is curved anteriorly and posteriorly to the same furrow. The transverse furrow and the two curves are seen in longitudinal section in Fig. 42 in the right sub-ventral wall (chit. arc. 1 and chit. arc. 2). The same details are shown in frontal projection in the left sub-ventral wall. The dorsal wall of the mouth shows the anterior curvature thicker and longer than the sub-ventral one (chit. arc. I dorsal wall). On longitudinal section it has the shape of the letter S. Its caudal end continues into the dorsal lining of the lumen of the oesophagus (Fig. 42, chit. arc. 2). The dorsal wall is divided along the longitudinal median axis by a deep cleft. At the posterior end of the cleft the buccal lancet is inserted. In Fig. 42 the left edge of the above cleft is represented (chit. arc. 1 dorsal wall).

Buccal Lancet.—The buccal lancet has a bilobular base, a pointed tip, and is compressed laterally like the blade of a knife. The dorsal edge is conspicuously curved, and has two thorn-shaped points, of which the more anterior one is the sharper (Fig. 42). The lancet is connected with the mouth capsule by an articulation which allows an oscillatory movement in a dorso-ventral direction. Two muscles, which may be called the muscles of the lancet, are inserted on its base. The more anterior one is the stronger (Fig. 42 m. abd. Ian.). It is inserted on the antero-dorsal lobe of the base of the lancet, from which it takes a dorsal direction, through the muscular fibres of the oesophagus, and ends apparently on the external surface of the oesophagus. This muscle is seen with difficulty in fixed

and cleared specimens, but it is quite distinct in fresh specimens, especially when the worm is still alive, and is moving the lancet. I call this muscle the "abductor of the lancet." The second muscle is inserted on the postero-ventral lobe of the base of the lancet, from where it is directed posteriorly, and after passing a comparatively long distance through the muscular walls of the oesophagus, it ends in the marginal portion of the oesophagus wall (Fig. 42). This muscle is less powerful than the first one, and is apparently compressed laterally. I call it the "adductor of the lancet" to distinguish its function from that of the former.

Function of the Mouth.—*hi* observing a live worm under strong magnification, it is possible to see rather complex and co-ordinated movements of the different parts of the mouth apparatus, of which there are four movements which are typical.

- (1) Periodical movements of the lips, resulting in changes of the mouth opening.
- (2) Anterior projection of the lancet.
- (3) Very frequent oscillatory movements of the lancet in the ventro-dorsal direction.
- (4) Some decided and marked jerks of the head in a ventro-dorsal direction.

The movements of dilatation of the lips appear to be produced by the cephalo-oesophageal muscles, which take insertion on the base of the lips. In connecting the movements of the mouth with its conformation, it is allowable to conclude that the lancet first pierces the mucosa of the stomach, the hooked point of the dorsal margin then lacerating the tissues as it is being withdrawn. The occasional jerks of the head have apparently also the purpose of lacerating the tissue. It could also be mentioned that the muscular walls of the oesophagus are sometimes seen in progressive contraction antero-posteriorly. In examining the intestinal contents of a *Haemonchus contortus*, it seems that small particles of the mucosa of the stomach are also ingested.

(Oesophagus.—The oesophagus is club-shaped, about 1.5 mm. long, with a diameter of 30 μ at the anterior end and 150 μ at the base. The lumen is tri-radiate when contracted (Figs. 43-44). Posteriorly the lumen ends in a short triangular cavity, the walls of the cavity forming three lips. The three lips represent the three oesophageal valves, very similar to those described in other strongylidae. The walls of the oesophagus are thick and muscular. Two portions of muscles can be distinguished, namely, the marginal portion, consisting of fibres arranged in three bundles, each one starting from the triangular edge bordering the lumen and diverging towards the periphery (Fig. 45, fbr., marg.), and the second portion representing the muscles proper of the oesophagus, radiating from the centre and in cross section appearing to be divided into three segments (Fig. 44, mu. aes.). Within the muscles are included the three oesophageal glands. The muscular fibres run at right angles to the axis of the oesophagus except for a short distance in the posterior part, where they are more obliquely disposed, and converge anteriorly. This tract only extends to within 40 μ or 50 μ of the end of the oesophagus, in which portion the muscles are again arranged

at right angles to the axis, and now represent the muscles of the oesophageal valves.

(Oesophageal Glands.—The oesophageal glands number three, each occupying a section of the muscular wall of the oesophagus. The dorsal oesophageal gland is the largest, and is seen on cross section to reach the anterior tip of the oesophagus (Fig. 43, gl. dors.). The two sub-ventral glands start anteriorly at the level of the cervical papillae. The oesophageal glands continue along the oesophagus, and towards the posterior end split into two, turning completely round in the form of two hooks. The two branches proceed anteriorly as far as the cervical papillae (Fig. 45, gl. oes. subr.). The nuclei of each oesophageal gland can easily be detected in cleared specimens where the oesophageal gland turns anteriorly, having a diameter of about 14μ . The efferent duct of the sub-ventral glands can be seen clearly outlined for a good distance, extending into the median trunk of each gland, until at about 95μ - 100μ from the anterior tip of the same trunk, the efferent duct turns off and opens into the oesophageal lumen. This opening is situated in the first half of the length of the oesophageal lumen, rather far back. The efferent duct of the dorsal gland passes from the anterior tip of the oesophagus to the dorsal lip of the mouth, and opens into the mouth cavity in the cleft in which the lancet is lodged.

Intestinal Valves.—The valvular apparatus between the oesophagus and the chyle intestine appears as a thick short cylinder about 47μ in length and 67μ in diameter, projecting into the lumen of the chyle intestine, and showing on its outer surface a circular sulcus. This sulcus divides the cylinder into the two rings already noted in the larval stage. The anterior ring has a fibrous appearance, surrounding the end of the oesophagus and connecting it with the outer wall of the chyle intestine. The second one protrudes into the intestinal lumen, and is characterized by its granular appearance.

Chyle Intestine.—The chyle intestine is 24-26 mm. long in the female, and 15-16 mm. in the male. In the female, from the oesophagus to the tip of the ovarian tube, it is loosely attached to the walls of the cavity. For two-thirds of its length from the oesophagus to the vulva, the chyle intestine and the genital tubes run parallel in a spiral. The thick spiral formed by the two organs occupies practically all the lumen of the coelomic cavity. At the level of the vulva, the intestine lies ventrally until it reaches the rectum. In cross sections of a female worm, the intestine appears round in the portion situated anteriorly to the ovary. At the level of the first portion of the ovaries it is semi-circular, about 228μ by 120μ , with a large lumen. Along the ovarian tube the intestine is more compressed (Fig. 51, int.). At the level of the ovijector and vagina, it is again more circular in shape, and the diameter measures 160μ by 120μ (Fig. 56, int.). Posteriorly to the vulva the intestine is semi-circular in shape. In the last portion it is still 214μ by 124μ , with thick walls rich in nuclei. In the male, at the level of the seminal vesicle, the chyle intestine is crescent shaped on section (Fig. 46, int.). Along the cement gland the intestine is compressed, and still crescent shaped on section. The lumen is sometimes S-shaped (Fig. 47, int.). The dimensions are.

about 173μ s a maximum diameter, and 80μ in the final portion of the intestine.

In conclusion it may be stated that in both male and female, the intestine is very plastic, and adapts itself to the disposition of the neighbouring organs. The cells composing the walls of the intestine are in both sexes more or less filled with granulations. In young worms the outlines of the chyle cells can sometimes be detected. The plasma granulations are more or less mixed with pigment, being coarser and more yellowish in the younger worms, and more abundant and black in colour in older specimens, and it appears on cross section that when the intestine is crescent shaped, the black granulations are more often found at the tip (Figs. 46-53, int.). The nuclei of the above cells are of two kinds, namely, a larger nucleus irregularly shaped, which is not so commonly found, and more commonly a smaller circular nucleus with a diameter of 15μ . The internal lining is cuticular in appearance, about 8μ in thickness, with vertical striations and a smooth surface.

Rectum of the Male.—In the male the rectum appears as a cone protruding into the bottom of the cloaca, and measures about 50μ in length, with a base diameter of 40μ . The lumen is $3-4\mu$ broad, and the lining appears chitinous, and is differentiated from the lining of the chyle intestine, which is always more brownish in colour. The chyle intestine is connected with the rectum by a thick granular band called the "anterior ring of the rectal ligament." It gives origin to three cells. Two of these cells have a diameter of $45-50\mu$, and are situated on the latero-ventral side of the rectum. The third one is dorsally situated. From the anterior rectal ring, a thin strand proceeds backwards for a short distance along the walls of the cloaca, bounded posteriorly by a second less conspicuous ring called the "posterior ring of the rectal ligament." From this ring three cells of about 15μ in diameter protrude ventrally. The "rectal sphincter" is represented by a muscular band which can be observed anterior to the anterior ring of the rectal ligament.

