Notes on the Biology of some of the More Common Queensland Muscoid Flies.

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The main object of the present paper is to place on record the results of a series of observations which aimed at determining the duration of the various stages of the life-cycle of some of the common Queensland Muscoid flies. Amongst those dealt with are the housefly; a number of blowflies including certain sheep maggot-flies; some species of *Sarcophaga* and *Musca*; and the stable fly *Stomoxys*.

Observations were recorded regarding the following:—Length of time taken by the egg to hatch; period during which the larva fed; time intervening between the cessation of feeding and the undergoing of obvious pupation (larval resting period or prepupal stage); length of time passed in the pupal condition; time elapsing between the deposition of a larva or egg and the emergence of the imago resulting from such larva or egg; the period between emergence and sexual maturity of the female as evidenced by the act of copulation (maturation period); time between emergence of the female and oviposition by it (preoviposition period); longevity of the adult in captivity.

The egg period was always obtained by observing the fly actually ovipositing and watching till the eggs hatched, the time being noted in hours. No attempt was made to ascertain the length of time passed in the various larval instars. The resting period was regarded as commencing when the larvæ began to leave their food material and to wander. This wandering is a marked characteristic of some of the species—e.g. *Lucilia* larvæ are capable of travelling many yards from the place of feeding until they find a suitable patch of soil in which to pupate; while *Chrysomyia albiceps* and *Sarcophaga* spp. likewise may wander for a considerable distance; on the other hand *Ophyra nigra* generally bores into the soil directly beneath, or in close proximity to, its feeding place.

Male flies appear to be sexually mature soon after emergence from the puparium, but females usually take some time

to reach maturity, the time being reckoned as from the date when copulation was observed to occur, as this no doubt takes place soon after the flies are mature. The determination of the length of adult life of the various flies, as recorded in this paper, is not very satisfactory since the insects had necessarily to be kept in confinement from the time of their emergence. Food, temperature, moisture, etc., all influence this period.

There are unfortunately numerous blanks in the tables given in this paper, some of them owing to the fact that a number of the flies would not copulate in captivity, though they were flying about in a large room with abundant bright and shady places in it. During the summer it was found possible to carry out monthly observations, but this could not be done in the winter, owing to the difficulty of obtaining suitable species when needed. As the length of the various periods in the case of *Lucilia* was ascertained to be fairly constant during the several winter months, it has been considered sufficient in most cases to record observations during the winter period (May to September) without specifying any particular months.

A curious fact noted was that while *all* the species of carrion-flies could be obtained during any month yet many species had a period during which they gradually increased in numbers relatively and eventually predominated over the other species.

The observations to be referred to, unless otherwise stated, were carried out in Brisbane from the beginning of September 1920 till the end of August 1921, i.e. a full year. Some observations made by Miss Bancroft in Eidsvold (Upper Burnett River) and in Brisbane during 1919 and early in 1920, in connection with work carried out in collaboration with the senior author, are included. Certain data presented in this paper were briefly referred to in an article by one of us last year (Johnston 1921).

Froggatt and Froggatt (1916, p. 9) have published a statement regarding the average number of eggs found in the ovaries of various blowflies in New South Wales. The larval stages of some of the flies referred to in this paper have been described recently by Sinton (1921), while short accounts were published some years ago by Messrs. W. W. and J. L. Froggatt. The dipterous larvæ which produce myiasis in man and domesticated animals have been reviewed by Patton (1921).

Lucilia sericata Meigen.

The fly to which this name is attached in Australia is very common during summer, being prevalent in the vicinity of houses. It is frequently seen in winter in Queensland, increasing in numbers gradually until it becomes the dominant blowfly in December. It is one of the sheep maggot-flies. Froggatt (1921, p. 812) has referred to its prevalence in New South Wales.

It is almost certain that more than one species is included under this name in Australia. The bronze-coloured forms so commonly met with are not necessarily specifically distinct from the bright-green individuals, as both may be found amongst the progeny of one female. The British Museum contains specimens with this specific designation from Melbourne, as well as from India, Egypt, South Africa, Great Britain, etc. One of the New Zealand sheep blowflies is identified as belonging to this European species.

LUCILIA SERICATA.

Periods.	January.	February.	March.	April.	May to September.	October.	November.	December.
Egg (hours) ..	16–17	16–17	16–17	18	24	20–22	16–23	16–22
Larval feeding (days)	4–5	4–5	4–5	5	5–6	5	4–6	4–5
Larval resting ..	3	2–5	2–7	3	5–22	4–5	3–5	3–5
Total larval ..	7–8	6–13	6–8	8–9	12–29	9–10	8–9	8–10
Pupal ..	7	6–8	6–8	7–8	11–17	7	7	6
Egg deposition to emergence of adult	13–16	12–16	14–16	15	26–28	15	12–13	12–16
Maturation ..	6–7	6–9	6–7	6–10	8–10	8	6–8	6–8
From emergence to oviposition	8–9	8–10	8–11	8–11	12	10	8–10	8–16
Adult longevity ..	25–35	12–25	12–36	28	20–29	..	15–35	15–36

In all tables in this paper the egg period is given in hours and the remaining periods in days unless otherwise indicated.

The egg period is generally between 16 and 17 hours in summer. The larval feeding stage usually occupies from 4 to 5 days except during winter when it takes 5 or 6; while the larval resting stage is generally 3 to 4 days in summer and

7 to 10 in winter. The pupal period is usually 7 days except during winter months when it may be twice as long. The time elapsing between the deposition of the egg and the emergence of the fly is generally about 13 days during summer, 15 days in spring and autumn, but considerably longer in winter. Generally about 8 days elapse between emergence of the adult and its subsequent oviposition. Longevity in captivity is usually about 20 days. Copulation may occur whilst on the wing and last only a few seconds or it may take place while the insects are resting and is then prolonged.

Froggatt (1913, pp. 25, 29) mentioned that in New South Wales eggs hatched out within a day (six hours in December) after having been laid ; that maggots were fully fed on meat in 6 or 7 days after hatching, pupating in the soil beneath ; and that flies emerged on the sixth day after commencement of pupation. The period from oviposition to emergence was thus about 12 or 13 days in summer, which corresponds with our observations in Brisbane during summer. In an earlier paper (1905, p. 17) he had stated that the larval stages occupied about a fortnight.

