fibrous membrane more than a quarter of an inch thick, so that it was quite difficult to penetrate it and commence its separation from the lung. The separation once started, however, its tough layers of newly-forming fibrous tissues were peeled off and torn away until the lung was freed. By the end of the operation the lung had so far expanded as to fill two-thirds of the cavity. A complete re-expansion of the lung followed in the subsequent days, the patient aiding in this by blowing bubbles. On February 13th, 1915 (two months after the operation), the wound had definitely healed and the patient had regained flesh and strength. When he stood upright with shoulders square there was no deformity to be seen from the front; from behind the spine was seen to be held quite straight, the only abnormality being a retracted scar below the right scapular angle. The man had already put on flesh, and was feeling well enough, after a short convalescence outside the hospital, to return to duty.

It is now recognized that the inflammatory fibrous tissue which covers the collapsed lung in empyema is formed in layers parallel to the surface of the lung from which in recent cases it is separable, so long as they are not tuberculous. Indeed the layer of this false membrane next the lung is vascular, containing newly formed blood vessels, and is loose in texture, as compared with the tougher outer layers. This inflammatory tissue forms a capsule within which the lung is confined in a state of pure atelectasis, but is capable of re-expansion when this capsule has been shelled off.

In this respect there is a marked contrast to the state of the parietal pleura in empyema. The parietal pleura is not only thickened and indurated, but the inflammatory induration is continued outwards in the subpleural connective tissue so that the parietal pleura becomes fused inseparably with the periosteum of the ribs and of the intercostal muscles. Hence in the operation of Estlander and Schede for the reduction of the cavity of an empyema the parietal pleura and intercostal tissues have to be removed with the ribs *en masse*. This operation leaves the compressed lung permanently inactive and useless, induces a deformity of the chest, and in young people a curvature of the spine supervenes with only one lung active. We are indebted for the discovery that the shelling out of the compressed lung from its inflammatory capsule is possible in recent non-tuberculous cases to Delorme, who described his operation of decortication of the lung in 1893. His method included the turning upwards of a large parietal flap so as freely to expose the capsule covering the compressed lung. This operation has been followed in a series of cases by a mortality from the operation of 15 per cent., which is much the same as the mortality after Estlander's operation. But Delorme's operation in its full extent is only needed for old-standing cases of empyema, although it has been reported that an operation combining removal of part of the chest wall with removal of the capsule compressing the lung was followed by re-expansion of the lung four years after the onset of the empyema.

For recent cases of empyema the essential thing is to sponge the cavity free from fibrin and pus, and then, by the finger, aided by sponges on holders, to seize portions of the capsule with forceps in order to free the lung. This can safely be done if the patient is given nitrous oxide gas with oxygen or air; as the lung is being freed a little ether will induce cough with which the lung will expand. The difficulty in children may be the occurrence of bronchopneumonia with the empyema. Then, after the pleural cavity has been cleared, the lung may be found free, but it cannot expand owing to consolidation. If the base of the lung is then drawn into the wound and fixed there by suture with a tube beside it leading into the cavity healing will soon occur.

In confirmation of the foregoing statements I may quote two cases of pneumococcal empyema recently in the Westminster Hospital.

A male, aged 32, was admitted with a left-sided empyema which had existed for about four months. At the first operation the pleural cavity was cleared of fibrin; a week later, the lung having shown no signs of re-expansion, it was freed from its capsule and fixed by a suture in the wound with a tube beside it. The patient was admitted on June 24th, 1914; he was shown to some American visitors on July 28th, with the lung fully expanded, and he was discharged on August 6th, soundly healed.

A female, aged 7, had right-sided bronchopneumonia and empyema of about a week's duration. After clearing out from the pleural cavity all pus and fibrin, the consolidated lung could be moved freely, showing no fibrinous covering, but it did

not expand with cough. The lower lobe of the solid lung was drawn forward and fixed by suture in the wound and a tube beside it into the pleural cavity. The child was admitted on February 2nd, 1915, and was soundly healed on March 15th following.

INSECTS AND WAR:

XIV.—THE MOSQUITO (*Anopheles maculipennis*).

