

A TICK-RESISTANT CONDITION IN CATTLE *

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INTRODUCTORY.

For about a quarter of a century Queensland has had to suffer from the presence of the cattle tick, variously known in Australian literature as *Boophilus australis*, *Rhipicephalus australis*, *Margaropus australis*, and as a variety *australis* or *microplus* of *Boophilus annulatus*. In this paper we intend to use the name *Boophilus australis* Fuller. A constant feature readily distinguishing *B*

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australis and *B. annulatus* was pointed out by Fuller (1899) in his original account, and by Crawley (in Cowley and Pound, 1913). Neumann, Patton and Cragg, and others refer to our cattle tick as *Margaropus annulatus* var. *australis*.

Its introduction from the East Indies and its spread from the Northern Territory into this State have been traced by Pound (1895, 1897), Dodd (1908), Gilruth (1912), Lewis (1913), Stewart and others (1906, 1917). The onward progress of the tick eastward and then southward can be followed by referring to the reports of the Inter-Colonial Stock Conference (R.I.S.C., 1896) and of the various Royal Commissions on the tick pest (R.S.C., 1899).

As early as 1899, Tidswell (p. 13) expressed his opinion that ticks would eventually infect New South Wales in spite of all the precautions. The extension into that State has been slow owing, at least in part, to vigorous quarantine regulations and to vigilant border inspection (Stewart, Symons and Cowley's reports in Jamieson, 1912).

EFFECTS DUE TO TICKS.

The losses caused directly and indirectly by the cattle tick in this continent have been enormous and still are very heavy. In the bulletin on "The Cattle Tick in Australia" (Stewart and others, 1917) an attempt has been made to give the Australian public some idea of the detrimental effects of the presence of the parasite. The losses are there divided into those caused by tick fever and those due to tick infestation; both sets of losses being subdivided into those caused by (a) mortality, (b) the loss of condition involving meat supply, (c) diminution of milk yield* and consequent influence on calf-raising, pig-rearing, bacon industry, butter and cheese-making, etc. In addition to these, mention is made of the great deterioration in the value of hides as a result of tick infestation.

*"The cattle tick has a decidedly injurious effect upon supposedly immune dairy cattle, the extent being largely dependent on the degree of infestation. The effect is more pronounced on milk production than upon the body weights when a sufficient supply of food is given." Woodward and Turner. The effect of the cattle tick upon the milk production of dairy cows. U.S.D.A., B.A.I., Bull. 147, 1915, p. 16.

These facts are stated in order to emphasise the seriousness of the tick problem in such an important beef and butter-producing State as Queensland.

Tick infestation may lead to one or both of the following complaints: *Tick fever* or *Piroplasmosis* (often termed Babesiasis, Texas fever, or redwater) and *Tick worry*, often called tick poverty or tick anaemia.

TICK FEVER.

The term "immunity" is commonly used in Queensland in connection with the tick but it is not strictly correct*. We speak of cattle becoming rendered naturally or artificially "immune" to tick fever, whereas this so-called "immune" condition is now known to remain usually for a comparatively short time—one or two years (Dodd, 1909, p. 84) though a case of 12 or even 13 years persistence is known (Schroeder, 1905, p. 71; Wallace, 1908, p. 320)—unless maintained by subsequent re-inoculation of the animal† (Smith and Kilborne, Hunt, Tidswell, Pound, Wallace, 1908, p. 320). This occurs naturally in tick-infested districts through the agency of larval ticks that are infected with the micro-organism *Babesia bovis* (*Piroplasma bigeminum*) which causes the tick fever. Such larvae are born infected through some of the organisms in the parent reaching its ovary and thus infecting the eggs from which larvæ ultimately develop.‡ The condition can also be brought about by inoculating the cattle with ox

*"The condition is termed 'immunity' simply for want of a better and more descriptive name. It is in fact a very mild chronic form of Texas fever, positively associated with the infectious agent of the affection." (Schroeder and Cotton, 1905, p. 76). "It is merely a tolerance for the infectious organism." (Schroeder, 1905, p. 62). Lignières has also discussed the question as to whether the condition is an immunity or only a tolerance.