A series of observations regarding the pupating habit of this fly was published recently by us (J. & T. 1921, pp. 114-5 ; 1922, p. 130).

Bishopp and Laake (1915, p. 473) as a result of observations at Dallas, Eastern Texas, reported that hatching required from less than 24 hours to 7 days; the larval period 4 to 9 days in summer, but from 3 to 4 months during late autumn and winter ; the pupal period about 5 days in summer but from 24 days to 5 months in winter ; the total developmental period 11 to 15 days in summer increasing to from 4 to 6 months during late autumn and winter ; longevity of adults in captivity 10 to 40 days ; emergence to egg-laying 4 to 21 days.

Bishopp, Mitchell, and Parman (1917) recorded that *L. sericata* appeared during the warmer days of spring and persisted through the summer in U.S.A., where it took about as long to pass through its development as did the common black wool-maggot fly, *Phormia regina* Meigen, viz. about 11 to 15 days from egg to emergence of the adult fly.

In regard to a related fly, *Lucilia cæsar*, Herms (1915) stated that the egg period was from 6 to 48 hours ; the larval feeding stage 3 to 7 (generally 5) days ; the larval resting or prepupal stage usually 6 ; the pupal 8 to 34 (commonly 12) days ; the total number of days elapsing betw♀n egg deposition and

emergence of the adult fly being from 16 to over 60 days, generally 24 days ; and the average longevity of the fly about 30 days. Pierce (1921, p. 132) mentioned that the larval period averaged 14 days and the pupal about the same length, but that in warm weather in Texas the larval stage occupied 3 to 12 days and the pupal 5 to 16 days while the total development (to emergence) required 11 to 24 days. Bishopp (1915, p. 323) stated that in Eastern Texas incubation required less than 24 hours in summer but up to 7 days in winter ; the larval stage 3 to 9 days ; pupal 3 to 13 ; egg to emergence of adult 9 to 21 days during comparatively warm weather ; and that oviposition occurred in from 5 to 9 days after emergence.

Patton (1922A) mentioned that in India the eggs of *Lucilia serenissima* F. incubated in from 24 to 36 hours according to temperature.

Chrysomyia albiceps Wied.

This is the adult of the larger so-called hairy maggot and is one of the worst of the sheep blowflies in New South Wales and Queensland, where it is generally known as *Pycnosoma* or *Chrysomyia rufifacies*. It is most abundant in Brisbane during January and February, while in sheep districts of Central and Western Queensland it is especially in evidence during March, April, and May and may occur in numbers even in June.

Mr. Froggatt (1921, p. 811 ; 1920, p. 472) has lately used the name *Chrysomyia albiceps* Wied, as being its correct name, the determination having been made by Patton, who mentioned that it was a common Indian species. The latter author (1922C) has just published an account of the fly and its larval stages.

CHRYSOMYIA ALBICEPS.

Periods.	January.	February.	March.	April.	May to September.	October.	November.	December.
Egg (hours) ..	16	16–17	16	19	21	18	18	16–17
Larval feeding (days)	4–5	4–5	4–5	5	5–6	5	5	5
Larval resting ..	2–3	1½–2	2	2–3	4–10	..	2–5	2–3
Total larval ..	6–8	5½–7	6–8	6–8	10–15	7–?	7–10	7–8
Pupal	4–8	3–5	5–8	7–8	10–20	6	4½–5	4½–5
Deposition of egg to emergence of adult	10–13	9–13	11–16	13–17	20–36	13	12–16	12–14
Longevity of adult	2–29	10–30	..	..	26	23	6–29	16–30

The larva usually feeds for about five days, then follows a resting period generally occupying from 5 to 6 days during winter and 2 days in summer. The total larval period during midsummer (January to March) is usually 6 days, but 8 days during early summer, and longer during winter. The pupal period is usually from $4\frac{1}{2}$ to 5 days during the whole summer. No definite information is available as to the time which elapses between adult emergence and sexual maturity, and between emergence and oviposition, but about 5 or 6 days appear to elapse in the latter case (midsummer). Longevity in captivity during summer commonly ranged between 15 and 26 days.

Jarvis (1913, p. 11), who bred it in confinement at an average mean temperature of 75·5° F. (Longreach district, during October), stated that 7 days intervened between egg-laying and pupation—flies emerging 4 days later (i.e., a pupation period of 4 days). Hence the total period between deposition of eggs and the emergence of flies which developed from them was 11 days (Jarvis stated 12 though his dates indicate only 11).

The most rapid development from egg deposition to emergence noted by us occupied 9 to 10 days (February), 3 to 4 days of which were spent in the pupal condition (J. & T. 1921, pp. 112, 116). Illingworth (1918) referred to a similar rapid development of this fly in Hawaii (midsummer, July), where less than 4 days elapsed from the time of the deposition of the egg to the end of the larval feeding stage. He reported that the pupal condition occupied about 6 days, but this interval would include the time that we have indicated under larval resting stage, which would probably be 1 to 2 days. The total time from egg deposition to emergence was about $9\frac{1}{2}$ days, just as in the case noted by us. Froggatt (1913, p. 26) stated that less than a fortnight elapsed between these periods (New South Wales).

Patton (1922c, p. 563) states that the second, but more especially the third, stage larva of *C. albiceps* is entirely predaceous, feeding on the larvæ of other Calliphorinæ, as well as those of certain species of *Musca* in Mesopotamia and India, a character which it shares with *C. villeneuvii*. J. L. Froggatt (1919, p. 259) had already mentioned that the " hairy " larvæ of *Pycnosoma rufifacies* and *P. varipes* attacked and devoured the smooth-skinned maggots of other blowflies

such as *Anestellorhina augur*, *Pollenia stygia*, and *Lucilia sericata*, while those of *Ophyra nigra* would attack all species.

Patton mentioned that the female lays her eggs amongst those of other Calliphorines; that the first instar lasts for about 36 hours, as in the case of *C. villeneuvii*, and the second from 2 to 3 days.