BY

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(Continued from p. 590.)

"Amongst aquatic larvae, the most beautiful and delicate are those of numerous species of gnat."—Goring and Pritchard's *Micrographia*, 1837.

THE LARVA.

In the young larva of *Anopheles* the head is broader and deeper than the thorax, but in the older larvae the segments that succeed the head have at least twice its diameter. It is a characteristic of true flies, or Diptera, that the thorax should not exhibit that separation into three divisions which is so usual in the less specialized insects, such as the cockroach, and this is peculiarly true of the larva of the mosquito—at any rate, so far as its external structure goes. The abdomen of the larva consists of nine free segments; the third, fourth, fifth, sixth, and seventh of these bear palmate hairs, something like a hand with fourteen fingers spread out. These hairs adhere to the under layer of the surface film of the water, and help to maintain the animal in a horizontal position just below that film. When the larva relaxes its hold and sinks into the water, it not unfrequently carries with it air bubbles enclosed by these fourteen "fingers."

The eighth abdominal segment bears the stigmata or the openings of the respiratory apparatus, and the ninth segment has abandoned the flattened and square cross-section of its predecessors, and is cylindrical and tapering. The posterior end of the body is cut off sharply. Round the posterior opening of the alimentary canal are four white, soft papillae, which are well supplied with tracheae and are capable of contracting and expanding. Above these are four very prominent hairs, two median and two lateral, and ventrally to the ninth abdominal segment is a fan-shaped arrangement of hairs springing from two pieces of very complicated structures. These hairs seem to act to some extent as a rudder, and they probably serve as an accessory organ of locomotion. Possibly they have also a sensory or tactile function, and act, as so many posterior filaments do in insects, as antennae "from behind."

We have referred above to the respiratory openings, and, indeed, these are the key to the whole situation. Close these openings, as they can be closed by floating petrol or other oil on the surface of the water, and the trick is done. The larvae and the pupae can no further breathe, and there is no imago. In *Culex* (the gnat) these respiratory orifices are borne on a long tube directing dorsally—a tube which is larger and longer than a segment of the body, and whose presence gives the larva the appearance of a Y with slightly unequal limbs. These breathing-openings are of the greatest complexity, but the outstanding fact is that these stigmata pierce through the watery film and put the respiratory system of the larva into communication with the atmosphere of the whole globe. If anything frightens the larva, certain side pieces and flaps fold suddenly backwards and over the stigmata, the connexion through the surface film is broken, and the little larva, like a German submarine when it sights an English battleship, darts below, frequently carrying with it the drop of air attached to the rim of the respiratory recesses which surrounds the openings of the two stigmata.

Not unfrequently the larva ceases to lie parallel with the surface of the water, its palmate hairs are put out of action, and then its body hangs down into the water, but it still maintains its respiratory connexion with the outer air through these breathing pores. From time to time the hairs mentioned above are brushed over by the mouth organs and cleaned of any debris.

The larvae when they leave the surface film sink by their own weight, but they not unfrequently swim actively

downwards, their swimming action being very like that of an eel. When returning to the surface they are entirely dependent upon their powers of swimming, being slightly heavier than water. When the tail reaches the surface film they are at once arrested and immediately cease their swimming movements. The larvae invariably move tail forwards, and the hairs which we have mentioned above at the posterior end of the body undoubtedly act as "buffers" or "fenders." As a rule, when they are above they are actively engaged in feeding, but at the bottom they lay inert, as if feigning to be dead. Kept in a glass beaker they are apt to lie with their respiratory apparatus attached to the concave film, which capillary attraction draws up on the surface of the glass. Their heads then point towards the surface of the beaker. If forcibly kept below, say by submerging them under a watch-glass, they are frequently enabled to breathe by attaching the openings of their respiratory apparatus to an air bubble.

The general colour of the larva is a mottled brown, darkened where the chitin is thickened. The older larvae are to some extent green, possibly due to their food; but this green colour is not by any means confined to the alimentary tract. After moulting the issuing larva is a uniform light lavender colour, which, however, very soon darkens.