Rectum of the Female.—The rectum in the female consists of a chitinous tube about 0.117μ in length. The anterior portion is connected with the chyle intestine, and appears funnel shaped, similar to that described in the earlier stages (Fig. 58). The length of this part is about 50μ , with a width of 20μ at the base; its connection with the chyle intestine is distinct. The succeeding portion of the rectum has a diameter of a few microns only, and runs nearly parallel to the ventral wall of the worm (Fig. 58, rct.). The lining of the rectum is chitinous, and thicker on the dorsal side of the second portion, where the maximum thickness of 14μ is registered. At the level of the anus the internal lining is quite distinct from the neighbouring skin cuticle. The pulvillus post analis, already noted in other stages, is now well marked. It consists of two portions, the anterior granular portion, with an average length of 80μ , and the posterior portion continuing to the tip of the tail (Fig. 58, pulv. p.a.). The anterior ring of the rectal ligament, as well as the thinner posterior portion extending on the walls of the rectum, are conspicuous (Figs. 58-59, lig. rect.). The posterior ring of the rectal ligament is covered by the pulvillus post analis. Both anterior and posterior rings show the three cells already mentioned in the male. The rectal

sphincter is seen on the edge of the anterior ring of the rectal ligament. From the dorsal side of the posterior rectal portion, a strand of muscular cells radiate dorsally with a fan shaped arrangement (the so-called "anal muscle") (Fig. 58, m. an.).

Genital Organs of the Male.

The genital tube is well developed and occupies the greater portion of the body cavity. In a full-grown male of 17 mm. in length the sexual tube is 11 mm. in length, varying in diameter in different parts of the body. The main portion of the sexual tube runs ventrally, but the anterior end can be found twisted round the intestine. The vesicula seminalis is sometimes seen dorsally or on the lateral side.

Testes.—The testes are the part of the tube bounded posteriorly by the vesicula seminalis. They are either slightly twisted around the chyle intestine or are stretched. The anterior end just fails to reach the level of the nucleus of the right cervical gland by a few microns. The length of the testes tube is about 4.5 mm. The external configuration of the anterior end is conical, and the diameter of the tube varies somewhat according to its position with the chyle intestine, but has an average diameter of 100 μ m in the anterior and 150 μ m in the posterior part. In examining a whole specimen its structure appears finely granular. On cross section the internal structure shows a layer of conically shaped cells disposed radially at right angles to the axis, leaving a central space occupied by round cells. More posteriorly the layer of peripheral cells can still be seen, and in the median axis runs a canal with a diameter of 4 μ . The more posterior part of the testes is full of spermatozoa (Fig. 40, te.).

Vesicula Seminalis.—This reservoir constitutes the posterior continuation of the testes and is frequently bottle shaped, with the base being situated anteriorly (Fig. 40, vs.). It is connected with the testes by the testicular canal about 200-250 μ in length by 57 μ m diameter. This canal is always coiled so that the two tips of the testes and the vesicula seminalis almost touch each other. Posteriorly the vesicula seminalis is connected with the cement gland by the "vesicular canal," having a length of 140 μ and a diameter of 40 μ . The vesicula seminalis varies between 350 μ m and 700 μ m in length. In cross section the thicker part of the vesicula seminalis is either oval or semi-circular in shape. The walls are thin and the seminal reservoir is full of spermatozoa (Fig. 46, vs.). There is a close similarity in the structure of the last portion of the testes, seminal duct, and vesicula spermatica, and the vesicula seminalis can be recognized as such by a simple constriction separating it from the posterior end of the seminal duct.

Spermatozoa.—The spermatozoa contained in the vesicula seminalis are small, spindle shaped bodies of about 3-5 μ m length by 1.5 μ thick, and consists of a strongly refragent substance. Each spermatozoon is surrounded by a mass of very finely granular protoplasm, spherical in shape and about 5-6 μ m diameter (Fig. 46, vs.).

Cement Gland.—The cement gland is the portion of the sexual tube connecting the vesicula seminalis with the cloaca. The following descriptions were taken from a specimen in which the length of the cement gland measured

6.85 mm. In its essential structure it consists of a canal with a comparatively thin lumen, and thick walls composed of two longitudinal lateral rows of cells. It is possible to distinguish two portions of the cement gland, the anterior and the posterior one, separated from each other by a slight constriction.

Anterior Portion.—The anterior portion measures about 4 mm. in length. From the external appearance the two rows of cells are flattened antero-posteriorly, slightly obliquely to the main axis of the canal (Fig. 40, gl. cem. 1). The cross section of the same portion appears slightly compressed dorso-ventrally. The lumen is nearly linear, and disposed in the direction of the shorter diameter of the section. The cells of the two lateral rows appear intact contrary to the appearance of these cells in the second portion of the gland.

Posterior Portion.—The posterior portion of the cement gland is about 3 mm. in length, passing posteriorly through the ligamentum rectalis, where it is reduced to a thin chitinous canal ending in the cloaca. Seen externally the cells of each lateral row are thin, sometimes hardly distinguishable from each other and placed more obliquely to the longitudinal axis of the tube than in the anterior portion of the gland. This arrangement has the appearance of the lateral barbs of a feather (Fig. 40, gl. cem. 2). On cross section the periphery of the tube resembles the anterior portion, but the inner portion of the cells protruding into the lumen of the canal is broken off and the base of the cell only remains (Fig. 47, gl. cem.). It appears that the cement is produced by the successive breaking down of the row of cells of the second portion, commencing with the cells nearer the efferent duct and proceeding anteriorly. The anterior part of the gland where the cells are still apparently intact would represent the portion not yet used.

Ano-genital Aperture.—It consists of a transverse slit opening in the ventral part of the floor of the bursa. It possesses a dorsal and a ventral lip. The dorsal lip is supported by a prominence of the floor of the bursa gradually rising from its dorsal edge and reaching a level above the dorsal lip. The ventral lip is supported by the genital cone. The genital cone rises for 70-75 μ above the floor of the bursa with a base of 150 μ . The walls of the genital cone are divided into three sections by two annular constrictions. The tip is reduced to a thin appendix of finger like appearance (Fig. 60, ge. co.). The pulp of the cone is a direct continuation of the ventral band. On each commissure of the ano-genital opening is present a small pyramidal protuberance, rising from the floor of the bursa. The two appendages with the above-mentioned supports of the two lips join to form a funnel shaped cavity, at the bottom of which is the ano-genital opening.

Cloaca.—This is an elongated cavity measuring about 70-85 μ in length. The anterior end is larger than the posterior one and receives the opening of the rectum, of the ejaculatory duct, and of the spicular canal. The dorsal wall has a deep cleft in which the spicules are seen when exerted. The ventral wall is formed by the ventral band. The posterior end corresponds to the ano-genital aperture.

Spicular Apparatus.—There are two spicules placed dorsally to the posterior part of the intestine and rectum. They have the appearance of a horn 460-470 μ long, slightly twisted, of brownish golden colour. The tip of each spicule is at the posterior end, and shows a small knob about 12 μ . in transversal diameter. At a distance of 20 μ for the left spicule and at a distance of 40 μ for the right spicule measured from the tip, a barb projects forwards. At a distance of 120 μ from the tip the median surface of each spicule is flat, gradually widening out until it reaches 16-20 μ in width. The borders are thick at the flattened parts and converge towards one another as thin bands (Fig. 47, spic). The last part of the spicular cavity contains a granular substance called by Looss "Pulp of the Spicule." Amongst it some granulations appear, resembling the cement granulations, very refragent, and with a diameter of 3.5 μ . Protruding from the cavity of the spicule a capsule or bag can be seen extending anteriorly, measuring 200-250 μ long and 70 μ broad, the walls being composed of two layers, of which the internal and more refragent one is 11-12 μ thick. "Pulpa spicularis" is also contained in this capsule. The "retractor muscles" of the spicule are 28 μ broad, proceed anteriorly along the walls of the intestine and finally are connected with the lateral bands, about 450 μ from the base of the spicule. The "exertor muscle" is sometimes seen, in a whole specimen, proceeding backwards along the walls of the spicule.

Spicular Canal.—The spicular canal is chitinous and protrudes into the cloaca dorsally to the rectum; its first portion consists of a simple canal. At the anterior end of the gubernaculum this canal bifurcates and at this level it is compressed dorso-ventrally, measuring about 70 μ by 30 μ in diameter. Proceeding further anteriorly the two bifurcations of the spicular canal are completely separated (Fig. 47, can. spic). They can be followed for some distance whilst diverging laterally, but the walls become thinner until they can no longer be seen.

Gubernaculum.—From both sides of the posterior portion of the spicular canal are chitinous appendages which converge dorsally and medially to meet each other. Where the two branches meet, they give rise to the gubernaculum (Fig. 47, can. spic). In a whole specimen the gubernaculum has the appearance of a date stone, measuring about 200-250 μ in length and 35-40 μ in width. The margins are curved dorsally, forming a deep longitudinal furrow (Fig. 47, gub.). The substance of the gubernaculum has the same appearance as that of the spicules. The two most prominent muscles of the gubernaculum detectable in cross section are :—

- (1) The Musculi Seducator Gubernaculi inserted into both sides of the gubernaculum and crossing the body cavity, proceeding to the lateral bands (Fig. 47, m. sed. gub.), and
- (2) The Musculi Supinator Gubernaculi. Portions of this muscle appear in cross section inserted in the dorsal part of the gubernaculum, from where they diverge towards the base of the bursa (Fig. 47, m. sup. gub.).

