THE EPIDEMIOLOGY OF Q FEVER

By E. H. DERRICK, *Department of Health, Brisbane, Queensland*

(With 1 Figure in the Text)

In 1935 the occurrence of cases of fever among meat workers in Brisbane caused concern. Investigations were begun by the Queensland Department of Health and continued in cooperation with the Walter and Eliza Hall Institute, Melbourne. The fever was found to be a rickettsiosis and to occur also among farm workers and others (Derrick, 1937; Burnet & Freeman, 1937). It was named Q fever and the causative organism *Rickettsia burneti*. Laboratory tests (guinea-pig inoculation and serum agglutination) were devised for its accurate diagnosis (Burnet & Freeman, 1938; Derrick, Smith, Brown & Freeman, 1939). Between September 1935 and August 1942, 176 cases were recognized. Much information about the mode of transmission has been obtained, and it seems desirable that this should now be reviewed, especially as the war has suspended further investigations.

All patients but two were males. Their ages ranged from 10 to 64 years. Three died.

The incidence of cases was much the same at all seasons.

GEOGRAPHICAL DISTRIBUTION

All the patients, with one possible exception, were domiciled in a coastal strip of south-east Queensland extending from Gladstone (24° S., 151° E.) to the border of New South Wales. The possible exception was a meat inspector who had worked both at Brisbane and at Cairns (17° S., 146° E.), North Queensland, before becoming ill. The most inland patients lived at Monto (25° S., 151° E.) and near Bell (27° S., 151° 30 E.). The latter place is just over 100 miles from the sea.

The annual rainfall in the area concerned varies from 30 in. in the more inland parts to over 60 in. at the coast. Originally the wetter parts were covered by rain forest, the drier by savannah. Most is now closely settled and occupied by sugar cane, dairy, fruit or mixed farms. The area includes the city of Brisbane (population 335,000) and many urban centres.

Of the patients, 129 lived in Brisbane and forty-seven in the countryside.

OCCUPATIONAL INCIDENCE

The Brisbane patients were employed as shown in Table 1. All, except four laboratory workers and two men who lived on the outskirts of Brisbane, were associated with meat works.

Early in the investigations it was hoped that a study of the distribution of cases at Meat Works A would indicate precisely the route of infection. Disappointingly, there was no illuminating selection of occupational groups (Table 2). Workers anywhere in the establishment were liable to infection. The list included those handling cattle, sheep and pigs. It included men skinning cattle—in contact with ectoparasites—as well as men handling meat in the canning and freezing departments. It included also a man in the fertilizer department handling only cooked, sterile material, a

Table 1. *Occupations of Q fever patients in Brisbane*

Employees of Meat Works A (handling cattle, sheep and pigs and their products)	83
Meat inspectors at Meat Works A	20
Meat canners at Meat Works A	3
Workers visiting Meat Works A	4
Workers constructing new buildings at Meat Works A	6
Employees of Meat Works B (handling cattle and pigs and their products)	7
Laboratory workers	4
Worker on new sewerage construction	1
Relief worker	1
Total	129

Table 2. *Distribution of Q fever patients at Meat Works A*

Department	Average no. employed	No. of cases of Q fever 1935–42	Percentage incidence
Foremen and clerks	62	4	6·5
Beef slaughter and offal	264	25	9·5
Calf slaughter	47	3	—
Sheep slaughter and offal	100	8	8
Pig slaughter and offal	26	4	—
Freezing	176	10	5·7
Tank and bone house	57	13	22·8
Boning room	32	5	—
Yard gang	35	2	—
Mechanical	90	9	10
Engine room	24	0	—
Watchmen	22	0	—
Various	7	0	—
Totals	942	83	8·8
Meat inspectors	28	20	

https://doi.org/10.1017/S0022172400013085 Published online by Cambridge University Press

laundryman, an electrician, carpenters and visiting truck drivers.

The highest relative incidence was among meat inspectors and employees in the tank and bone house. Meat inspectors are transferred freely to and from other meat works. Each year many at Meat Works A are new arrivals. It is likely that new arrivals have an increased risk of infection, for, no doubt, many meat workers of long standing have been immunized by obvious or inapparent infections. The reason for the high incidence among workers in the tank and bone house is not evident.

The occurrence of cases at Meat Works A has seemed curiously haphazard and spasmodic. Sometimes a series of successive cases has come from the one department. Thus patients 118, 119, 120 and 121 all worked in the freezing rooms. Of the twenty infections among meat inspectors in the seven years, four occurred in one period of 10 days. Sometimes a number of widely scattered men have been infected at the same time. Thus after an interval of 4 months without a case, four men—a boner, a pig slaughterman, and two tank house workers—became ill within 3 days. There was only one other case in the next 2 months.