A strong wind passing over a pool where *Anopheles* eggs, larvae or pupae are floating, will gradually pile them all up on the side towards which it is blowing. The *Anopheles* larvae undoubtedly are braver than those of the *Culex*—that is to say, a disturbance which will send all *Culex* larvae to the bottom will leave the *Anopheles* larvae unmoved.

When first hatched the larvae measure somewhere about 0.07 to 0.095 mm., but when ready to pupate they have attained the length of 7 mm. The rate of development is greatly influenced by the temperature, and a few cold days will markedly retard the larval growth. In warm, sunny weather, larvae will pupate between the second and third week, but larvae taken in August (if the autumn be cold) do not attain their full growth until November. The young larvae undoubtedly die in considerable numbers, and the act of pupating is also undoubtedly attended with certain dangers. Out of 834 larvae and pupae caught in Cambridgeshire, 636 were small larvae, measuring less than 4 mm., 181 were large larvae, measuring up to 7 mm. But only 17 pupae were taken. There are other facts which show that the larvae in Nature succumb in very considerable numbers.

THE PUPA.

When the larva is about to turn into a pupa it comes to rest, and now the thoracic regions are more swollen than ever. Soon a dorsal slit appears along the larval cuticle and the pupa slowly but gradually emerges through this slit and leaves the larval chitinous cuticle behind it. On first emerging, the pupa measures about 6.5 mm., the head and thorax making up one-third of this. During the last larval stage many of the pupa organs have been re-forming and are more or less visible through the cuticle. The mouth parts and limbs of the third stage—the future imago—show no relation to those of the larva. They are there enclosed in their respective sheaths, but these are quite independent of the larval "appendages." The respiratory trumpets, which, as in the larva, pierce the surface film, are ready to act as breathing organs. Whereas the larvae breathe through two stigmata at the posterior end of the abdomen, the pupae breathe through two respiratory trumpets issuing from the anterior dorsal surface, and it is these trumpets together with certain palmate hairs which support the pupae in the right position and put the respiratory organs at this stage into communication with the outer atmosphere. During the pupa stage *Anopheles*, like the pupa of other insects, takes no food.

The pupa is something like the tadpole, with its tail flapping dorso-ventrally, and bent under its body, instead of from side to side. The whole pupa is enclosed in a thin semi-transparent membrane through which the organs of the adult can be readily seen. As it grows older its colour darkens. Until about the time when it will give rise to the fly, the pupa floats quietly at the surface, breathing through its respiratory trumpets. When disturbed it shows considerable activity, and it is by no means always easy to capture by means of a pipette. At

the least sign of danger it starts below with a series of intermittent strokes and rests at the bottom of the water. Its own buoyancy brings it back to the surface, as, unlike the larva, it is lighter than water. Not only has it a certain amount of air in its trachea, but there is a reservoir of air at the posterior end of the thorax which acts as a very efficient float. When retreating below the surface the respiratory trumpets usually carry down with them two minute air bubbles. As a rule the pupa stage lasts three or four days, but much depends upon the temperature.

The sex of the pupa can be determined by the lobes at the posterior end of the tail, A and B (Fig. 1) representing the male, and C and D the corresponding parts of the

Fig. 1.—A, Side view, B, ventral view, of the pupa of a male *A. maculipennis*; C and D, the same views of the female pupa.

female. The duration of the pupa life is generally three to four days, but conditions of temperature and the state of the natural surroundings exert considerable influence upon the rate of development. Howard has pointed out that the addition of creosote or creosote-oil to the water in which the larvae are living hastens the metamorphosis into pupae, and the pupa stage is passed through in as short a time as fifteen hours instead of the normal forty-eight hours of the warm waters of the southern States in America. It has also been observed that showery weather hastens the rate of development.