Bursal Apparatus.—The bursa of *Haemonchus contortus* consists of two symmetrical lateral lobes and an asymmetrical dorsal one. Each

lateral lobe starts from the posterior end of the body as a trunk with a diameter of 150μ (Fig. 49, tru. 1, lob.). The membrane of the lobe starts dorsally near the floor of the bursa, and ventrally at the base of the genital cone (Fig. 48, ge. co.). The dorsal and ventral origin of the membrane is shown in cross section in Fig. 49 (ma. dors, and ma. ven.). The appearance of a lateral lobe when distended is that of a roughly rectangular leaf with the posterior end convex (Fig. 48). On cross section the disposition of a lateral lobe is semi-circular (Figs. 49-50), with the posterior part slightly turned inwards (Figs. 40 and 60). On the external surface the lateral lobes are transversely striated (Fig. 50, cut. ext.). At a short distance from the margin of the bursa the transversal striations bifurcate. Two papillae are found in the external surface of the lateral lobe, corresponding to the tip of the externo-dorsal and externo-lateral rays. The inner surface of a lateral lobe has first a rather deep and narrow groove originating at the base of the genital cone. It runs rather close and parallel to the ventral margin until it crosses the ventro-ventral ray. From this point the groove turns in a median direction, and with its two branches ends on the medio-lateral ray (Figs. 48, 49, 50, int. gr.). I call this groove the "internal groove of the lateral lobe." The outer side of the groove is bordered by a rather large corrugated ridge (Figs. 48, 50, rid. int. gr.), which in the more posterior course branches towards the posterior margin of the lobe. The inner border of the internal groove is also rather prominent and can be easily seen in sections (Fig. 50, rid. int. gr.). The second prominent structure of the medial surface of the lateral lobe is a finely lobulated protuberance ending with the anterior tip between the postero- and medio-lateral rays at the level of the tip of the externo-dorsal ray, increasing forward in width and decreasing in thickness till it reaches the internal groove. This structure is called in the present paper the "internal gibbosity of the lateral lobe," and is seen in frontal view in Fig. 48 (int. gib.), and in section is represented by the morula-like protuberances at the level of the three lateral rays in Fig. 50. Some cuticular tubercles also appear on the posterior portion of the three lateral rays. Along the margin of the lobe the cuticular layer shows a very fine striation corresponding to a similar disposition seen on the external surface, giving the margin of the lobe a denticulated appearance (Fig. 48). Four papillae are also seen in the inner surface of the lateral lobe corresponding to the tip of the postero and medio-lateral rays and to the tip of the latero and ventro-ventral rays. The already mentioned corrugated structure of the medial surface of the lateral lobe is peculiarly adapted to increase the adhesive power of the bursa in gripping the female.

Substance of the lateral lobes of the bursa.—The bursa appears composed of an external and internal cuticular layer, between which is contained a single thick subcuticular layer. The external cuticular layer is also rather thick and in direct continuity with the cuticle of the body (Fig. 50 cut. ext.). The internal cuticular layer is not always distinct on account of the tubercles already described as occurring in the medial surface of the lateral lobe. The subcuticular layer is rather coarse grained where the so-called "cuticular granules" are very numerous and large (Figs. 48, 49, 50, gran. cut.). In the subcuticular layer are the rays of the bursa.

The rays in the transversal section appear round or oval with a proper envelope. In the internal cavity appears a granular substance (Fig. 48. pul. ray.), a rather thick muscular coat formed by the costal muscles (Figs. 49-50), and a nervous fibre called " Costal nerve " (Figs. 49-50, nrv. co.).

Disposition of the rays in the lateral lobe of the bursa.—At about 50 μ from its origin, the common trunk of the rays gives off the *externo-dorsal ray*. This ray diverges slightly from the common trunk, running straight to the dorsal margin of the lobe. After a distance of about 500 μ it ends, at 28 μ from the dorsal margin, in a papilla situated on the external surface of the lobe. It is the thinnest of the rays of the lateral lobe, and slightly decreases in diameter towards the tip (Figs. 48, 49, 50, ex. drs. r.). At about 180 μ from its origin the common trunk divides into the trunk of the lateral rays and the trunk of the ventral rays. The trunk of the lateral rays proceeds undivided along the median axis of the lobe for about 100 μ , where dorsally it gives off the postero-lateral ray. After another 70 μ it divides into the medio-lateral and externo-lateral ray. The *extsrno-lateral ray* appears like the continuation of the common trunk of the lateral rays and runs along the median axis of the lobe, ending at about 40 μ from the posterior margin of the lobe in a papilla situated on the external surface of the lobe. It is the thickest of the lateral rays, about 470 μ in length and about 57 μ in breath at the base (Figs. 48, 50, ex. l. r.). The *medio-lateral ray* runs close to the externo-lateral one for a short distance, and afterwards curves towards the dorsal margin of the lobe, where it ends in a papilla situated on the inner face of the lobe at about 15 μ from its margin. It is about 456 μ long by 50 μ thick at the base (Figs. 48-50, md. l. r.). The *postero-lateral ray* runs very close and nearly parallel to the medio-lateral ray. It is about 530 μ long by 35 μ thick on the base, ending at 10 μ from the dorsal margin of the lobe in a papilla situated on the internal face of the lobe (Fig. 48, ps. l. r.). The common trunk of the ventral rays runs undivided and close to the externo-lateral ray for about 140 μ (Fig. 48, ven. r.), and divides into the latero-ventral and ventro-ventral ray. The *latero-ventral rays* runs for a short distance with the externo-lateral ray and then curves suddenly towards the point of division between the dorsal and posterior margin of the lobe (Fig. 48). It is about 371 μ long, 35 μ thick on the base, and ends at about 15 μ from the margin in a papilla situated on the internal surface of the lobe (Figs. 48-50, lat. ven. r.). The *ventro-ventral ray* is the shortest ray of the lateral lobe, diverging suddenly from the latero-ventral ray towards the ventral margin, where it ends about 7 μ distant in a papilla situated on the inner surface of the lobe. It is 192 μ long by 22 μ thick on the base (Figs. 48-50, ven. ven. r.).

Asymmetrical dorsal lobe of the bursa.—This lobe takes origin on the internal surface of the left lateral lobe and at the base on the dorsal margin of the internal gibbosity. It is directed medially and slightly dorsally to the main axis of the body. Its shape is roughly quadrangular, about 160 μ broad by 150 μ long. The margin is irregularly lobulated (Fig. 48, drs. lb.). The root is thick and nearly round, with coarse cuticular granules (Fig. 49, drs. lb.). The dorsal ray takes origin from the common trunk of the lateral rays near the origin of the externo-dorsal ray. On

cross section it is slightly oval (Fig. 49, drs. r.). The dorsal ray runs undivided along the axis of the dorsal lobe for about half its length, then bifurcates into two equal thin branches running to the corners of the lobe, and ends in two very small secondary branches. The external branch ends in a small papilla on the inner surface of the lobe. The median one protrudes for some microns through the margin of the lobe (Fig. 48, drs. r.) and forms a small pointed hook.

Genital Organs of the Female.

Position of the Genital Opening.—The genital opening, or vulva, is situated in the ventral side of the body at about one-fifth or one-sixth of the body length from the tip of the tail. The following are the measurements of six worms, showing the exact place at which the vulva was situated :—

(1)	Total length of worm	18 mm.,	vulva situated	3.5 mm.	distant.
(2)	„ „	20 mm.,	„	3.4 mm.	
(3)	„ „	24 mm.,	„	4.5 mm.	„
(4)	„ „	27 mm.,	„	5 mm.	„
(5)	„ „	30 mm.,	„	5.5 mm.	„
(6)	„ „	33 mm.,	„	5.5 mm.	„

The anterior genital tube commences at the vulva, and as a rule proceeds obliquely to the dorso-lateral side of the intestines and maintains that position for the length of the uterus (Fig. 52). In other cases the anterior uterus crosses the intestinal tube dorsally and descends in the opposite side (Fig. 41, ant. ut), where it makes a large loop before assuming the spiral shaped disposition. The posterior genital tube proceeds along the latero-ventral side of the body for the whole length of the uterus (Fig. 52). The following ovarian tube turns sharply in front of the anus and runs ventrally again until it reaches the level of the genital opening. It then crosses the genital apparatus and the chyle intestine dorsally (Fig. 41), turning again ventrally along the right side of the anterior uterus, and then coiling around the chyle intestine together with the anterior ovarian tube (Fig. 41). Altogether the two ovarian tubes make 12-14 turns around the intestine, developing a length of 23-25 mm. They end at about the level of the nucleus of the right cervical gland, that is to say 15-16 mm. from the vulva in an average sized specimen. The posterior ovarian tube is 3-4 mm. longer by reason of its origin. The tip of the anterior ovarian tube is usually a short distance in front of the tip of the posterior ovarian tube (Fig. 41).

In old worms the anterior end of one or both of the ovarian tubes turns backwards, making another turn around the intestine, so that the transverse section of this portion may show four ovarian tubes instead of two. The diameter of the tubes decreases slightly from the place of origin. The average thickness of the anterior tube can be taken as 135μ in the posterior end, and 75μ in the anterior portion. In each coil the thinner of the two tubes is usually the posterior one (Fig. 51). The following notes on the different sections of the genital apparatus refer to the anterior tube.