Of the forty-seven country patients, thirty-two lived or worked on dairy farms. These included two females—the wife of one dairy farmer and the daughter of another—as well as two boys aged fourteen and ten years. Five more worked on various kinds of farms, two were timber getters, two foresters and two meat workers. The others were a bush worker, an agricultural student, a labourer in a butter factory and a man camping in the bush.

There has been no evidence of direct spread from case to case. No secondary infections have been recognized among family contacts, physicians or nurses.

THE SOURCE OF INFECTION

Naturally occurring Q fever was sought in bush animals, dairy cattle and their parasites (Table 3). *Rickettsia burneti* was obtained from three bandicoots (*Isoodon torosus*) (Derrick & Smith, 1940) and six batches of bandicoot ticks (*Haemaphysalis humerosa*) (Smith & Derrick, 1940). The serum of many bandicoots showed agglutination (Freeman, Smith & Brown, 1940). (The bandicoots of the Australian region are a family—the Peramelidae—of marsupials. They and certain rodents are among the commonest animals of the Queensland bush.)

The results from Moreton Island, where the fauna is much more limited in variety than on the mainland, were interesting. There, *Isoodon torosus* is common. It is heavily infested with *Haemaphysalis humerosa*, which is, except for several species of mites, its only ectoparasite. The high infection rate among the bandicoots there (34 % showed agglutination) and among their ticks, together with the transmission experiments mentioned below, indicate that *Isoodon torosus* is a reservoir of infection and that *Haemaphysalis humerosa* is a vector among bandicoots.

Table 3. *Results of tests for natural Q fever*

	Guinea-pig inoculation			Serum agglutination	
Animal or parasite	No. tested	No. of guinea-pigs inoculated	No. positive	No. examined	No. positive
Isoodon torosus:					
Moreton Island	43	43	2	107	36
Mainland	60	60	1	73	3
Rattus c. youngi	9	9	0	14	1
Hydromys chrysogaster	6	6	0	13	2
Other bush animals	27	27	0	34	0
Cattle	—	—	—	984	14
Ticks:					
Haemaphysalis humerosa:					
Moreton Island	439	39	6	—	—
Mainland	63	13	0	—	—
Haemaphysalis bispinosa	64	9	0	—	—
Boophilus a. microplus	1160	16	0	—	—
Ixodes holocyclus	220	29	0	—	—
Rhipicephalus sanguineus	94	9	0	—	—
Mites, fleas, lice	Many	—	0	—	—

All species of bush animals tested (seven rodents and three marsupials) were found susceptible to experimental inoculation with Q fever (Derrick *et al.* 1940). This, together with the positive agglutinators found in the small series of *Rattus culmorum youngi* and water rats (*Hydromys chrysogaster*), suggests that other animals in the bush assist the bandicoot to provide the reservoir of infection.

The discovery of the bandicoot-tick-bandicoot cycle did not solve the problem of human infection, for *Haemaphysalis humerosa* does not naturally attack man, though it will feed on him, reluctantly, in the laboratory. Further, most of the patients denied having been bitten by ticks.

The next steps were the study of all the common local ticks, and the demonstration of the intermediary which carried infection from the bush reservoir to man.

INVESTIGATION OF TICKS

It was found in the laboratory that *Haemaphysalis humerosa* could readily become infected with *Rickettsia*

https://doi.org/10.1017/S0022172400013085 Published online by Cambridge University Press

burneti by feeding on infected guinea-pigs (Smith, 1940). Infection could be acquired at every instar, and was transmitted from larva to nymph and from nymph to adult. Hereditary transmission was not proved and, from the distribution of rickettsiae in the tick, seems unlikely. Infected nymphs and adults infected some of the guinea-pigs upon which they fed.

In the infected tick the rickettsiae were confined to the lining epithelium and the lumen of the gut. They were often present there in enormous numbers. The faeces were highly infective. Faecal contamination of the bite wound would be the likely mode of infection of the host.

Three other ticks, *Rhipicephalus sanguineus*, *Ixodes holocyclus*, and *Haemaphysalis bispinosa* could also be infected by feeding on infected guinea-pigs and could transmit infection to their host when they fed at the next stage (Smith, 1941*b*, 1942*a*, 1942*b*). Each therefore is a potential vector. Each is present in the Q-endemic area.

As all stages of *Ixodes holocyclus* are commonly found on mainland bandicoots, it is a likely vector of Q fever among them. It bites cattle and man and may also transmit the disease to them. Several Q fever patients from the country gave a history of tick bite. The ticks were not identified but the circumstances indicated *Ixodes holocyclus*.