When the adult mosquito is about to emerge, a certain amount of air is secreted under the chitinous casing of the pupa. Fine streaks containing air appear along the back extending between the respiratory trumpets and the base of the head. This central streak gradually passes backwards until it reaches the seventh abdominal segment, and then suddenly the pupa extends its abdomen so that it floats parallel to the surface of the water instead of being under the rest of the body. The chitinous integument now splits along the median dorsal line, through the slit thus made the surface of the thorax protrudes. By gradually pressing its abdomen against the pupa-case, the body of the perfect insect is slowly but gradually raised above the surface of the water. The head is pulled backwards and upwards, and millimetre by millimetre the mouth parts, the palps and antennae are withdrawn, and at first remain bent backwards beneath the body of the insect. Gradually the bases of the wings and the abdomen emerge, and soon the wings are freed and immediately flatten out and begin to harden. The legs and the tip of the abdomen alone now remain to be dealt with. At this stage the insect projects far beyond the anterior end of the pupa encasement, and somewhat resembles an exaggerated figurehead on a ship. The pupa-case is still filled with air, and acts as a float to support the emerging insect. At last the front legs are being freed, the second and third pair of legs soon follow, and now the insect is standing on the surface of the water raised on its tarsal joints, the tip of the abdomen being the last part to free itself from the pupa-case.

Fig. 2.—Imago extracting itself from the pupa-case, which floats on the surface of the water. Magnified. From Guiard.

The exit of the fly is naturally a very critical period in its life-history, and in many cases it is fatal. The freeing process takes between five and ten minutes. When undisturbed the emergent fly rests for a time until its wings and limbs are sufficiently hardened to enable it to fly, or at least to walk about. Sometimes the mosquito takes its first flight straight from the pupa case; at other times it rests awhile before taking to the air. The young imago is pale in colour, the thorax being brown and the abdomen transparent, with a greenish tinge. At first the abdomen is much longer than it is later, for almost immediately after the mosquito's exit from the pupa-case its abdomen begins to contract and from its hinder end four or five drops of a white, glistening, greenish fluid are exuded.

The newly-born imago generally take to flight between five and ten minutes after they have emerged, and they at once begin to darken in colour, and in two hours assume the normal dusky colour of the adult. If anything hinders the insect from properly extending its limbs immediately on issuing from the pupa-case, the parts harden and remain distorted throughout life.

Anyone who has spent a day or two in Lille or Bruges, or other towns in Picardy and in Southern Belgium, will understand why, as my Uncle Toby has it, "Our army swore terribly in Flanders." The incessant and tireless biting of mosquitos would make any army swear, even though they were ignorant, as my Uncle Toby's army certainly was ignorant, that the gnats, as they called them, conveyed tertian and quartan ague. In Europe the trouble is a summer or early autumn trouble; but our troops are fighting in many tropical and subtropical countries, where the mosquitos—like the poor—are always with them.

That the plague can now be checked is shown by the making of the Panama Canal, and that this check is due to British science is shown by the work on the life-history of the malarial organism, first investigated by Sir Ronald Ross, and, as regard the human parasites, by certain Italian savants. It is also due to the public health services of one or two British medical officers of health in the East. Their methods have been applied and improved by those responsible for the channel which now separates North from South America.

We have seen that the larva and the pupa hang on to the surface film of the water by means of certain suspensory hairs, and by the openings of their breathing apparatus. Anything which prevents the breathing tubes reaching the air ensures the death of the larva and pupa, and then there is no issuing adult. Hence the use of paraffin on the pools or breeding places. It, or any other oily fluid, spreads as a thin layer over the surface of the pools and puddles, and clogs the respiratory pores, and the larvae or pupae die of suffocation.

In Ismailia the disease has been reduced to an amazing extent, and remarkable results have followed the use of these preventive measures at Port Swettenham in the Federated Malay States. Within two months of the opening of the port in 1902, 41 out of 49 of the Government quarters were infected, and 118 out of 196 Government servants were ill. Now, after filling up all pools and cleaning the jungle, no single officer has suffered from malaria since July, 1904, and the number of cases amongst the children fell from 34.8 to 0.77 per cent. The only melancholy feature about this wonderful alleviation of suffering due to the untiring efforts of the district surgeon, Dr. Malcolm Watson, is that his fees for attending malarial cases dropped to zero.