The biology of the related fly *Chrysomyia* (or better, *Cochliomyia*) *macellaria* Fabr., well known as the American screw-worm, which deposits its eggs in living domesticated animals as well as in man, but especially in cattle and sheep, has been worked out by various investigators. Bishopp, Mitchell, and Parman (1917) reported that eggs hatch in less than 4 hours, and when infesting living animals the larvæ are mature and drop from the wound in from 4 to 5 days, but when in carcasses they require 6 to 20 days unless the weather be hot and damp. The maggots burrow from 1 to 4 inches into the ground before pupating. The pupal stage lasts from 3 to 14 days, when the flies emerge and are soon ready (3 to 18 days) for egg-laying. The whole life-cycle is completed in from 1 to 4 weeks according to temperature and humidity. The adult fly lives only a short time—from 2 to 6 weeks. (*See also* Bishopp, 1915, p. 325-6.)

Herms (1915, p. 235) reported that the shortest period observed to elapse between the deposition of the egg or maggot to the emergence of the imago was 9 days, lengthening to 2 weeks or more under less favourable circumstances. Castellani and Chalmers (1919, p. 848) stated that the eggs hatched in from 1 to 9 hours, the larva matured in from 5 to 7 days, and the pupa in from 9 to 14 days. (*See also* Hall, 1921, p. 15.)

Chrysomyia (Microcalliphora) varipes Macquart.

This is the smaller hairy maggot-fly, commonly known as *Pycnosoma varipes*. Probably more than one species has been included in the previous accounts given under this name. Townsend in 1916 made it the type of his genus *Microcalliphora*. Though common during summer, this fly reaches its maximum development in Brisbane in February, during which month its life-cycle may be very much shortened, at times not more than 8 days elapsing between the deposition of the egg and the emergence of the resulting fly. The usual period during summer was found to be 10 or 11 days, increasing as winter approached, when over a month might be required.

MICROCALLIPHORA VARIPES.

Periods.	January.	February.	March.	April.	May to September.	October.	November.	December.
Egg (hours) ..	17	17	17–18	18	..	18	17–19	17–19
Larval feeding (days)	$2\frac{3}{4}$–$4\frac{1}{2}$	$2\frac{3}{4}$–5	4–5	4–5	5	$4\frac{1}{2}$–5	$4\frac{1}{2}$–5	$4\frac{1}{2}$–5
Larval resting ..	1–2	1–2	$1\frac{1}{2}$–2	2–3	3–8	..	$1\frac{1}{2}$–2	1–$1\frac{1}{2}$
Total larval ..	$4\frac{1}{4}$–6	5–7	$5\frac{1}{2}$–7	6–8	8–13	..	6–7	$5\frac{1}{2}$–6
Pupal	2–10	3–5	$4\frac{1}{2}$–5	5	8–21	..	$4\frac{1}{2}$–5	$4\frac{1}{2}$
Deposition of egg to emergence of adult	9–14	8–11	10–11	11–14	17–36	12–15	10–12	10–11
Longevity of adult	19–28	26–28	26	26–28	29	23–29	20–28	28–29

The larval feeding period generally occupied 3 days in January and $4\frac{1}{2}$ to 5 days for most of the year; while the larval resting period usually extended over 1 or 2 days in summer but 5 or 6 in winter. The pupal period commonly occupied 4 to $4\frac{1}{2}$ days in summer.

Chrysomyia megacephala Fabr.

This large, deep-blue blowfly is more commonly known in Queensland, the East Indies, and Hawaii as *C. dux* Esch. Van der Wulp in his "Catalogue of the described Diptera from S. E. Asia" (1896, p. 148) quotes the latter name with *Lucilia flaviceps* of Macquart and of Walker as a synonym.

Froggatt has referred to it frequently and figured it as *Lucilia tasmaniensis* (Brisbane, New Hebrides, and Solomon Islands), but recently (1921, p. 812) has recorded it as *C. flaviceps* apparently on the authority of W. S. Patton, who reports it as a common "bluebottle" blowfly of Eastern bazaars and as one which breeds readily in decaying animal matter.

It appears in Brisbane in great numbers during the summer but does not become the dominant species until about March. It occurs in Sydney but is not so abundant there. The British Museum contains specimens from the Northern Territory and many North Queensland localities.

Though it is readily attracted to decomposing animal matter we have not yet observed it ovipositing nor have we bred it out from carrion.

Patton (1922B), who recognised this fly as belonging to Fabricius' species, described the larval stages and mentioned that the larvæ hatch out in about 24 hours in India. Though various stages in the related Indian blowflies, *Chrysomyia bezziana* and *C. nigriceps*, have been described by Patton (Ind. Jour. Med. Res. 8 (1), 1920, pp. 17-29 ; 1922B), the times occupied by them are not mentioned.

Neopollenia stygia F.

The golden-haired blowfly, known also as *Calliphora villosa*, occurs very commonly during the winter months in Western Queensland. It becomes less abundant in September and diminishes in numbers as summer approaches, when it is seldom seen. Froggatt reports it as being prevalent in New South Wales sheep-country from September onwards well into the summer. He states that it is common throughout the year in Sydney.

We have not kept records of the developmental periods of this fly. Froggatt (1915, p. 20) states that the time required for the egg to develop into a fly in summer in New South Wales averages a fortnight.

Paracalliphora augur L.

This blowfly is known under a variety of names—*Calliphora oceaniæ*, *C. augur*, *Anestellorhina augur*, etc. The genus *Paracalliphora* was erected for it by Townsend (Canad. Entom. 48, 1916, p. 151).

The fly is quite common in Brisbane during the winter (May onwards), increasing as *N. stygia* begins to diminish, but it is not abundant in summer. It is capable of depositing either eggs or maggots and at times both may be deposited on the same occasion. Eggs usually hatch out in about six hours in Brisbane. The larval feeding period is about 4 days, while the resting stage occupies about 5 days except during winter when it is usually 6.

PARACALLIPHORA AUGUR.