†Nuttall, G., in his lecture on Piroplasmosis (Herter Lectures, iii., John Hopkins Hosp. Bull., 24, 1913), has stated that recovered or salted animals are not susceptible to reinfection. This is contrary to Australian experience. He has pointed out (p. 309) that animals which have recovered from cattle tick fever caused by *Piroplasma divergens* are susceptible to Texas fever (due to *P. bigeminum*).

‡Crawley. Jour. Parasitol., 2, 1916, p. 87.

blood containing the piroplasm*. Animals which have passed through one attack of tick fever may pass through a second or even a third attack, especially if the vitality of the cattle becomes lowered by adverse conditions, *e.g.*, if they be over-driven, roughly handled, more or less deprived of food and water, etc. Dodd (1908, p. 16) states that the power of the micro-parasite varies a great deal in different regions and the immunity which may be sufficient in one district may not be enough to protect the cattle if moved to another district. He goes on to say that it is a well-known fact both in Queensland and South Africa that cattle which are immune in one district have contracted tick fever again when removed to another. Cory (1916, p. 80) stated that it had been frequently noticed that toleration broke down when cattle were removed to another tick infested district although they were apparently immune against pathogenic ticks before removal†.

Protective inoculation is widely practised in Queensland, especially in the case of stock imported from tick-free districts into ticky country. This operation does not really "protect" the animal from piroplasmosis but actually causes an attack of the disease which, however, is generally less severe and usually minimises the danger from a subsequent attack. Such, however, may occur but they are as a rule quite mild. In Queensland, blood for inoculation is nearly always taken from a "recovered animal," that is, one which has apparently recovered from tick fever. Such "recovered blood" is injected with due precaution into the cattle which it is desired to protect. The method locally practised has been carefully described by various workers (Hunt, Pound, Dodd, Tidswell and others). The mortality from natural tick infection in the case of

*Hunt and Collins (1896, p. 6-7) refer to a case in Washington, D.C., U.S.A., where blood taken from a cow which had been kept away from ticks and tick-infested districts for over six years, set up virulent (and sometimes fatal) tick fever on inoculation into susceptible cattle; and yet after careful examination of four thousand blood smears, only five infected corpuscles were found by Schroeder and Kilborne.

†A number of Queensland instances are quoted by the Editor, Queensland Agr. Journal, 20, 1908, pp. 325-7, in an article entitled "Tick fever—Is general immunity attainable?"

adult animals is generally high, being often from 50-90%*, whereas that resulting from protective inoculation is often under 2% (Dodd, 1908, p. 10). Many years earlier, Tidswell gave the percentages as 60-70% and 3-5% respectively (1899a). Pound (1899, p. 100) gave an even lower figure, viz. 1% on a total of over 30,000 head protectively inoculated. He also published a list of percentage losses (0.5-5%) experienced by a number of Queensland graziers. Dodd, several years later (1908), mentioned that during nine months of 1908 the average mortality in this State was 1.98% in the case of highly susceptible animals (that is, those from herds which had not contracted fever though in fevered districts), and 0.58 in the case of partially susceptible animals (*i.e.*, those from herds in which tick fever was known to have appeared), while the average total loss from inoculation amongst the animals of both classes was about 1.5%. In 1909 (Dodd, 1909, p. 85) he gave the average loss for 1908-9 as being only slightly over 1%†. Mortality is especially high in older animals, in bulls and in very fat or very thin cattle (Tidswell, 1899a).

The amount of resistance to tick fever displayed by cattle has been summarised thus by Pound (1897, p. 473): "When ticks first appear in a herd the first animals to succumb to tick fever are bulls, especially the old ones; next in order come breeding cattle (cows); then bullocks and spayed cows; but the least susceptible of all are the young animals, and practically speaking, there is little or no mortality from tick fever among yearlings or calves at foot."

*Smith and Kilborne (1893, p. 274) in their account of an outbreak in U.S.A., stated that natural immunity of cattle more than a year old in the case of animals outside of tick-infested areas and which had not previously been tick-fevered, was so slight that the mortality in many cases was nearly 100%. Still, however, there were animals which had more or less immunity though they had never been previously exposed to the disease. Salmon (1899, p. 221), mentioned that 75-90% of adult cattle in fevered districts died of Texas fever in hot weather in the early days of the outbreak. G. Tucker (in Ann. Rep. Dept. Agr. Qld., 1916-7 (1917), pp. 88-9) referred to recent heavy losses in Northern Queensland owing to tick infestation.