Structure of the Ovaries and Oviduct.—The anterior portion of the ovarian tube appears as a canal with thin transparent walls. It contains

the ovarian cells grouped radially around a granular medial axis (rachis), and directed in an oblique direction, resembling a fir cone. The rachis with the adhering ovarian cells is easily observed in dissecting out the anterior portion of the ovarian tubes from a fresh worm. The rachis is seen protruding from the canal for a long distance with the eggs attached by a short thin peduncle proceeding backwards. The ovarian cells are about 10-15 μ thick, flat antero-posteriorly, and in a transversal section of the ovarian tube they are seen occupying about one-third of the circumference. They consist of a thin membrane with granular contents, and possess a large spherical nucleus. Proceeding further backwards the rachis disappears, and the eggs increase in size and become irregular in shape owing to compression by the other eggs. They are free in the ovarian tube (Fig 51, ant ov; Fig. 53, post, ov.) For the last 3 mm., the oviduct decreases in diameter until it reaches a distance 35 μ from the end, where the walls appear thicker. Eggs are seen in this portion placed in a long row, sometimes close together and at other times separated from each other.

Uterus.—The uterus is about 2.25 mm. long, and is generally spindle shaped. The thickness varies according to the number of eggs present in its cavity (Fig. 41, ant. ut.; Fig. 53, ant. ut.). The walls of the uterus are thin and no external muscular layer is seen (Fig. 53, ant. ut.). The epithelial layer, representing the internal lining, consists of rhomboidal cells disposed in circular rows (Fig. 52, post. ut.). In the distended part of the uterus the epithelial cells are rather thin. The anterior 8-10 rows of epithelial cells protrude conspicuously into the lumen of the uterus, taking a disposition similar to the leaves of an onion. In the posterior portion of the uterus the epithelial cells are rather thick and give the walls of the lumen a rough surface (Fig. 52, ant. ut.). This part of the uterus contains the greatest number of spermatozoa of any part of the genital tube. It seems to correspond to the "Receptaculum seminis" recorded by Looss in the *Ankylostoma Duodenale*.

Spermatozoa.—The spermatozoa found in the seminal receptacle are similar to those found in the seminal vesicle of the male. When the seminal receptacle is dissected and the spermatozoa on the slide come in contact with water, the surrounding protoplasmic sphere is broken and the spermatozoa resemble small bacteria, very refragent, and capable of marked motility.

Ovijector : Pars haustrix.—The length is about 350 μ , with an anterior diameter of 150 μ and posterior of 170-175 μ . The inner walls are formed anteriorly by four large cells arranged longitudinally in pairs, and having the appearance of a petal of a calix (Fig. 52, pars h. 1). Posteriorly the above four cells are followed by four smaller ones, protruding into the lumen of the pars ejetrix like a plug (Fig. 52, pars h. 2). The external muscular layer of the pars haustrix is comparatively thin and transversely striated (Figs. 52 and 54, m.p.h.).

Pars ejetrix.—The pars ejetrix is roughly cylindrical in shape. It is placed in the left ventral side of the body in front of the vulva. In length it measures 215 μ . The more anterior portion is formed into a

sphincter, and appears like a short bulb; the muscular walls are very thick and transversely striated. The diameter of this section measures 146μ (Fig. 52, pars ejec, 1). The rest of the pars ejectrix is about 150μ thick, with the muscular walls thinner than the anterior portion and longitudinally striated (Fig. 52, pars ejec. 2). The inner walls of the pars ejectrix show numerous folds separated by longitudinal and transversal furrows (Fig. 52, pars ejec. 2; Fig. 55, int. l.p. ejec).

Unpaired Part.—The unpaired tube joins the proximal ends of the posterior and anterior ovijector, and as a consequence is situated rather transversely to the main axis, proceeding from the left ventral to the left lateral side (Fig. 52, u. pars.). In length it is about 210μ , the ventral wall being nearly straight, whilst the dorsal wall is convex. In the centre its diameter is 112μ and at the end 80μ . The external layer is granular and $5-6\mu$ thick (Fig. 56, u. pars.). The muscular wall is about 11μ thick with longitudinal striations (Fig. 52, u. pars.). At the point of connection with the pars ejectrix, a marked constriction is noted, but the muscular fibres are not broken. Between the muscular layer and the inner lining a cuticular wall can be seen, with a thickness of about $6-8\mu$. The internal lining is longitudinally folded (Fig. 52, u. pars.). In this unpaired part, three or four eggs are frequently present during the period of oviposition. In the ventral wall and in the centre, a circular opening with a diameter of $35-40\mu$, surrounded by a strong sphincter, gives entrance to the vagina. Other authors dealing with different worms of similar structure assume that this portion of the genital canal belongs to the pars ejectrix, but the distinct function and sharp external delimitation from the two opposite ejectrix organs and from the vagina would suggest the advisability of considering this unpaired tube in the *Haemonchus contortus* as a vestibule between the vagina and the two paired genital tubes.

Vagina.—The vagina is a short tube joining the unpaired tube with the vulva (Fig. 52, vag.). It is 150μ long by $80-85\mu$ in diameter, externally. The lumen undergoes dilatation and contraction. Conspicuous and numerous muscular fibres, in bundles, start perpendicularly from the walls and radiate into the granular mass of the linguiform process (Figs. 52 and 56, m. vag.). The walls are cuticular, $6-8\mu$ thick. The internal lining shows numerous longitudinal folds. The posterior end reaches the linguiform process on the base of its medial wall (Figs. 52 and 56, m. vag.).

Vulva.—The vulval opening is situated at the base of the linguiform process (Fig. 52). It possesses conspicuous cuticular lips protruding outside perpendicularly to the axis of the linguiform process, and consequently towards the axis of the body. These lips form a slight tube compressed antero-posteriorly. The anterior wall is flat and the posterior wall slightly curved (Fig. 52, 1. vulv.). When the lips are pressed against the body by the linguiform process, the vulva remains closed.

Physiology of the Ovijector.—In observing a living female worm under fairly high magnification, the irritation of manipulation causes the female to lay eggs, so that it is quite easy to observe the mechanism of this process. The eggs are passed out singly or a few at a time with intervals in between. One ovijector is used at a time. In considering for instance the anterior

ovijector, the following mechanism can be observed ;—The pars haustrix is projected anteriorly, and at the same time opens (Fig. 52, pars, h. 1). By this movement two or three eggs are engulfed in it. Immediately afterwards the pars haustrix returns to its original position and the eggs are pushed into the pars ejectrix. The marked constriction of the anterior part of the pars ejectrix (Fig. 52, pars ejec. 1) is now followed by a gradual contraction of the subsequent fibres and the eggs are pushed into the vestibule (Fig. 52, u. pars). Here, other eggs are usually present, and by the pressure of the oncoming ones they are pushed through the vagina and the vulval opening. The function of the vestibule is a passive one, except for the slight pressure exerted by the dorsal wall, by which the egg is diverted ventrally to fall into the vagina. The dilatation and the sudden contraction of the vulval opening after the expulsion of the eggs is very marked. Briefly, it can be said, that the mechanical act of laying eggs consists of two distinct processes. In the first place the pars haustrix receives the eggs from the uterus and transmits them to the subsequent portion of the tube. In the second process undertaken exclusively by the pars ejectrix, the eggs are pushed through the vestibule of the vagina into the vulval opening.

Linguiform Process of the Vulva.—This is very conspicuous, commencing just in front of the vulva and extending backwards in a slightly oblique direction (Fig. 52, ling. proa). Its length is about 750μ by 250μ . At the base it is compressed dorso-ventrally. The internal side is slightly concave, whilst the external side is convex (Fig. 56, lin. proc). The chitinous mantle is very thick and shows transverse striations on the surface. The internal part of the linguiform process has a granular appearance, and is a deviation of the ventral band. The cuticular granules are sometimes very numerous (Fig. 56, gran. cut.). The structure of the linguiform process and its temporary changes suggest that it is an organ erectile during copulation.

Lateral Vesicles.—At the time of copulation, there is present, on one or both sides of the body at about the level of the base of the linguiform process, a more or less conspicuous cuticular vesicle varying in diameter from $50-350\mu$ (Fig. 56, lat. ves.). The base of this vesicle is usually smaller and more laterally compressed like a peduncle. Judging by section, these vesicles seem to be formed by a simple swelling of the external cuticular layer at the level of the lateral bands. The walls are transparent and show marked transverse striations. Sometimes they contain a granular substance, spreading like a fan from the base. At other times the vesicle seems empty. During copulation the lateral vesicles are usually covered by the lateral lobes of the bursa of the male. The predominant appearance of these vesicles at the time of copulation, their temporary disappearance, and their varying numbers, indicate that they are accessory organs for the copulatory act.

Apparent Anomalies of the Vulval Linguiform Process.—In general I found that the anatomy of *Haemonchus contortus* was fairly constant in regard to appearance and size of the different organs, but at the time of marked reproductive activity I met with a very large number of rather old female worms, showing peculiar differences in the linguiform process.

In some sheep about 25 per cent, female worms showed the following peculiarities:—The linguiform process was unusually short, measuring 250μ in length and about 170μ at the base. It was conical in shape, adhering to the body and slanting towards the tip, with contents granular in appearance. In other specimens it was represented by a pimple-like body, protruding for a distance of about 25μ , sometimes placed anteriorly and at other times situated laterally to the vulva. In some specimens the linguiform process was quite absent and the opening of the vulva was only indicated by a rudiment of the above-mentioned vulval lips. There were no other remarkable changes in the remainder of the genital organs except that the vagina was sometimes situated in a direction perpendicular to the ventral side of the body, instead of occupying the oblique position already described. The laying of eggs was performed quite normally. I might also add that the anomalies mentioned were found in different seasons of the year.