Periods.	January.	February.	March.	April.	May to September.	October.	November.	December.
Larval feeding ..	4	..	..	..	5	4	4	4
Larval resting ..	..	..	..	..	5–8	4–6	5	4–5
Total larval ..	..	..	..	..	10–14	8–9	9	8–9
Pupal	..	..	..	10–14	10–19	13–14	13	13
Egg deposition to adult emergence	..	20	..	..	21–33	21	19–20	20

Froggatt (1915, p. 19) reported breeding the species from carrion all the year round though it was during winter that it infested sheep. He recorded that during winter the larvæ required 2 to 3 weeks to become fully fed while the pupal stage occupied a month to 6 weeks, so that from 6 weeks to 2 months were required under laboratory conditions, but that a fortnight or even a month longer was necessary under natural conditions. During summer, he stated, only 14 days intervene between the egg and the emergence of the adult fly, larvæ being fully fed on the seventh day.

In an earlier paper (1913A, p. 23) he mentioned that eggs laid in November gave rise to larvæ which pupated in 6 days and emerged 11 days later, the period from the egg to emergence of the fly being 14 to 15 days (his dates show a period of 17 days). During December, 18 days elapsed in a case recorded.

Calliphora erythrocephala Meigen.

This large, dark blowfly, an importation from Europe, is common in New Zealand and in Sydney. As we have seen only one specimen in Brisbane it must be very rare, though it may succeed in establishing itself. No data regarding its biology in Australia have been published.

Bishopp (1915, p. 327) mentioned that in Eastern Texas the incubation period was 24 hours ; the larval feeding stage 3 or 4 days ; the pupal stage 7 to 9 days ; the period from

egg deposition to emergence ranged from 15 to 20 days ; and that oviposition occurred in from 12 to 17 days after emergence.

Pierce (1921, p. 131) stated that the eggs required 10 to 24 hours to hatch ; the larva 7½ to 8 days at 23° C. (73·5° Fahr.) ; and the pupa 14 days for development, though larvæ had been known to attain full development in from 3 to 4 days and the flies to emerge in from 15 to 20 days after the eggs had been deposited. (*See also* Hewitt, 1914.)

Sarcophaga spp.

Flesh-flies are to be met with in Brisbane throughout the year but are particularly plentiful during March and April. They are larviparous. The larval feeding stage occupies about 4 or 5 days during summer. The pupal stage is greatly prolonged during winter, some of our specimens taking from 8 to 16 weeks before emerging. Overwintering evidently takes place in the pupal condition. From 12 to 18 days elapse during summer between larviposition and the emergence of the adult. In 2 or 3 days after emergence copulation occurs.

Herms (1915, p. 238) states that under optimum conditions, presumably at Berkeley, California, *Sarcophaga sarraceniæ* Riley requires 5 days for its larval development and 13 for the pupal, a total of 18 days from larviposition to emergence.

Sarcophaga peregrina R. D.

Period (days).	Nov.–Dec.	Jan.–Feb.	March–April.	Winter.
Larval feeding	3–6	3–5	5–6	..
Larval resting	3	3	2–3	..
Total larval	6–9	6–8	7–9	..
Pupal	8	8–9	3 to 9 weeks	8 to16 weeks
Larviposition to emergence	14–17	14–17	20 days to 10 weeks	..
Emergence to copulation	2–3	2–3	2–6	2–8
Emergence to larviposition	11	11	11	12
Larviposition to larviposition	25–28	25–28	31 days to 11 weeks	..

Sarcophaga tryoni J. & T.

During the winter this large golden fly takes 7 days to pass through its larval feeding stage, 7 to 8 days for the larval resting or prepupal stage, and 7 weeks to complete its pupal stage.

Sarcophaga impatiens Walker.

Period (days).	Jan.–Feb.	Winter.	October.
Larval feeding	5–6	7	4
Larval resting	2–3	7–8	7–8
Total larval	7–9	14–15	11–12
Pupal	5–9	19 days to 10 weeks	5–6
Larviposition to emergence ..	12–18	33 days to 12 weeks	16–18
Emergence to copulation ..	2–3	2–3	2–3
Emergence to larviposition ..	11	10–12	11
Larviposition to larviposition ..	23–30	30 days to 14 weeks	28 ?

Sarcophaga omikron J. & T.

The pupal stage (bred from decaying potato) in the Upper Burnett district during January 1920 was about 13 days (*M. J. Bancroft*).

Ophyra nigra Wied.

This shining black Anthomyid blowfly is extremely common in Southern Queensland and in New South Wales, and is readily attracted to carrion, where it may be collected all the year round.

In Brisbane the eggs usually require 24 to 25 hours for hatching. The larva feeds for 5 or 6 days and then passes through a resting stage varying in length from 7 to 11 days in summer and from 3 to 4 weeks during winter. The pupal stage lasts for about 8 days in summer and 2 to 3 weeks in winter. The period elapsing between the deposition of the egg and the emergence of the resulting fly is about 20 days in midsummer, increasing to about 30 in autumn and spring, while during winter about 10 weeks are required. In about 5 days after emergence, copulation occurs, egg-laying taking place within 1 or 2 days. The fly lives for about a month in captivity.

Ophyra nigra.

Periods.	January.	February.	March.	April.	May to September.	October.	November.	December.
Egg	24	24	24–27	25	27	..	25	25
Larval feeding ..	5–6	5–6	5–6	5–6	6–7	..	5½–6	5–6
Larval resting ..	10–11	10–11	7–8	15–25	20–30	11	9–11	6–7
Total larval ..	15–16	15–16	12–15	20–30	26–30	..	15	12–13
Pupal	8 ·	8	8–9	9–12	13–25	8	6–8	7–8
Egg deposition to adult emergence	19–24	19–24	21–30	28–29	about 10 wks.	28	21	19
Maturation ..	4½–5	4½	5	5	..	..	5	5
Emergence to oviposition	5–6	5–7	6–7	6–7	..	..	6	5
Adult longevity ..	22–29	20–28	..	..	29	28	22–29	20–29

Stomoyxs calcitrans L.

We have not attempted to ascertain the length of the various stages in the life-cycle of the stable-fly. The time which elapsed between the deposition of eggs and the emergence of the adult fly from them in Brisbane was found to be from 14 to 19 days during January and February, 20 to 33 during April, 24 to 40 during winter (May to October), 20 to 21 during November and December. The usual time in S. E. Queensland seems to be about 20 days during summer, though less in midsummer, increasing to from 3 to 5 weeks during winter. Hill's data (1918) show that a total of 21 days elapsed in Melbourne during January and February.