†See also Editorial articles "Inoculation for tick fever" Q.A.J., 2, 1898, p. 517, *re* slight losses experienced.

In some cases extremely heavy losses have been experienced owing to the use of an unsuitable "bleeder" (as the animal from which the inoculating blood is periodically drawn, is termed); to conditions exciting the cattle just before or after inoculation; to carelessness which brings about contamination of inoculating blood; and to low condition of the inoculated cattle.

Tidswell (1900, p. 13) found that the amount of resistance to tick fever did not depend on controllable factors since "in certain animals the resistance was equally perfect though inoculation treatment had been different in each case; and on the other hand in certain other animals the resistance exhibited was very different although the inoculation treatment was the same in each case." His observations did not reveal correspondence between any special feature of inoculation and the amount of resistance obtained, the issue appearing to depend more on the individual peculiarities of the animals than upon anything under human control. He went on to say that "It is known that the infectivity of the blood of inoculated animals does not depend on controllable factors. The duration of infectivity does not depend necessarily upon the source of inoculating blood nor on the amount used at one time nor on the total amount used on several occasions nor on the number of inoculations, nor the severity of the reaction, nor the kind of blood used (whether "recovered blood" or "virulent blood," *i.e.*, blood taken from an animal during the height of the fever). Loss of infectivity does not imply loss of protection and the protection of the mother does not imply protection of the offspring. . . . From these various observations it appeared that the retention or loss of infectivity had no dependence upon any of the controllable factors of inoculation. One is forced to conclude that this feature like the protection is a matter of idiosyncrasy." (Tidswell, 1900, p. 14, 15).

The same ideas are expressed by Stewart and others (1917, pp. 12-13) who state that the infectivity of recovered blood varies both in degree and duration in individual beasts; and that the protection produced is not absolute but is more of the nature of a tolerance than of an immunity, its duration and degree being subject to variation

and apparently largely depending on the idiosyncrasy of the animal. Hunt (1898, p. 452) stated that probably individual animals differ somewhat in natural susceptibility to tick fever and perhaps various breeds of animals differ also, just as individuals and races of men differ in natural susceptibility to any given disease or noxious influence; but that he was not aware that constitution, breed or colour had been proved to have any protective influence or that there was any special protective virtue in one class of country over another except in so far as it might be unfavourable or otherwise to the life of the cattle tick. Cattle from all classes of country were attacked alike, when removed to places where the ticks were fever carriers.

As already mentioned, resistance to tick fever is known to be most satisfactorily attained during early life. Young calves have great powers of resistance and may pass through an attack so mild in form as to be unnoticed by an ordinary observer. Dodd (1908, p. 6) suggests that this may be partly due to the great activity of young animals in producing blood cells counterbalancing the destruction of erythrocytes by the piroplasm.

Practically all cattle in permanently tick-infested districts of Queensland are now "immune" (Pound, 1899, p. 99; Dodd, 1904) and the losses that are occasionally reported are generally due to the break-down of "immunity" by some means such as over-driving, injury, starvation, rough handling, want of water, etc., or the introduction of susceptible animals (Dodd, 1908, p. 1, p. 6).

Pound (1899, p. 103) has given an instance of the occurrence of what he terms hereditary immunity, but the context shows that he really means to state that calves are occasionally born "immune," that is, that they have actually suffered from an attack of tick fever while in utero, due to the passage of piroplasms through the maternal placenta.

To sum up: There exists in many cattle a "resistance" more or less marked, to tick fever, such resistance depending on age, sex, sexual development, food supply, contentment, general health and apparently on some individual characteristic.

TICK WORRY.

In addition to tick fever, ticks may cause tick worry. The two conditions may occur independently but they are generally associated in the tick-fevered districts in this State. As already stated, tick fever may be produced without the agency of ticks, *e.g.*, by inoculation of cattle with ox-blood containing the parasite. The other condition is the result of tick infestation apart from the presence of *Babesia*.

The names tick poverty and tick anæmia are often applied to it, particularly to the more serious stages. As one would expect, ticks set up a local irritation which may cause marked uneasiness according to the degree and site of the infestation and according to the individual animal affected. The attacked areas may become infected by pus-producing organisms and thus tick sores arise. Sometimes these latter are extensive and are reported to become sometimes flyblown (Hunt & Collins, 1896, p. 27 ; Stewart, 1906 ; Tidswell, 1898 ; Stewart and others, 1917, p. 16).