Thus, even ten years ago, a considerable degree of success had attended the efforts of the sanitary authorities, largely at the instigation of Sir Ronald Ross, all over the world, to diminish the mosquito plague. It is, of course, equally important to try and destroy the parasite in man by means of quinine. This is, however, a matter of great difficulty. In Africa and in the East nearly all native children are infected with malaria, though they suffer little, and gradually acquire a high degree of immunity. Still, they are always a source of infection; and soldiers stationed in malarious districts should always place their dwellings to the windward of the native settlements.

Knowing the cause, we can now guard against malaria; mosquito nets and wire-protected windows and doors are a sufficient check on the access of *Anopheles* to man. If the mosquito and man could only be kept permanently

apart, we might hope for the disappearance of the parasite from our fauna. In relieving man from this world-wide pest, all genuine lovers of animals will rejoice that we are also relieving the far more acute sufferings of one of the most delicate and beautiful insects that we know.

It has always been a source of surprise to me that the great resources and the very evident enthusiasm of the anti-vivisection societies have not been turned in this direction. In the malarial parasite we have a most potent vivisection of the entrails of one of the most charming and graceful of creatures, whose poetry of movement is hardly approached and never equalled by the ladies of the Russian ballet. A little help, a very little help, would free these fascinating flies from a form of trouble far worse than the human, alternative, host suffers. Yet as far as I know these societies and the societies for the prevention of cruelty to animals have declined to help in any way, and have knowingly allowed hundreds of millions of animals to perish annually by a most painful death and have never stretched out a helping hand to the fairy-like and fascinating mosquito.

ON THE CURVE OF THE EPIDEMIC.

BY

JOHN BROWNLEE, M.D., D.Sc.

In the issue of the JOURNAL for March 27th Sir Ronald Ross published a preliminary communication on the theory of the form of epidemics and allied subjects from a very interesting point of view. My work, as he says, has developed on different lines. As in the immediate future I shall have little time to extend the investigation, I wish to state the conclusions I have come to since my last published paper.¹

Though I have never denied that an epidemic might not end by lack of susceptible persons (the epidemic of small-pox in Boston, U.S.A., 1721, is a marked instance of this), yet I have hitherto been of the opinion that the loss of infecting power on the part of the organism is much the most potent factor in determining the end of an epidemic. This opinion has been based on three grounds: (1) The form of the curve of the epidemic; (2) the variation in infectivity of the organisms of certain diseases (of which measles and small-pox are prominent examples) between epidemic and interepidemic times—this, I think, is proved by observation; (3) the nature of space distribution of an epidemic—for example, the last great epidemic of small-pox in London in 1901, which had a well-marked centre of great prevalence, from which the amount of disease radially decreased. Sir Ronald Ross's notes demand that my arguments on the first count should be reconsidered.

I have formed a general epidemic equation by means of which any conceivable law can be reduced to an approximate mathematical formula and tested against the facts. The general equation is obtained as follows: Let there be an amount of disease y at any period of time; after a unit of time equivalent to the incubation period, let there be $y + \Delta y$: let $\frac{y + \Delta y}{y}$ be called the infectivity at t , t being counted from the commencement of the epidemic. This will be some function of the time, say $f(t)$. Then $\frac{y + \Delta y}{y} = f(t)$.

On the assumption that the law holds also for small fractions of this time, the equation becomes

$$1 + \frac{\Delta y}{y} = (f(t))^{dt}$$

or $1 + \frac{\Delta y}{y} = 1 + \log f(t) dt + \text{terms in higher powers of } dt$. So that in the limit $\frac{1}{y} \frac{dy}{dt} = \log f(t)$.

The most easily imagined cases are as follow:

1. That the infectivity of the organism decreases in a geometrical progression—that is, let $f(t) = e^{a-bt}$, then $\frac{1}{y} \frac{dy}{dt} = a - bt$ and $y = Ce^{at - \frac{1}{2}bt^2}$, C being a constant.

This is the normal curve of error, and represents the form of the epidemic curve given by Farr in 1866, though he did not state it in an equation, but as a relationship between the successive numbers in the epidemic wave. It