Bishopp (1913, 1916, 1920) has investigated the biology of *S. calcitrans* in Dallas, Texas, U.S.A. During late autumn (Sept. and Oct. 1912) he found that the egg period ranged from 1 to 4 days ; larval from 11 to over 30 ; pupal 6 to 20 ; the time elapsing from oviposition to emergence being from 19 to over 42 days (1913, p. 121-2). In a later paper (1916), he gave a more complete account and stated (p. 17) that on the average the last-named period generally ranged from 21 to 25 days when conditions were very favourable ; that the longest period observed for complete development was 43 days, though

it was certain that during late autumn and winter a much longer period (up to 3 months) was necessary in Northern Texas. Flies were found to live about 17 days (occasionally 29 days) in confinement when supplied with blood as food. Similar information was republished by him in 1920.

Herms (1915) reported that in the vicinity of San Francisco, California, at a temperature of 21° to 26° C. (70° to 80° Fahr.), the following periods were observed :—Egg stage 2 to 5 days, average 3 days ; larval stage 14 to 26, usually 15 days ; pupal stage 6 to 26, generally 10 days ; time elapsing from oviposition to emergence 22 to 57 days, average 28 days. Copulation was found to occur within a week from emergence and egg deposition about 18 days after emergence, at the temperatures stated. The longevity of adults averaged 20 days, the maximum observed being 69 days.

Hewitt (1914, p. 200) reported that (in England, presumably) the egg required from 24 hours to 4 days to hatch ; the larva 7 to 30 days for its development ; and the pupa 5 to 20 days before emergence. The period from egg deposition to the emergence of adults varied from 13 days to 10 weeks. Flies were found to live from 72 to 94 days in captivity and to begin to oviposit on the 9th day after leaving the puparium.

Newstead (1906) found that in England, at a day temperature of 72° Fahr. and a night temperature of 65° Fahr., eggs hatched in 2 to 3 days [1] ; the larval stages occupied 14 to 21 days (or even as much as 78 days when conditions were unfavourable) ; the pupa 9 to 13 days ; while the period from egg deposition to emergence required from 25 to 37 days, but when conditions were drier and the larval stage as a consequence was lengthened, then the cycle occupied from 42 to 78 days. Howard (1912) and Hindle (1914) republished Newstead's figures. (*See also* Newstead, Dutton, and Todd, 1907, pp. 75-86.)

Mitzmain (1913), working in the Philippines at a warm temperature of 30-31° C. (86°-91° Fahr.), found that the larval life averaged 12 days, the pupal 5 days, while the maximum period for which flies lived in captivity was found to be 72 days in the case of a female and 94 for a male.

[1] Newstead (in Newstead, Dutton, and Todd, 1907, p. 87) states that at a temperature of 64-67° F. eggs did not hatch until the 8th day.

Patton and Cragg (1913, p. 366) reported that in India the egg hatched in 12 hours, the larva matured in from 7 to 21 days, and the pupa in about 4 days. Hence the total period from egg deposition to emergence occupied from about 11 to 25 days.

Lyperosia exigua Meijere.

The bionomics of the buffalo-fly (a relative of *Stomoxys*), in the Northern Territory, were briefly dealt with by Hill (1916). The egg stage occupied 18 to 20 hours ; larval, i.e. from the hatching of the egg to the formation of the puparium, 72 to 96 hours ; pupal stage 72 to 120 hours. The life-cycle (egg to emergence) was found under laboratory conditions, in the case of flies reared in March (late summer) to average 169 hours (7 days), ranging from 120 hours during warm sultry weather and 192 to 195 when the weather was rather cooler ; while in the case of a fly reared in June when the weather was still cooler, 208 hours (nearly 9 days) elapsed. Patton and Cragg (1913, p. 376) state that in India the fly emerges in from 5 to 8 days from the time the eggs are deposited.

The biology of *Lyperosia* (or *Hæmatobia*) *irritans* L. in Europe has been studied by Wilhelmi (1921). Pierce (1921, p. 234) states that in U.S.A. this species, the hornfly, requires about 17 days from egg to adult.

Musca domestica L.

With the exception of a casual record by Johnston and Bancroft (1920), the only work published relating to the biology of the common housefly in Australia is that of Willis (1913), though Cleland (1913) has given information regarding the percentage of this species amongst the flies caught in houses in Sydney. Froggatt (1910, p. 246) referred to the stages of housefly development, but there is nothing to indicate that his periods relate to actual observations in Australia.

Except in a few cases, no attempt was made by us to determine the length of time passed by the fly in its various developmental stages. It was ascertained that in Eidsvold during November the egg required a day to hatch ; the first instar was passed through in a day ; the second in a similar period ; the third in 3 or 4 days (making a total egg and larval period of 6 to 7 days) ; the pupal stage in 9 to 10 days ; making a total of from 15 to 17 days from oviposition to emergence (Johnston and Bancroft, 1920, p. 5).

During November 1919 in Brisbane the combined egg and larval stages required from 5 to 7 days (generally 6), and the pupa from 8 to 10 (generally 9) days for development, so that the total period from egg deposition to adult emergence was from 14 to 16 days. This month was dry. During the succeeding January and February (1920) the periods were—Egg plus larval, 4 to 6 days; pupal, 4 to 8; the period between oviposition and emergence ranging from 8 to 12 days during these hot, moist months.

From later observations made by us in Brisbane (1920, 1921), it was ascertained that the housefly could pass through its stages from the egg to the imago in from 7 to 8 days during midsummer, but needed from 11 to 15 during autumn (April and May), and 12 to 16 during winter. Horse-manure was used as the pabulum in all our breeding work with houseflies. Copulation took place in from 4 to 8 days after emergence and oviposition occurred 4 days later.

Willis (1913), working in Sydney during November and December 1910, gave his minimal observation in the case of material incubated at 28-30° C. (82-86° F.), when a period of 12 days elapsed between the date when eggs were first seen and adults first emerged, while with a temperature maintained at 30-34° C. (86°-93° F.) it was not quite 10 days. He noted that pairing seemed to occur two days after emergence, and reported that oviposition took place six days after emergence, at the higher temperatures mentioned.