Apart from lesions just referred to, there may be tick anæmia or poverty where the health of the infested animal becomes seriously affected, the vitality being lowered and condition lost, while the anæmia produced may lead to exhaustion and even death. As already mentioned, tick fever is usually co-existent though generally in a mild chronic form (the animals being in the so-called "immune" condition), but in the early days of the tick outbreak in Queensland Dr. Hunt was able to show that ticks in fever-free areas (*i.e.*, in areas where ticks were not pathogenic) caused cattle to lose condition and sometimes die, and that the blood of such animals when inoculated into healthy animals did not cause piroplasmiasis, while those which survived the tick poverty were not protected against tick fever. The two complaints are distinct (Hunt, 1898*a* ; 1898, p. 449 ; 1898, p. 116-118 ; 1899*c*, p. 758 ; 1898*c* ; Gordon, 1899, p. 92 ; Thompson, 1899, p. 742 ; Tidswell, 1899, p. 5 ; 1899*b*, p. 749 ; 1900, p. 112 ; Stewart, 1906, pp. 1155-1157). Pound has drawn attention to the fact that protective inoculation protects cattle against piroplasmiasis and not against tick attacks, immune animals having been known to die of tick anæmia following gross infestation (1899, p. 107).

HABITUATION OF CATTLE TO TICK INFESTATION.

Hunt says (1899, p. 118) that two things only appear to be effective against tick poverty—habituation and dipping. “By use and wont, cattle become to a great extent tick proof and by dipping they may be relieved from time to time till this tick proof condition is established. . . . The comparative immunity to tick irritation which comes of habituation, does not necessarily afford any protection against Texas fever.” The same idea had already been expressed by him in 1898 (1898, p. 450). Pound (1899, p. 117) stated that some immunised cattle in grossly-infested districts were in no way inconvenienced by tick infestation while others became gradually inured to the irritation and annoyance caused by the ticks, more particularly in their larval stages. Though dips are of unquestionable value in combating the poverty from gross infestation, they are quite ineffective in protecting cattle from the fever (Hunt, 1898, p. 450).

“It is said that in time the cattle become habituated to ticks and do not suffer from the effect first described (tick worry and tick sores). I understand that their acquisition of this satisfactory state implies fatness or at least good condition. It is so far in keeping with this statement that the few animals in our herd which remained fairly fat suffered least. But I could not decide. . . . whether the animals did not suffer because they remained fat, or remained fat because they did not suffer. They appeared to harbour few ticks, and it is at least a plausible supposition that the maintenance of a healthy skin, with plenty of fat under it, and normal secretion of fatty sebaceous matter upon it, affords an undesirable and less tenable resting place for ticks than when the functions of the skin are less perfectly discharged owing to leanness and ill health.” (Tidswell, 1900, p. 12).

Stewart (1906, p. 1156) has mentioned that cattle newly exposed to infestation not only suffer more from tick irritation than those accustomed to ticky pastures, but become more grossly infested, while those born and reared on infested pastures seem to acquire a certain tolerance to the tick.

Nuttall and Strickland* when referring to the toxic effects following the bites of *Argas persicus* which attacks man (and poultry), mentioned that strangers to tick-infested districts suffer more than others do, reminding one of the kind of immunity to mosquito bites experienced by many people—a form of habituation. This supported the view that ticks give off something of the nature of a posion when inflicting their bites.

It is a common report in Queensland that ticks, mosquitoes and even leeches will much more readily attack a townsman in preference to a “bushman” when the two are in company in a scrub—the explanation being almost certainly due to the existence of a greater or less degree of immunity, probably the result of previous attacks.

TICK POISON.

Tidswell (1899, p. 5) in commenting on the greater virulence of piroplasma infection by ticks over infection by inoculation, was led to suspect that ticks themselves might have some injurious effect apart from causing tick fever and that such effect was not a question of anæmia caused by the amount of blood lost, since that loss is comparatively slowly brought about and the time taken would permit regenerative activity of the host tissues. He suggested the possibility of some poison being injected by the tick and mentioned the well known effect often produced in dogs in this continent by the attack of ticks belonging to a certain species (*Ixodes holocyclus* Neum).