Nervous System.

The nervous system of *Haemonchus contortus* very closely resembles that described in *Ascaris megalcephala* and *lumbricoides* by Leukart, and in *Ankylostoma duodenale* by Looss. The nomenclature and the method of investigation of Looss constitute an advance in our knowledge of the anatomy of the nervous system of nematodes. I have therefore adopted them, and the following notes are intended chiefly as a comparison between the nervous system of *Haemonchus contortus* and that of *Ankylostoma duodenale*. The corresponding drawings, as also the notes themselves, were made from specimens cleared in glycerine. Comparatively young worms were selected as being more transparent and less pigmented. The males were 12 mm., in length and the female specimens 17 mm. For the more minute details a magnification of 1334 diameters was used.

Central Nervous System.—The central nervous system appears to be composed of the "nerve ring," the "cephalic ventral ganglion," two "cephalic lateral ganglia," and the cephalic "anterior commissure."

Nerve Ring (Cephalic Commissure).—In the male the nerve ring is situated about 270μ , and in the female 285μ , from the anterior end of the body. In lateral view it has a slightly oblique direction antero-posteriorly from the dorsal to the ventral side. In dorso and ventral view it is situated transversely to the body, and measures about 22μ in thickness (Fig. 57, co. ceph.). When seen in cross section it occupies the larger part of the coelomic cavity around the oesophagus (Fig. 44, co. ceph.). It appears to be composed of very fine fibres arranged in bundles, having a slightly wavy appearance. Only a few nucleated cells are present amongst the fibres of the nerve ring. In the latero-ventral view the superficial nerve fibres are seen to take a more oblique direction than the inner ones, and proceed from the lateral to the ventral cephalic ganglion (Fig. 57, sup. f.). This peculiar disposition of the two layers of fibres results in the formation of a small area in the ventral side of the nerve ring, where nerve fibres are very rare or completely absent (Fig. 57).

As stated above in dealing with the "subcuticle" the four subcuticular longitudinal bands run on the periphery of the nerve, acting as

a kind of support. The dorsal band bifurcates at the nerving, forming two lateral bridges (Fig. 44). The lateral bands are also bifurcated, and of these two bridges the upper branch is connected with the lateral adventitious cell. The ventral band running alongside the nerve ring is connected on both sides with the two ventral adventitious cells.

Cephalic Ventral Ganglion.—In ventral or latero-ventral position a certain number of pyriform nerve cells are seen just under the ventral band, and projecting backwards behind the nerve ring (Fig. 57, ggl. ceph. v.). This group of cells represents the "cephalic ventral ganglion." It is horse-shoe shaped, with the five more anterior cells adhering to the posterior margin of the nerve ring, and the two branches, each composed of ten or eleven cells, directed backwards and slightly diverging on to both sides of the excretory pore. Of the five anterior cells, the three middle ones are more developed, the central one being the largest, 11μ long by 8.4μ thick, and situated more superficially. This arrangement closely corresponds to that described by Looss in the Cephalic Ventral Ganglion of *Ankylostoma duodenale*.

The Cephalic Lateral Ganglia.—This ganglion is fairly distinct in lateral view, and more so in latero-ventral view (Fig. 57, ggl. ceph. l). It is situated between the oesophagus and the lateral band, and is composed of about 15 cells, similar in shape to those of the ventral ganglion. The bunch of cells measures about 42μ in length, and is thicker on the anterior part where it connects with the nerve ring. Each cell appears connected by a thin fibre with the nerve ring so that the cells are not all massed together. In cross section, just posteriorly to the nerve ring, this ganglion is represented by 3-4 cells of about 8μ in diameter, situated between the oesophagus and the pulp of the lateral bands. The further connections of this ganglion with the rest of the central nerves will be referred to later.

Subcutaneous cephalic commissure.—If a living or recently dead *Haemonchus contortus* is examined on the ventro-lateral side under high magnification, it is possible to find just at the level of the nerve ring a fine strip, apparently composed of a few nervous fibres, running between the cuticle and subcuticle from the ventral to the lateral subcuticular bands in a direction perpendicular to the axis of the worm. In specimens dead for some time or in specimens cleared by glycerine I was not able to find this structure. No further investigations were made, but it appears that this strand of nerve fibres represents the "Commissura (ventro-lateralis) cephalica cutanea" described by Looss in the *Ankylostoma duodenale*. In living specimens, two other fine bundles of fibres are seen which have a common origin with the subcutaneous cephalic commissure. From the point of connection both bundles curve outwardly, joining the ventral sublateral bands.

The Cephalic Internal Commissure.—In ventro-lateral view numerous nerve anastomoses are seen between the cells of the cephalic ventral and the cephalic lateral ganglia (Fig. 57, nrv. anas.). The posterior anastomosis is a more conspicuous one and takes its origin in one of the posterior cells of the cephalic ventral ganglion. For a short distance it has a common course with the ventro-post-lateral commissure (*vide infra*), then turning

rather sharply anteriorly joins the posterior cell of the cephalic lateral ganglion (Fig. 57, co. ceph. vtr. lat. 2). This anastomosis closely corresponds with the cephalic internal commissure of *Ankylostoma duodenale*.

The Peripheral Nervous System.

Nerves of the Cephalic Papillae.—In specimens cleared in glycerine, and examined chiefly in ventral and dorsal view, the above nerves can easily be distinguished at their origin from the central nervous system. The two sub-median, dorsal, or ventral ones start directly from the nerve ring. In figure 57 are seen the two ventral nerves (nrv. pap. v.) and the dorsal one (nrv. pap. d.). The nerves of the lateral papillae commence from the lateral cephalic ganglion (Fig. 57, nrv., pap. 1). Each nerve is rather thin, and along the first portion a few small spindle shaped cells can be seen. On section each nerve appears composed of a few fibres running along the periphery of the oesophagus, the lateral ones between the oesophagus and the lateral bands, and the sub-median ones about midway in each oesophageal quadrant. These nerves are surrounded by a granular substance. In cross section closer to the mouth the above nerves cannot always be detected with certainty, but in a whole specimen it is sometimes possible to trace their course until they reach the cephalic papillae.

The Post-lateral Cephalic Ganglia.—From the posterior end of the cephalic lateral ganglion a few nerve fibres (which were described by Looss in the *Ankylostoma duodenale* as fibres of the lateral cephalic papillae) run on the inner surface of the lateral bands until they reach the base of the cervical papillae, or a point slightly beyond it. Here they join two or three ganglion cells, situated on the dorsal part of the lateral bands. These cells represent the post-lateral cephalic ganglion (Fig. 57, ggl. ceph. post-lat.).

Nerves of the Cervical Papillae.—These nerve fibres leave the post-lateral ganglion through the pulp of the lateral band, usually making a slight curve anteriorly and entering the base of the cervical papillae (Fig. 57, nrv. pap. cerv.).

Ventro Post-lateral Commissure.—This is rather a conspicuous nerve, having its origin together with the cephalic internal commissure at the ventral cephalic ganglion. It then runs posteriorly and laterally, joining the post-lateral cephalic ganglion. (Fig. 57, co. ceph. ventr. post-lat.).

Longitudinal Nerves.

Ventral Nerves.—The ventral nerve starts from the ventral cephalic ganglion, and is composed of two bundles of nerve fibres. Each bundle consists of nerve fibres starting directly from the more superficial layer of the nerve ring and of others starting from the cells of the cephalic ventral ganglion (Fig. 57, nrv. vtr.). The two resulting branches of the ventral nerve are thus seen gradually converging towards the median line, until they join together at the level of the anterior end of the cervical glands. From this point the trunk of the ventral nerve proceeds backwards on the inner surface of the ventral band. In the female, just in front of the

vulva, the ventral nerve enters a small ganglion, called the "vulval ganglion." From this ganglion a thin nerve fibre goes into the vulval linguiform process. The trunk of the ventral nerve appears posteriorly to the above ganglion, having, after bifurcation, encircled the vulva. Proceeding backwards, it again appears in a single trunk. Frequently, ganglion cells are present along its course, from which lateral nerve fibres take their origin.

Lateral Nerves.—From the posterior end of the lateral cephalic ganglion another large bundle of fibres takes origin. These soon reach the ventral margin of the lateral band, where they receive a few fibres from the post-lateral cephalic ganglion and run backwards along the lateral band. They represent the "ventro lateral nerves."

Sub-lateral Nerves.—The origin of the ventral sub-lateral nerves has been described in dealing with the "subcutaneous cephalic commissure." There is ground to admit the presence of the dorso sub-lateral nerves in view of the fairly well marked development of the sub-lateral bands. Along the length of the body transverse nerve fibres run across the lateral bands, or run from one side to the corresponding sub-lateral bands.

Dorsal Nerve.—In latero-dorsal view of cleared specimens a very thin bundle of fibres is seen to start from the posterior margin of the nerve at the level of the dorsal band. These nerve fibres join the inner surface of the dorsal band after describing a slightly oblique course where they enter two ganglion cells. These cells represent the "dorsal ganglion." From the dorsal ganglion the dorsal nerve, which is very thin, runs along the inner surface of the dorsal band throughout its length.