Hill (1918) reported that in Melbourne eggs hatched in from 12 to 24 hours, flies emerging during midsummer in about 14 days after eggs had been laid. Such flies mated in from 4 to 6 days after emergence and oviposition occurred about 4 days later. Midsummer in the Southern States of Australia is comparatively dry whereas in Brisbane it is normally moist (January to March).

Patton and Cragg (1913) reported that, in India, houseflies emerged about the 6th or 7th day after the eggs were laid; while Smith (1907) recorded that a period of 8 days elapsed when flies were bred from horse-manure at Benares, India. These abbreviated periods are comparable with those above recorded by us as observed during the moist midsummer of S. E. Queensland.

Hewitt (1914, p. 109) reported that the shortest periods

observed by him during the summer in Manchester were—Egg, 8 hours ; first instar 24 hours, second 24 hours, third 3 days ; pupa 3 days ; total 8 days 4 hours,—but that probably not less than 9 days, and commonly 10 or more, elapsed under natural conditions. It should be mentioned, however, that Griffith (1908) obtained a minimum of 8 days (egg to pupa $4\frac{1}{2}$ to 6 days, pupa to fly $3\frac{1}{2}$ days) in the south of England. The minimum obtained by Newstead (1907) in Liverpool was 10 days, as also was that recorded by Packard, observed in Massachusetts, U.S.A. At an average daily temperature of 22·5° C. in England, flies require 14 to 20 days to emerge when eggs were laid and the larvæ developed in horse-manure (Hewitt).

The influence of moisture and temperature on the length of the various periods in fly development has been studied by Newstead (1907) and by Hewitt (1914). (*See also* Graham Smith, 1914, p. 42.) Egg period at 10° C. 2 to 3 days ; at 15-20° C. about 24 hours ; at 25-35° C. 8 to 12 hours. Larval period—first instar 20 to 36 hours or even to 4 days ; second instar 24 hours (25-30° C.) to several days ; third instar (including prepupal stage) 3 to 4 days (25-35° C.) ranging to 8 or 9 when conditions less suitable ; total larval period 5 to 8 days (when conditions of temperature and fermentation favourable) ranging to 8 weeks. Pupal period between 3 and 4 days (at 35° C.) ranging to several weeks. The temperatures mentioned (25-35° C.) approximately correspond with those in tropical climates and in subtropical regions (such as Brisbane) during midsummer, and the results obtained by Hewitt, using incubators, are similar to those recorded by Patton and Cragg and by Smith for Indian conditions, and by us for Eastern Queensland.

Howard and Hutchison (1915, 1917) gave the larval period (including egg stage) as 4 to 5 days under favourable conditions in U.S.A. ; pupal 3 to 10 days in midsummer (up to 5 months during midwinter) ; and mentioned that the shortest time recorded as elapsing between egg deposition and adult emergence in U.S.A. was 8 days, records of 10 to 12 days being common ; and that only 3 or 4 days were needed during midsummer for females to reach maturity after emergence.

This preoviposition period, as it has been named, has been carefully studied by Hutchison (1916), who attempted to represent graphically its relation to temperature. The time

varied from 2½ to 23 days, from 3 to 5 days being required when the temperature was in the vicinity of 80° F. (which corresponds with Brisbane summer).

Howard (1912) reported that in Washington D.C., during midsummer, larval life occupied 5 days (24 hours + 24 hours + 72 hours) and the pupal normally 5 days ; while Pierce (1921, p. 129) gave them as 4 and 3 to 10 respectively (U.S.A.).

Herms (1915) published maximum and minimum periods for egg, larval, and pupal stages as well as for total periods from egg to imago, based on observations in Berkeley, California. In regard to the last-named period he found it to vary from 12 to 18 days, usually from 14 to 18, but at a temperature maintained at 30° C. the minimum observed was 9⅓ days. The average, minimum, and maximum lengths of time in days required between egg deposition and emergence at certain temperatures were found to be respectively as follows :—At 16° C.—44·8, 40·5, 48·6 ; at 18° C.—26·7, 23·1, 30·25 ; at 20° C.—20·5, 18·8, 22·25 ; at 25° C.—16·1, 14·5, 17·8 ; at 30° C.—10·4, 9·3, 11·5.

Stiles (1921) stated that larvæ matured in the shortest time in fermenting materials at a temperature of 90-98° F. (32·2°-36·7° C.) and that at higher temperatures (100-110° F.) they left the hotter portion of the manure in which they were feeding. At temperatures between 65° and 75° F. (18·3-23·9°C.) the "duration of life-round" was 3 weeks, presumably in the vicinity of Washington D.C.

Hewitt (1914) reported that flies reached sexual maturity in England in August and September in from 10 to 14 days after emergence, oviposition occurring 4 days later. Hutchison (1916) stated that copulation may occur on the first day after emergence, but usually took place between the 3rd and 6th days, provided the temperature was not below 55° F.

Austen (1920, p. 19) reported that, in June 1915 at Rouen during very hot weather, houseflies bred out in a little more than 6 days from eggs laid in horse-manure, while at Kantara, Suez Canal, in May 1916 during extremely hot weather, about 7½ days elapsed, but that in England under very favourable circumstances 7 to 8 days were needed. To the latter period there must be added from 14 to 18 days before the emerging flies can lay eggs ; hence in the British Isles during very hot weather about 3 weeks would be sufficient to elapse between

egg deposition by a fly and oviposition by the progeny of such fly (p. 16). Howard and Hutchison (1915, 1917) showed that in Washington D.C. such would be possible in from 11 to 14 days during midsummer. We do not know the minimum preoviposition period in Brisbane, but, as our climatic conditions during summer are somewhat similar to those in which Hutchison obtained his minimum results, it is likely that in the coastal districts of Queensland during midsummer (say January to March) a period of from 9 to 11 days may represent the minimum period between egg deposition by a fly and by its progeny.

We have no information regarding the length of time houseflies can live in captivity in Australia, but Austen (1920) mentioned 7 to 16 weeks in England; while Howard and Hutchison (1915) recorded periods of 30 days during winter (New Orleans), 35 to 40 days at temperatures of 65-75° F. (Virginia), one of 70 days at a temperature ranging from 32° to 50° F. (Virginia), and (1917) one of 91 days (44-57° F.). Hutchison (1916) recorded a longevity varying from 1 to 54 days (average of 3,000 records being 19+ days) during summer and autumn (U.S.A.). On account of the much warmer climate of Australia, such long life-periods are unlikely to occur here normally.