Thus patient 88, who had previously lived in the city for 6 years, began work on a forest reserve clearing undergrowth. He developed Q fever 19 days later. He stated that during this time he had three tick bites. Patient 152, another forestry worker, said that ticks abounded after the rains began—a month before his illness.

Rhipicephalus sanguineus, the cosmopolitan dog tick, was first reported from Queensland in 1897 and is now widespread throughout the state. It has not been reported from bush animals and does not seem at present a likely vector. As, however, its principal host is susceptible to Q fever (Derrick, Johnson, Smith & Brown, 1938) and it occasionally attacks cattle and man, it is potentially important.

Ornithodorus gurneyi, a kangaroo tick, can be infected in the laboratory (Smith, 1942*b*). It is not present in the Q-endemic area.

Important facts about the ticks which have been tested are set out in Table 4. There are still other ticks which may come into the story, and study also of the Trombidiid mites as possible vectors is called for.

CATTLE AND THEIR TICKS

The outstanding feature of the occupations of Q fever patients has been the association with cattle. The selection of dairy farmers in the country and meat workers in the city makes it clear that infection is carried to the city by stock from the rural endemic area. (Meat workers handle also sheep and pigs. There are practically no sheep in the endemic area. Pigs are present there and have not been thoroughly investigated, but seem unlikely carriers because of their freedom from suitable parasites.)

It was found that calves could be infected experimentally with Q fever (Derrick *et al.* 1942). They had a brief, mild illness. A serum agglutination survey showed that dairy cattle in the endemic area were being naturally infected (Table 3). These infections were inapparent.

If infected cattle were slaughtered, their blood or tissues might infect a meat worker especially if his skin was cut or abraded. But the low infectivity of cattle tissues and the infection of workers (e.g. carpenters) not actually handling meat focus attention rather on the ticks carried by the cattle. There are two species of these—*Boophilus annulatus microplus* (very abundant) and *Haemaphysalis bispinosa*.

Some *Boophilus annulatus microplus*, fed on one of the experimental calves, became infected. As this is a one-host tick its opportunities for spreading infection from one cow to another are limited. Crushed ticks or tick faeces would be a possible source of infection for other cattle as well as for cattlemen and meat workers.

Haemaphysalis bispinosa has a wide distribution in southern Asia. It was first recognized in Australia (in northern New South Wales) in 1911. In the last few years it has become a serious pest of cattle in several areas in south-east Queensland—areas where Q fever is endemic. Though less common than *Boophilus annulatus microplus*, it has, as a three-host tick, greater possibilities of vectorship among cattle. Further, it has a greater host-range, which has not (in Queensland) been fully studied and may perhaps include bush animals.

Table 4. *Ticks of possible significance in the transmission of Q fever*

Tick	Distribution in Queensland	No. of hosts	Principal host	Other reported hosts	Relation to Q fever
H. humerosa	Eastern coastal strip	3	Bandicoot	*Rattus rattus*, *R. c. youngi*, opossum, cattle, horse *E. orientalis*	Proved vector among bandicoots
H. bispinosa	South-east corner	3	Cattle	Sheep, horse, man, dog	Potential vector
B. a. microplus	Eastern coastal strip	1	Cattle	Sheep	Can be infected
I. holocyclus	Eastern coastal strip	3	Bandicoot	Man, most bush and domestic animals	Probable vector
R. sanguineus	Whole state	3	Dog	Sheep, cattle, horse, cat, man	Potential vector
O. gurneyi	Western part	Many	Kangaroo	Man	Can be infected. Unlikely to be a vector

DISCUSSION

The cases of Q fever at Meat Works A resemble in their scattered distribution an outbreak at the National Institute of Health at Washington (Hornibrook & Nelson, 1940). These authors suggested inhalation of

https://doi.org/10.1017/S0022172400013085 Published online by Cambridge University Press

infected dust as a possible explanation of their cases. A similar mode would go far to explain the infections among Brisbane meat workers, and might also explain some of the laboratory infections in Melbourne (Burnet & Freeman, 1939) and in Brisbane (Smith *et al.* 1939). At the meat works a source of infected dust might well be tick faeces. These form a fine powder which could might carry disease from one continent to another. Many birds migrate between eastern Asia and Australia. No systematic study of their ectoparasites has been made by us, but there is one record of *Haemaphysalis humerosa* being found on a migratory bird (*Eurystomus orientalis*—the dollar bird) at Maryborough, Queensland (Smith, 1941*a*).