Nerves of the Posterior end in the Female.

Ganglia Anal.—At the posterior end of the chyle intestine the ventral nerve (Figs. 58, 59, nrv. vtr.) is divided into two bundles of fibres, each one passing through a longitudinal group of ganglion cells, which correspond to the "Anal ganglia" (Figs. 58, 59, ggl. an.). These two ganglia diverge slightly posteriorly, and the cells are scattered and not very conspicuous. Posteriorly to the ganglion the bifurcations of the ventral nerve turn laterally and anteriorly, each describing an arc which joins the lumbar ganglia. "These arcs represent the "ano-lumbar commissure" (Figs. 58, 59, co. ano. lumb.).

Lumbar Ganglia.—In examining a clear specimen from the ventral side, two groups of nerve cells are seen, each adhering to the lateral bands on each side of the ano-rectal ligament. They represent the "lumbar ganglia." Each ganglion is about 64 μ long and consists of two pairs of cells, with an unpaired cell at both ends (Figs. 58, 59, ggl. lumb.). The ventro-lateral nerve enters this ganglion and then proceeds backwards. At the level of the anus two or three oval-shaped nerve cells are still seen enclosed in the same lateral nerve. The nerve ends at the caudal papillae (Figs. 58, 59, nrv. lat. v.). It may be mentioned here, that in the same ventral view of the worm, just behind the end of the genital tube, a rather conspicuous bundle of nerve fibres can be seen situated obliquely to the axis of the body and apparently running from the right ventral band to

the left. These fibres then run posteriorly for a short distance and enter into five or six large ganglion cells. From these cells a similar bundle of fibres is seen running towards the median line of the body. I am not in the position to say what they represent.

Rectal Ganglion.—The rectal ganglion is also well represented in *Haemonchus contortus* by six or seven conspicuous cells situated under the anterior nose-like protuberance of the pulvillum post analis, and consequently lying dorsally to the rectum (Figs. 58, 59, ggl. rct.). The cells are rather close together and form a well defined group. From both lateral sides of the anal ganglion a bundle of nerve filaments is sent to the rectal ganglion. This bundle of fibres represents the "ano-rectal commissure" (Figs. 58, 59, co. ano. ret.).

The Anal Ring.—From the anal ganglion and between the origin of the ano-rectal and ano-lumbar commissure a bundle of two or three nerve fibres starts independently, directed dorsally around the rectum and having the appearance of a well defined ring. Looss does not describe this ring in *Ankylostoma duodenale*, but it apparently corresponds to the structure in *Ascaris*, called the "Anal King" (Figs. 58, 59, an. ri.). Sometimes the nerve fibres of the anal ring are very numerous, forming a broad band. A few thin nerve fibres run along the dorsal wall of the rectum, connecting the anal ring with the rectal ganglion.

Dorsal Nerve.—In the rectal region the dorsal nerve is represented by a thin bundle of nerve fibres, which at the level of the anal muscle appears turned ventrally, joining a conspicuous nerve ganglion. This ganglion is situated dorsally to the anus and rather close to it. (Figs. 58, 59, ggl. nrv. d.).

Nerves of the Posterior End in the Male.

Anal Ganglia.—As in the female the ventral nerve is broad in its posterior portion. At the level of the anterior part of the rectum it bifurcates and on each side enters two ganglia situated on the ventral bands. The more anterior one is called the "Anal Ganglion" (Fig. 60, ggl. an.), and the posterior one the "sub-Anal Ganglion" (Fig. 60, ggl. suban.). These two ganglia can easily be confused with neighbouring structures and their presence is not always detected. Proceeding from each sub-anal ganglion is a thin nerve lying along the ventral wall of the cloaca, corresponding to the "Terminal Nerve" (Fig. 60, n;v. term.).

Lateral Ganglia.—At the level of the base of the spicule the ventro-lateral nerve is seen lying along the ventral side of the lateral band. In its posterior course three successive ganglia are found. The more anterior is called the "lumbar ganglion" and is found at the level of the anterior end of the gubernaculum (Fig. 60, ggl. lumb.). Viewed dorsally it is covered by the musculus sedator gubernaculi. It is composed of two or three cells, the more dorsal one being the largest. This cell is oval shaped, measures about 28 μ m in its widest part, and contains a distinct nucleus. By the side of the ano-lumbar commissure (*vide infra*), two other strong nerves take origin from the lumbar ganglion, and are directed posteriorly and medially. The next is the "post-lumbar ganglion," It

is situated at about the level of the pre-bursal papilla, and consists of six or seven oval cells adhering to the lateral bands (Fig. 60, ggl. post-lumb.). The more posterior ganglion is called the "Costal ganglion." It is seen on the base of the main trunk of the bursa and sends nerves to the lateral and dorsal region (Fig. 60, ggl. cost.).

The Ano-Lumbar Commissures.—The anal ganglia are connected with the lumbar ganglia by two commissures. The more anterior is the "Ano-Lumbar Commissure," connecting each anal ganglion with the lumbar ganglion of the same side (Fig. 60, co. ano. lumb.). It is rather short and describes in its course a slight posterior convexity. The second one is the "Sub-Ano Post Lumbar Commissure," connecting the sub-anal ganglion with the respective post lumbar ganglion (Fig. 60, co. suban. post-lumb.). The posterior convexity described by these commissures is quite distinct, and about midway a nerve starts posteriorly directed to the ventral rays of the bursa (Fig. 60, nrv. v. ray.).

Rectal Ganglion.—In the dorsal view of a cleared specimen the rectal ganglion is rather conspicuous. It is situated slightly anteriorly to the gubernaculum above the spicular canal, and has a typical horse-shoe formation (Fig. 60, ggl. rct.). It appears to be composed of four ganglion cells pressed rather close together. It is connected on each side by a conspicuous bundle of fibres proceeding to the pair of anal ganglia. These fibres represent the "ano-rectal commissure" (Fig. 60, co. ano ret.). Sometimes I found the ano-rectal commissure directed posteriorly (Fig. 60) from the anal ganglion instead of anteriorly. This fact is explained by displacement of the spicular apparatus.

Sub-Rectal Ganglion.—This ganglion was not very distinct, but two bundles of thin nerve fibres were seen starting from each side of the anal ganglion (Fig. 60, co. ano sub. ret.). These fibres correspond very closely to the similar structure identified by Looss as the "Ano Sub-Rectal Commissure" of the *Ankylostoma duodenale*.

Excretory Apparatus.

The excretory pore is found in the ventral side of the body, situated between the two divergent parts of the cephalic ventral ganglion (Fig. 57, p. ex.). On the cuticle it appears like a small opening surrounded by a round, flat area, where the anular striations of the skin are missing. The excretory vesicle can hardly be seen in fixed specimens, even in those cleared in glycerine, and it appears always deformed (Fig. 57). In living worms, or worms freshly killed, examined in water between a slide and a cover glass, a pear-shaped vesicle about 250μ long appears quite clearly on lateral view, and is connected by the thin anterior end with the excretory pore, running nearly parallel to the walls of the body between the ventral band and the oesophagus. At the posterior end it receives the two different ducts of the cervical glands. The degree of expansion of this vesicle varies in different specimens and sometimes it is found contracted to such an extent that it appears as a thin line.

Bridge of the Excretory Apparatus.—In glycerinated specimens observed in ventral view a spindle-shaped deviation from the ventral side of the

lateral band is seen just anteriorly to the nerve ring. In fresh specimens observed in lateral view it is also possible to distinguish a strand of fibres connecting the above spindle-shaped body and reaching the ventral band at the level of the excretory pore. It appears that the spindle-shaped body and the fibre-like strand represent the "suspensory cell of the excretory apparatus" described in the *Ankylostoma duodenale* by Looss. In addition the "carrying cell of the excretory vesicle," and the "carrying cell of the cervical glands" described by the same author, appear to be represented by a granular mass surrounding the excretory vesicle.

The body of the cervical glands starts anteriorly at the level of the angle formed by the cervical papillae and the body walls. The anterior end is smooth and round (Fig. 57, gl. cerv.). The first portion of the cervical glands is rather thick, slightly compressed dorso-ventrally and occupying nearly all the space between the oesophagus and the ventral walls of the body (Fig. 45, gl. cerv.). At the level of the thicker part of the oesophagus the glands are reduced in diameter by the pressure of that organ. Proceeding posteriorly the diameter of the glands lessens until about midway. The posterior half of the gland gradually increases in diameter and then decreases, assuming roughly a lancet shape. The right gland is usually slightly thicker than the left one. The nucleus lies at the level of the largest diameter of the posterior portion. The total length of the gland varies from 3.7-4 mm. In the female the cervical glands are frequently seen to be slightly shorter than they are in the male. The right gland exceeds the length of the left one by a few hundred microns. Throughout their length the cervical glands lie free in the coelomic cavity, kept in a latero-ventral position by the pressure of the intestine, and separated from each other. The pointed posterior tip of the gland is adherent to the ventral walls of the intestine. This fact can be clearly seen on cutting a fresh worm just posteriorly to the oesophagus and placing the specimen on a slide with some drops of water. As soon as the two pieces of the body are separated the chyle intestine in the posterior portion of the specimen protrudes for some distance from the coelomic cavity. The posterior portions of the cut cervical glands are then seen to lie free in the water except for the adherence of the posterior tip.