Bishopp, Dove, and Parman (1915), working at Dallas and Uvalde, Texas, found that eggs hatched in less than 24 hours even in winter; the larval stages required from $3\frac{1}{2}$ days to about 3 weeks, usually 4 to 7 days during warm weather; pupal stage 3 to 26 days, ranging to more than 2 months during winter; time from egg to emergence 8 to 11 days (midsummer) increasing to 25 to 51 (midwinter); and in one case the combined larval and pupal stages occupied 6 months (November to May). Copulation was observed to occur from 1 to 16 days after emergence. Oviposition took place in from 4 to 20 days after emergence—usually 4 to 9 days in summer and 10 or more in autumn. Longevity in captivity was found to be from 2 to 53 days—generally 2 to 4 weeks during summer when food was sufficient.

Musca vetustissima Walker.

This is the common, small, dark, bush fly of Australia and has been referred to in literature under a variety of names. Coquillet determined it for Froggatt (1905) as *Musca corvina* Fabr. (a European fly now known as *M. autumnalis* Geer.),

and it is under such name that the latter author has figured it and written of it in his various papers excepting in a recent article (1921) where he calls it *Eumusca australis*, though it has been shown that the latter specific name belongs to a quite distinct fly (Johnston and Bancroft 1920A, 1920C). It has also been referred to as *Eumusca vetustissima*, as it falls within Townsend's genus if the latter is recognised as valid (Johnston and Bancroft 1920C, Johnston 1921B).

Bezzi determined it for G. F. Hill as *Musca humilis* Wied., an Indian fly, and it is under this name that Hill mentioned it recently (1921). Dr. Patton, in a letter to the senior author dated August 1921, stated that Walker's species was a synonym of Wiedemann's, but in a letter a few months later (Dec. 1921) he said that *M. vetustissima* was certainly not *M. humilis*, but was Macquart's *M. pumila*. Our bush fly is certainly very much like the figure of *M. humilis* given by Patton in Indian Journal of Medical Research, 7, (4), plate 68[2] (For further references to *M. humilis see* Patton, l.c. 8 (1), 1920, pp. 1-16 ; Rev. Appl. Ent. B. 9 (6), p. 102.) In view of the above contradictory statements we prefer to retain Walker's name until some authoritative pronouncement shall have been made.

The biology of the fly under the climatic conditions occurring in Brisbane and in Eidsvold (Upper Burnett River district) has been made known by Johnston and Bancroft. The time passed in the egg stage and in the various instars and pupa has been ascertained, the egg and larval stages usually requiring 4 to 5 days and the pupal about 6 in summer, whereas in spring and winter the latter may need 7 to 9 days. The total period from egg to imago was found to be from 10 to 14 days in Eidsvold during November when the weather was rather dry. (Johnston and Bancroft 1920A ; 1920C, pp. 35, 41 ; Johnston 1921B.)

Other observations during October, November, and December confirm the above results, the egg hatching out in less than 24 hours ; the combined egg-plus-larval period being from 4 to 6 days, generally 5 ; the pupal period 6 to 10, usually 6 or 7 days ; the total period from egg deposition to emergence being 11 to 13 days. No doubt all stages would

[2] The life history and breeding habits of *M. determinata* and *M. humilis* are described in the paper, pages 754-5, 757-8.

be abbreviated during the moister summer months (January to March or April), but we have no records for that part of the year.

Awati (1920), in dealing with the biology of certain Indian species of *Musca*, stated that *M. promiscua* (a species with thoracic stripes somewhat like those of *M. vetustissima*) passed through its stages from the egg to the sexually mature imago in 9 to 10 days (egg less than one day ; larva 1 ; pupa 4 ; adult 4 days before maturity was reached), eggs being laid from 4 to 10 days after copulation. The time elapsing between egg deposition by a fly and by its progeny from such eggs (i.e. from egg stage to egg stage) was found to be from 19 to 28 days. The longevity varied from 42 to 56 in the different species of *Musca* under observation.

Musca fergusoni Johnston and Bancroft.

This is much more robust than the last-mentioned species and has four well-defined thoracic stripes. It has received several names. Macquart described it as *M. australis*, but the name was already preoccupied by Boisduval. Hill (1921) quoted these names as synonyms of *M. lusoria* Wied., an Indian fly, the determination having been made by Bezzi. Johnston and Bancroft transferred the species to *Viviparomusca* Townsend (Johnston and Bancroft 1920c ; Johnston 1921b).

Dr. Patton in a letter dated August 1921 stated that the species belonged to the *lusoria-bezzii* group, but in a later note (Dec. 1921) informed us that it was *M. convexifrons* Thomson (*nec* Bezzi). Its similarity to *M. bezzi* Patton and Cragg was pointed out in the original account (J. and B. 1920a). Until the synonymy is definitely established we think it preferable to use the above name.

The various stages in the life-cycle and the periods of time occupied have been dealt with (J. and B. 1920a ; Johnston 1921b). The fly is practically larviparous, as a larva in the second instar escapes from the thin eggshell immediately the egg is deposited by the female. Pupation occurs on the 3rd day, the larval stages requiring 2 or a little over 2 days during summer, but 4 in October and up to 6 in winter. The pupal stage required from 9 to 15 days in summer and 27 to 32 days in winter (Eidsvold).

The fly has been found breeding throughout the year in

the Brisbane district, but generally only a few pupæ of the species can be collected even from considerable quantities of cow-manure during winter. The pupæ are to be found in the manure close to the surface. The species occurred most commonly during March and April.

Additional observations during 1919 and 1920 regarding the life-cycle may be mentioned—(*a*) days in larval stage, (*b*) length of pupal stage, (*c*) total time elapsing between larviposition and emergence :—

——	(*a*) Larva.	(*b*) Pupa.	(*c*) Total.
January	2	7–8	9–10
February	2	7–8	9–10
March	2–3	7–12	9–14
April	3– ?	13–15	16–18
May	5–6	?–26–32	19–38
June	7–8	26– ?	33–40
July to September	7–8	27–39	34– ? 47
October	4	11–12	15–16
November	3	8–9	10–12
December	2–3	8	10–11

The total cycle in Brisbane apparently requires about 10 days for its completion during summer, and over a month during winter. The pupal stage occupies about 8 days during summer but about 4 weeks during winter, though our longest record was 39 days. There is a marked lengthening of the larval period during winter months. Flies kept in captivity during winter lived for periods varying from 10 to 31 days, usually about 24 days.