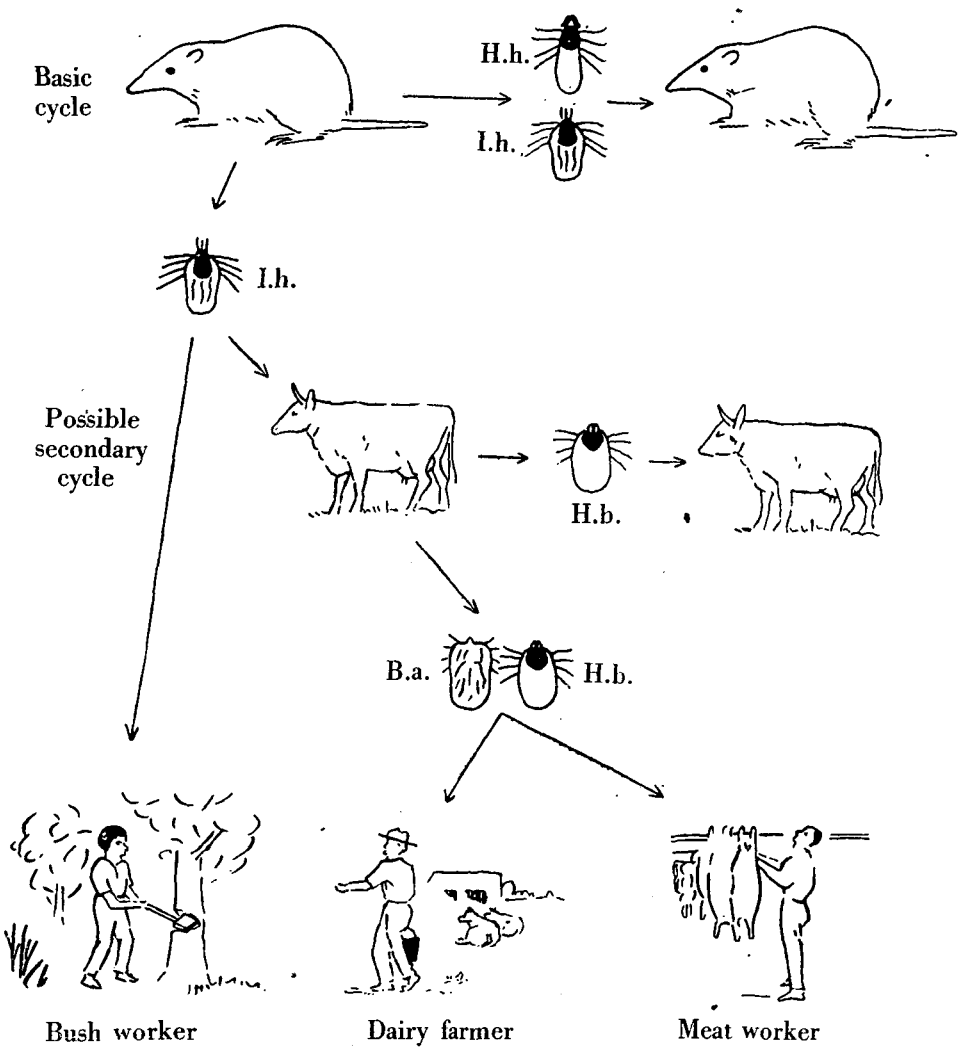

Fig. 1. The natural history of Q fever. *B.a. Boophilus annulatus microplus*; *H.b. Haemaphysalis bispinosa*; *H.h. Haemaphysalis humerosa*; *I.h. Ixodes holocyclus.*

readily be blown about in the wind. Infected tick faeces may retain their infectivity over long periods (65 and 87 days in two experiments).

The free association of *Rickettsia burneti* with bandicoots and their ticks on Moreton Island, where there are no cattle and very little settlement, indicates that Q fever is indigenous in the Queensland bush, antedating the arrival of the white man. What genealogical relationship it bears to the Q fever of America is a field for speculation. Migratory birds, if hosts of infected ticks,

SUMMARY

In seven years 176 cases of Q fever have been diagnosed in Queensland. Nearly all the 129 patients who lived in Brisbane were associated with meat works. Most of the forty-seven country patients worked on dairy farms.

Investigation of native animals, cattle and ticks, has indicated in outline the natural history of

https://doi.org/10.1017/S0022172400013085 Published online by Cambridge University Press

Q fever, which is set out diagrammatically in Fig. 1. (Several steps in this outline need confirmation and much detail remains to be filled in.)