Peripheral Excretory Canals.—These two canals wind along the ventral portion of the lateral band. The anterior portion of each canal starts from the head and ends in the excretory vesicle at the level of the excretory bridge (Figs. 43-44, ex.). The posterior portion forms a common junction with the anterior portion before reaching the excretory vesicle, and ends posteriorly at the level of the anus in the female and at the base of the bursa in the male (Figs. 46-47, ex.). The connection between the excretory canals and the excretory vesicle is difficult to detect. Fresh specimens are better for this purpose than those cleared in glycerine.

Cephalic Glands.—The excretory canal of the cephalic gland does not appear distinct in glycerinated specimens. In living or freshly killed worms, it appears as a thin clear canal opening through a small hole in the neighbourhood of the lateral cephalic papillae. The excretory canal surrounded by a granular strand of the cephalic gland, increasing in thickness posteriorly, and compressing the substance of the lateral bands.

In the precerebral portion, the cephalic glands are bean-shaped in cross section. They measure about 9μ by 4μ , and are situated between the two bridges of the lateral bands and the oesophagus (Fig. 43, gl. ceph.). Just behind the nerve ring the cephalic glands compress the lateral bands. At this point they measure 16μ , in diameter and are uniformly granular (Fig. 45, gl. ceph.). More posteriorly they are reduced considerably by the pressure of the oesophageal end. The nucleus of the cephalic gland is situated just behind the base of the cervical papilla. In the male the nucleus is about 28μ long, 16μ broad, and is somewhat darker than the surrounding tissue (Fig. 45, nu. gl. ceph.). Between the oesophagus and the genital tube, the cephalic gland increases in size, reaches 14μ in diameter and presses against the pulp of the lateral bands. Proceeding backwards the granular body of the cephalic gland steadily decreases in size. It was not found possible to detect any traces of the cephalic gland in cross sections made at, or beyond, the level of the seminal vesicle in the male or the initial ovarian spiral of the female.

P L A T E S .

- Fig. 1. — Egg of *Haemonchus contortus*, taken from the distal portion of the uterus of a young worm preserved in glycerine (380 diam.).
- Fig. 2-3. — Eggs of *Haemonchus contortus*, taken from the distal portion of the uterus of a well-grown worm preserved in glycerine (380 diam.).
- Fig. 4. — Egg of *Haemonchus contortus*, taken from the median portion of the uterus of a well-grown worm preserved in glycerine (380 diam.).
- Fig. 5. — Egg of *Haemonchus contortus*, taken from the proximal portion of the uterus of a well-grown worm preserved in glycerine (380 diam.).
- Fig. 6. — Egg of *Haemonchus contortus* (11-cell stage), from the stomach contents of an infected sheep (380 diam.). Note the four ectoderm cells of the right side disposed in the form of a cross.
- Fig. 7. — Egg of *Haemonchus contortus* (26-cell stage), from the stomach of an infected sheep (380 diam.). Note the eight ectoderm cells of the right side disposed in the form of a rosette.
- Fig. 8. — Egg of *Haemonchus contortus* at "morula stage," from fresh faeces of a sheep (380 diam.).
- Fig. 9. — Egg of *Haemonchus contortus* between the morula and the tadpole stage. Dorsal view. From faeces of a sheep a few hours after having been passed. Ambient temperature 18° C. (380 diam.).
- Fig. 10-11. — Eggs of *Haemonchus contortus* at "tadpole stage." In Fig. 10 the embryo is seen in lateral view. In Fig. 11 the embryo appears more developed, and is seen in latero-ventral view. Both eggs from faeces of a sheep 10 hours after having been passed. Ambient temperature 18° C. (380 diam.).
- Fig. 12-13. — Eggs of *Haemonchus contortus* with the embryo about two or three times the length of the egg-shell. From faeces of a sheep fifteen hours after defaecation. Ambient temperature 18° C. (380 diam.).
- Fig. 14. — Egg of *Haemonchus contortus* with "mature embryo." From faeces of a sheep eighteen hours after having been passed. Ambient temperature 18° C. (380 diam.).
- Fig. 15. — Newly hatched larva of *Haemonchus contortus*. Killed with hot water (380 diam.).
- Fig. 16. — Larva in the first stage. External view, lateral aspect. The larva is magnified by 380, while the lateral line is seen with a magnification of 1400 diam.
- Fig. 17. — Larva in first lethargus (380 diam.).
- Fig. 18. — Larva in the first ecdysis, casting off the old skin. From a living worm in a culture with liquid medium. The tail of the old skin is hooked and attached to small solid particles at the bottom of the culture; the body of the larva is "whipping" in the liquid medium (380 diam.).
- Fig. 19. — Larva in the beginning of the second stage, lateral view, from specimen killed with hot water (380 diam.).
- Fig. 20. — Larva just before the second lethargus. From a living worm in a liquid medium. External appearance. Lateral view. The lateral line is slightly exaggerated in breadth, and is drawn as it was seen in a magnification of 700 diam. The larva is magnified by 380.
- Fig. 21. — Mature larva, after about a week of maturity. The larvae were grown in faeces, and attained a maximal length. The more external line represents the old skin (380 diam.).
- Fig. 21A. — Transversal section of a mature larva, made in the anterior portion of the chyle intestine. The section was made by the freezing process (1600 diam.).

- Fig. 22.— Mature larva two months old and still alive, collected on the walls of a jar, where the moisture was rather scarce. Note the signs of age, viz., contraction of the larva, decrease of granulations, and appearance of vacuoles in the chyle intestinal cells, disappearance of the internal structure (380 diam.).
- Fig. 23.— Mature larvae preserved in ice for three and a half months, and found dead—The outer skin is almost completely filled by the larva. The chyle intestinal cells are replaced by vacuoles, and the internal structure has disappeared (380 diam.).
- Fig. 23A.— Culture of larvae in a jar. The colony of mature larvae is seen on the walls in ascending migration.
- Fig. 24.— Anterior end of a larva in the parasitic part of the third stage (first parasitic stage), just before the third lethargus (1600 diam.).
- Fig. 25.— Posterior end of a larva in the parasitic part of the third stage (first parasitic stage), just before the third lethargus (1100 diam.).
- Fig. 26.— Larva casting the old skin at the completion of the third ecdysis (150 diam.).
- Fig. 27.— Anterior end of a larva in the beginning of the fourth stage (second parasitic stage). The thickness of the head cuticle is somewhat exaggerated (1600 diam.).
- Fig. 28.— Posterior end of a larva at the beginning of the fourth stage (second parasitic stage) (1400 diam.).
- Fig. 29-30.—Posterior end of the male and female in the fourth stage, three days after infection of the host. To illustrate the first structural differences appearing in the distinction of the two sexes.
 Fig. 29.—Male (180 diam.).
 Fig. 30.—Female (95 diam.).
- Fig. 31-32.—Posterior end of male and female in the fourth stage, 4-5 days after infection of the host. To illustrate the development of the genital rudiment and the difference in the tail.
 Fig. 31.—Male. The posterior end does not yet appear bilobated. The lateral lobes of the bursa are not yet defined (180 diam.).
 Fig. 32.—Female (100 diam.).
- Fig. 33-34.—Posterior end of male and female in the fourth stage, 6-7 days after infection of the host.
 Fig. 33.—Male. Posterior end of the body bilobated. Outlines of the bursa distinct. Genital tube reaches the cloaca (100 diam.).
 Fig. 34.—Female (180 diam.).
- Fig. 35.— Anterior end of female just before the fourth lethargus. Nine days after infection of the host (1040 diam.).
- Fig. 36.— Nine to ten days after infection of the host. Anterior end of female in the fourth ecdysis. The old skin is separated from the body (1040 diam.).
- Fig. 37.— Portion of the body of a female in the region of the vulva (fourth ecdysis). The old skin is separated from the body (140 diam.).
- Fig. 38.— Posterior end of a female in fourth ecdysis (300 diam.).
- Fig. 39.— Posterior end of a male in fourth ecdysis. Nine to ten days after infection of the host. The old skin is already detached, but not separated from the body (560 diam.).
- Fig. 40.— Adult male preserved in glycerine. From the ventral side (12 diam.).
- Fig. 41.— Adult female preserved in glycerine. From the left side (12 diam.).
- Fig. 41A.— Portion of a ventral muscular quadrant showing the connection of the muscular cells of two neighbouring rings (260 diam.).
- Fig. 42.— Longitudinal section of the head of an adult male preserved in glycerine. The section is made through the median line of the dorsal lip and the ventral cephalic papilla of the right subventral lip (1700 diam.).
- Fig. 43.— Section through the body of a male at the anterior end of the oesophagus (600 diam.).
- Fig. 44.— Section through the body of a male at the anterior edge of the nerve ring. The cell of the dorsal ganglion was drawn from a posterior section (600 diam.).