Musca terræ-reginæ Jnstn. and Bancroft.

The biology of this rather uncommon fly has been studied by Johnston and Bancroft (1920A, pp. 34, 35 ; Johnston, 1921B), whose observations were made chiefly at Eidsvold, Upper Burnett River, the results obtained being practically the same as those ascertained in the case of *Musca domestica* when

under similar conditions (egg less than 24 hours ; first instar 24 hours, second 24 to 48 hours, third 2 to 3 days, total larval 5 to 7 days ; pupal 7 to 10 days ; total from egg to emergence 12 to 17—while the total in the case of the housefly during the same month, November, was from 15 to 17 days).

Additional data :—

——	Larval.	Pupal.	Egg to Emergence.
November	5–9	7–11	13–18
December	5–7	5–8	10–14
January	4–5	6	10–11

Musca hilli Jnstn. and Bancroft.

This is also a rather uncommon fly. Observations regarding its biology have been made by Johnston and Bancroft (1920A, p. 38 ; Johnston 1921B), working at Eidsvold and in Brisbane during midsummer, the periods being found to be similar to those of the housefly under similar conditions (larva 5 to 6 days ; pupa 6 to 9 ; total 11 to 15 days). In another paper (J. and B. 1920B, p. 74) they refer to a total period of from 8 to 10 days from egg to emergence in Brisbane during midsummer.

Observations show that the larval period in Brisbane during midsummer ranges from 4 to 6 days (generally 5 or 6) ; the pupal 5 to 8 (usually 6 days) ; and the total period between egg deposition and emergence from 10 to 14 (usually 11 to 12) days.

Hill (1921) refers to this species as a synonym of *M. nebulo* F., a common Indian fly, his information having been derived from Prof. Bezzi. Major Patton in a letter (August 1921) to the senior author stated that *M. hilli* was *M. ventrosa* Wied., but in a later letter he reserved judgment. But Hill (1921) recorded certain specimens from North Queensland as *M. ventrosa* Wied. (syn. *M. nigrithorax* Stein)—Bezzi's determinations,—but this refers to a different fly. We prefer to retain the above name until the synonymy shall have been settled.

Awati (1920) did not fix *M. nebulo* on account of its scanty original description, and in dealing with the biology of one of the Indian flies with a four-striped thorax, *M. divaricata*, he added (? *nebulo*). In regard to this fly he stated that the egg required about a day, the larva a day, and the pupa 4 to 6 days—thus 6 to 8 days from egg to emergence; while 4 to 8 days were required for maturity, giving a total of 10 to 16 days. Egg-laying occurred 4 to 10 days afterwards, the period elapsing between the time of oviposition of a fly and that of its offspring arising from such oviposition (i.e. from egg to egg) being from 19 to 28 days.

Pyrellia proerna Walker.

This handsome greenish-blue fly, which in Brisbane so commonly frequents cowdung for food and for the purpose of oviposition, has been referred to in earlier papers by Johnston and Bancroft as *Lasiopyrellia* sp. (1920A, p. 182) and *Pseudopyrellia* sp. (1920B, p. 74; 1029C, p. 42). The species occurs in North Queensland also. The flies commonly become a deep blue after having been dead a few days.

Specimens taken by the senior author to the National Museum, Washington D.C., and to the British Museum, were determined by Dr. Aldrich as *Pseudorthellia viridiceps* Macq. and by Major Austen as *Pyrellia proerna* Walker, respectively. The material was compared by Austen with Walker's type (a female—locality unknown) in the British Museum, and as Walker's name *Musca proerna* (List Dipt. Brit. Mus. 4, 1849, p. 888) has a slight priority over Macquart's *Lucilia viridiceps* (Dipt. Exot. Suppl. 4, 1850, p. 249) Walker's name is here used. Townsend made Macquart's species the type of his genus *Pseudorthellia*, hence if this prove to be valid the correct name will be *Pseudorthellia proerna* (Walker). Dr. Aldrich stated that *Pyrellia viridifrons* Macq. was probably a synonym.

Though we collected all the stages of this fly, we did not keep records of the periods beyond noting that during May and June the pupal condition lasted for 18 days.

Johnston and Bancroft (1920B, p. 74) have shown that under experimental conditions the fly readily breeds in horse-dung and can become an intermediate host of the two nematodes, *Habronema musca* and *H. megastoma*.

ADDENDUM.

While this paper was in the press, three recent papers by W. S. Patton relating to the subject have reached Australia :— (1) " Notes on the Species of the Genus *Musca* " (Bull. Ent. Res., 12 (4), 1922, pp. 411-426) ; (2) " Some Notes on Indian Calliphorinæ, No. 6 " (Ind Jour. Med. Res., 9, 1922, pp. 635-653) ; (3) " Somes Notes on Indian Calliphorinæ, No. 7." (l.c., pp. 654-657).

In the first paper there are changes in the names of the Indian flies referred to in our paper. *M. determinata* Wlk. is a synonym of *M. nebulo* ; *M. determinata* Awati is *M. domestica* (atypical) ; while *M promiscua* Awati is *M. humilis* Wied. The following information is given relating to Australian species :—*M. vetustissima* Wlk., *M. minor* Mcq., and *M. humilis* Stein (nec. Wied.) are quoted as synonyms of *M. pumila* Mcq.; *M. fergusoni* J. & B. as a synonym of *M. convexifrons* Thomson ; while *M. hilli* J. & B. is probably identical with *M. ventrosa* Wied.

In the second paper information is published regarding the adults and larvæ of various blowflies, including *Chrysomyia albiceps* and *C. megacephala*.

In the third paper data are published regarding the biology of another Indian blowfly *C. bezziana*, and reference is made to various Australian sheep-maggot flies, more particularly to the predaceous habits of the third laval stage of *C. albiceps*.

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