First there is a basic cycle of infection with the bandicoot (and probably other bush animals) as reservoir, and *Haemaphysalis humerosa* (and probably *Ixodes holocyclus*) as vector. A bush worker may interrupt this cycle and get Q fever from the attack of *Ixodes holocyclus*.

Cattle become infected, probably through *Ixodes holocyclus* and perhaps through other ticks. It is possible that there is a secondary cycle: cattle-*Haemaphysalis bispinosa*-cattle.

Ticks on the cattle (*Boophilus annulatus microplus* or *Haemaphysalis bispinosa*) are probably the source of human infection. It is suggested that inhalation of tick faeces is the likely mode of entry of *Rickettsia burneti*.

I am grateful to Sir Raphael Cilento, Director-General of Health and Medical Services, Queensland, for his continual encouragement and for permission to publish, to Dr F. M. Burnet and Miss M. Freeman for their co-operation, to Mr G. Tomlins and his staff for much valuable information, and particularly to Messrs D. J. W. Smith and H. E. Brown who have shared the labour and the zest of the investigations.

REFERENCES

BURNET, F. M. & FREEMAN, M. (1937). Experimental studies on the virus of Q fever. *Med. J. Aust.* **2**, 299.

BURNET, F. M. & FREEMAN, M. (1938). The rickettsia of Q fever: further experimental studies. *Med. J. Aust.* **1**, 296.

BURNET, F. M. & FREEMAN, M. (1939). Note on a series of laboratory infections with the rickettsia of Q fever. *Med. J. Aust.* **1**, 11.

DERRICK, E. H. (1937). Q Fever, a new fever entity: clinical features, diagnosis and laboratory investigation. *Med. J. Aust.* **2**, 281.

DERRICK, E. H., JOHNSON, D. W., SMITH, D. J. W. & BROWN, H. E. (1938). The susceptibility of the dog to Q fever. *Aust. J. Exp. Biol.* **16**, 245.

DERRICK, E. H., SMITH, D. J. W., BROWN, H. E. & FREEMAN, M. (1939). The role of the bandicoot in the epidemiology of Q fever: a preliminary study. *Med. J. Aust.* **1**, 150.

DERRICK, E. H. *et al.* (1940). The susceptibility of various animals to Q fever. *Aust. J. Exp. Biol.* **18**, 409.

DERRICK, E. H., SMITH, D. J. W. & BROWN, H. E. (1942). The role of the cow in the transmission of human Q fever. *Aust. J. Exp. Biol.* **20**, 105.

DERRICK, E. H. & SMITH, D. J. W. (1940). The isolation of three strains of *Rickettsia burneti* from the bandicoot *Isoodon torosus*. *Aust. J. Exp. Biol.* **18**, 99.

FREEMAN, M., SMITH, D. J. W. & BROWN, H. E. (1940). Surveys of human and animal sera for *Rickettsia burneti* agglutinins. *Aust. J. Exp. Biol.* **18**, 193.

HORNIBROOK J. W. & NELSON, K. R. (1940). An institutional outbreak of pneumonitis. I. Epidemiological and clinical studies. *Publ. Hlth Rep.* **55**, 1936.

SMITH, D. J. W. (1940). The transmission of Q fever by the tick *Haemaphysalis humerosa*. *Aust. J. Exp. Biol.* **18**, 103.

SMITH, D. J. W. (1941*a*). The biology of *Haemaphysalis humerosa* Warburton & Nuttall (Acarina, Ixodidae) in Queensland. *Aust. J. Exp. Biol.* **19**, 73.

SMITH, D. J. W. (1941*b*). The transmission of Q fever by the tick *Rhipicephalus sanguineus*. *Aust. J. Exp. Biol.* **19**, 133.

SMITH, D. J. W. (1942*a*). The transmission of Q fever by the tick *Ixodes holocyclus* (with notes on tick paralysis in bandicoots). *Aust. J. Exp. Biol.* **20**, 213.

SMITH, D. J. W. (1942*b*). Experimental infection of the ticks *Haemaphysalis bispinosa* and *Ornithodorus* sp. with *Rickettsia burneti*. *Aust. J. Exp. Biol.* **20**, 295.

SMITH, D. J. W., BROWN, H. E. & DERRICK, E. H. (1939). A further series of laboratory infections with the rickettsia of Q fever. *Med. J. Aust.* **1**, 13.

SMITH, D. J. W. & DERRICK, E. H. (1940). The isolation of six strains of *Rickettsia burneti* from the tick *Haemaphysalis humerosa*. *Aust. J. Exp. Biol.* **18**, 1.

(*MS. received for publication* 24. v. 43.—Ed.)