- Fig. 45.— Section through the body of a male at the base of the cervical papillae (600 diam.).
- Fig. 46.— Section through the body of a male at the level of the seminal vesicle (250 diam.).
- Fig. 47.— Section through the body of a male at the level of the anterior portion of the gubernaculum (250 diam.).
- Fig. 48.— Left ventral lobe of the bursa seen from the internal surface (130 diam.).
- Fig. 49.— Section through the left lateral lobe of the bursa at the level of the origin of the asymmetrical dorsal lobe (250 diam.).
- Fig. 50.— Section through the left lateral lobe of the bursa at the level of the tip of the externo-dorsal ray (250 diam.).
- Fig. 51.— Section through the body of a female in the last portion of the anterior ovary (180 diam.).
- Fig. 52.— Genital tubes in a female in the region of the vulva. The anterior uterus and ovijector, the unpaired tube, and the vagina show the internal structure. The posterior ovijector and uterus show the external muscular coat. The two punctated lines mark the course of the intestine (90 diam.).
- Fig. 53.— Section through the body of a female, midway through the anterior uterus (180 diam.).
- Fig. 54.— Section of the anterior portion of the "pars haustrix" (180 diam.).
- Fig. 55.— Section of the posterior portion of the "pars ejectrix" (180 diam.).
- Fig. 56.— Section of the female at the base of the linguiform process of the vulva (180 diam.).
- Fig. 57.— Nervous system in the anterior end of the body. Left latero-ventral view. From a female 18 days old and 17 mm. in length (320 diam.).
(In calculating the distance between the different structural details the perspective should be taken into consideration).
- Fig. 58.— Nervous system in the posterior end of the body of a female, lateral view. From a specimen of about the same age and length as used in Fig. 57 (320 diam.).
- Fig. 59.— Nervous system in the posterior end of the body of a female, ventral view. From a specimen similar to that used for Fig. 57 (320 diam.).
- Fig. 60.— Nervous system of the posterior end of the body of a male, dorsal view. From a specimen as used in Fig. 57.

NOTE.— All the plates were drawn by the Abbe apparatus with Bernard table, and the magnification in diameters calculated by the same apparatus.

C H A R T S .

- Charts No. 1-2.— Showing the effect of low temperature on the migration of larvae (see Thigmotropism of larvae—Temperature).
- Chart No. 3.— Showing the effect of changes in diffused light on the migration of larvae (see Phototropism of mature larvae—Changes in diffused light).
- Chart No. 4. — Showing the effect of cloudy weather on the migration of larvae (see Phototropism of mature larvae—Changes in diffused light).
- Charts No. 5-18.— Showing the migration of a colony of mature larvae under the alternating effect of day and night, and the final passage in the ground.

NOTE.— The Charts Nos. 1-18 are reduced to one-fourth from the original drawings.

————— = Level of the culture of faeces.
 --- = Curve of the colony between sunset and sunrise.
 - - - - - Curve of the colony in the day time.
 ||||| = Scale in centimetres.

REFERENCE LETTERS.

- an. = anus.
 an. ri. = anal ring.
 ant. ov. = anterior ovary.
 ant. ut. = anterior uterus.
- b. dors. = dorsal band,
 b. lat. = lateral band,
 b. sub. = sublateral band.
 b. vent. = ventral band,
 buc. lan. = buccal lancet,
 burs. = bursa.
 burs. d. lob. = dorsal lobe of the bursa,
 burs. l. lob. = lateral lobe of the bursa.
- c. adv. 1. = adventitious cells fixing the nerve ring to the lateral bands.
 c. adv. v. = similar cells connecting the nerve ring with the ventral band.
 c. 1. lig. ret. = cells of the anterior ring of the rectal ligament.
 c. v. ex. = cell containing the vesicle of the excretory system.
 can. spic. = spicular canal.
 chit. = longitudinal chitinous rod of the skin.
 chit. = chitine.
 chit. arc. 1. = anterior curvature of the walls of the mouth.
 chit. arc. 2. = posterior curvature of the walls of the mouth.
 chit. br. = bridge between the walls of the mouth and the walls of the body.
 clo = cloaca.
 co. C3ph. = cephalic nerve commissure (nerve ring),
 co. ceph. vtr. lat. 2. = internal cephalic commissure,
 co. ceph. vtr. postlat. = ventro post-lateral commissure,
 co. suban. = subanal commissure.
 coel. = coelomiarian muscular cell of the somatic muscular coat,
 cut. ext. = external cuticle,
 cut. int. = internal cuticle.
- drs. lob. = dorsal lobe of the bursa.
 drs. r. = ray of the dorsal lobe of the bursa.
 drs. marg. = dorsal margin of the lateral lobes of the bursa.
- ex. = excretory canal.
 ex. drs. r. = externo-dorsal ray.
 ex. gl. cerv. = excretory ducts of the cervical glands,
 ex. l. r. = externo-lateral ray.
- f br. marg. = marginal fibres of the oesophagus.
- ge. co. = genital cone.
 ggl. an. = anal ganglion.
 ggl. ceph. 1. = lateral cephalic ganglion.
 ggl. ceph. postlat. = post-lateral cephalic ganglion.
 ggl. ceph. v. = ventral cephalic ganglion.
 ggl. cost. = costal ganglion.
 ggl. dors. = dorsal cephalic ganglion.
 ggl. lumb. = lumbar ganglion.
 ggl. nrv. d. = ganglion in "the course of the dorsal nerve between the two portions
 of the anal muscle,
 ggl. nrv. ry. = ganglion of the nerve of the ventral rays,
 ggl. ret. = rectal ganglion.
 ggl. sec. = secondary ganglion in the course of the ventro-lateral nerve,
 ggl. suban. = subanal ganglion,
 gl. cem. = cement gland.
 gl. cem. 1. = anterior portion of the cement gland,
 gl. cem. 2. = posterior portion of the cement gland,
 gl. ceph. = cephalic glands,
 gl. cerv. = cervical glands.

gl. dors. 1. = lateral stem of the dorsal oesophageal gland,
 gl. dors. m. = median stem of the dorsal oesophageal gland,
 gl. oes. subv. = subventral oesophageal glands,
 gn. pr. = genital primordium.
 gr. 1. p. ejec. == external granular layer of the "pars ejetrix."
 gr. 1. p. h. = external granular layer of the "pars haustrix."
 gr. tiss. = granular tissue.
 gran. cut. = deposit of granular masses within the internal layer of the skin,
 gub. = gubernaculum.

int. = intestine.
 int. gib. = internal gibbosity of the lateral lobes of the bursa,
 int. gr. = internal groove of the lateral lobes of the bursa,
 int. 1. p. ejec. = internal lining of the "pars ejetrix."

1. lat. = lateral line.
 1. vulv. = lips of the vulva.
 lat. ves. = lateral vesicles of the linguiform process of the vulva.
 lig. rect. = rectal ligament.
 lin. proe. = linguiform process of the vulva.
 It. ven. r. = latero-ventral ray.
 In. oes. = oesophageal lumen.

m. an. = anal muscle.
 m. bas. burs. = basal muscle of the bursa,
 m. burs. = bursal muscles,
 m. cap. = mouth capsule,
 m. cav. = mouth cavity.
 m. ceph. oes. a. = anterior cephalo-oesophageal muscle.
 m. ceph. oes. p. = posterior cephalo-oesophageal muscle.
 m. cost. lat. ext. ant. = anterior externo-lateral costal muscle.
 m. cost. 1. ext. post. = posterior externo-lateral costal muscle.
 m. cost. 1. ext. post r.i. = inner branch of the letter muscle.
 m. cost. 1. int. = interno-lateral costal muscle.
 m. p. ejec. = musculature of the "pars ejetrix."
 m. p. h. = musculature of the "pars haustrix."
 m. sed. gub. = muscle "sedator gubernaculi."
 m. som. = somatic muscles.
 m. sup. gub. = supinator muscle of the gubernaculum.
 m. vag. = muscles of the vagina.
 ma. drs. / ma. ven} = dorsal and ventral margins of the lateral lobes of the bursa
 marg. or. = mouth opening.
 md. exs. spic. — exertor muscle of the spiculae.
 mu. oes. = oesophageal muscles.

- pap. caud = caudal papilla.
 pap. cerv. = cervical papilla.
 pap. dors. = dorsal cephalic papilla.
 pap. lt. ven. r. = terminal papilla of the latero-ventral ray.
 pap. preab. = prebursal papilla,
 pap. v. = ventral cephalic papilla.
 pars. ejec. 1 = sphincter like portion of the " pars ejetrix."
 pars. ejec. 2 = cylindrical portion of the " pars ejetrix."
 pars. h.l = one of the four anterior cells of the " pars haustrix."
 plat. = platymyarian muscular cell of the somatic muscular coat.
 proc. mu. = muscular processes.
 ps. l. r. = postero-lateral ray.
 pul. ray. = pulpa of the rays of the bursa.
 pulv. = pulvillum postanalís.
- ret. = rectum.
- rid. int. gr. = ridge of the internal groove of the bursa,
- spic. = spicula.
- sup. f. = superficial nerve fibres of the " commissura cephalica."
- te. = testicular tube.
- tru. l. lob. = common trunk of the rays of the lateral lobes of the bursa,
 tru. ven. r. = common trunk of the ventral rays of the bursa.
 u. part. = unpaired part of the genital tube of the female,
 ut. = uterus.
 v.s. = seminal vesicle,
 vag. = vagina.
 ven. mar. = ventral margin of the lateral lobes of the bursa,
 ven. ven. ry. = ventro-ventral ray.
 vulv. = vulva.