The possibility of the cattle tick injecting a poison and thus setting up a toxæmia was mentioned also by Hunt (1898, p. 448), by Thompson (1899, p. 742), and by Schroeder (1906, p. 59). In accounting for tick worry J. D. Stewart (1906, p. 1156) says, “In our present knowledge the mechanical irritation caused by the ticks in their attachment, the loss of blood extracted by them, and particularly by the maturing females, together with the effects of toxines absorbed from the sloughing wounds, might reasonably be accepted as sufficient to account for the condition. It is, however, possible that the tick injects a secretion when it attaches itself. . . .”

*Nuttall and Strickland, Parasitol., 1, 1908, p. 302.

That some ticks do inject a toxic substance, is now well-known. Nuttall* in referring to the effects (which commonly include paralysis—"tick paralysis") stated that they may prove to be due either to a toxin emanating from the tick or to a specific virus. He gave the name "tick bite fever" to the condition set up. A tick immunity becomes subsequently established. Tick bite fever is referred to by Brumpt† as occurring in man in South Africa, as a result of infestation by larvæ of *Margaropus* (i.e., *Boophilus*) *decoloratus* and also by *Rhipicephalus* *simus*, immunity following.

There are many published references to the effects on man and domesticated animals resulting from tick bites in countries other than Australia‡.

The best known Australian example is *Ixodes holocyclus* Neum., commonly called in Eastern Australia the scrub tick or bottle tick. It frequently attacks man, sometimes with fatal results.** Dogs are especially liable to

*Nuttall, G. On symptoms following tick bites in man. *Parasitology*, 4, 1911, pp. 89-93 (re *Amblyomma* and *Boophilus*).

†Brumpt. *Precis de Parasitologie*. Paris, 1913, p. 581-2 (refers to work of various observers).

‡Nuttall, 1911, *l.c.*; Nuttall, Tick paralysis in man and animals, *Parasitology*, 7, 1914, pp. 95-104; Hadwen, On Tick paralysis in sheep and man following the bites of *Dermacentor venustus*. *Parasitol.*, 6, 1913, pp. 283-297; Nuttall and Hadwen, Experimental tick paralysis in the dog (from *Dermacentor venustus*). *Parasitol.*, 6, 1913, pp. 298-301; Nuttall, Biology of Ixodidae, *Parasitol.*, 6, 1913 (pp. 84-5 re bites of *Ixodes putus*); Sant Anna, On a disease in man following tick bites and occurring in Lourenço Marques, *Parasitol.*, 4, 1911, p. 87-8; Nuttall and Strickland, On the presence of an anticoagulin in the salivary glands and intestine of *Argas persicus*. *Parasitol.*, 1, 1908, pp. 302-10 (references to tick bites and toxic effects, p. 302); Nuttall, Warburton and others, Ticks, a Monogr. Ixodoidea, part I., 1908, pp. 85-8, 92-4 (*Argas*); pp. 98, 102-4 (*Ornithodoros*); part 2., p. 313, etc. (*Ixodes*); Todd, Tick paralysis. *Jour. Parasit.*, 1, 1915, p. 55; McCaffrey, The effect of tick bites on man. *Jour. Parasit.*, 2, 1916, p. 193-4 (*Dermacentor venustus*); Herms, The Pajaroello tick (*Ornithodoros coriaceus* K.) *Jour. Parasit.*, 2, 1916, pp. 137-142 (effects on man and various experimental animals).

**J. B. Cleland, *Jour. Trop. Med. Hyg.*, 16, 1913, pp. 43-5; 188-9, and in Fantham, Stevens and Theobald, *Animal Parasites of Man*, 1916, p. 499; Injuries and diseases of man in Australia, attributable to animals. *Austr. Med. Gaz.*, Sept., 1912; J. Bancroft. Queensland Ticks and Tick blindness, *Aust. Med. Gaz.*, Nov., 1884; Anderson Stuart, P.R.S., N.S.W., 28, 1894 (pp. 10-11 re "poison of the Australian bush tick.")

its effects, paralysis and death being usual. Other animals are attacked, sometimes fatally, *e.g.*, cats, pigs, horses and cattle (especially while young), and even ducks.*

Having in mind certain resemblances between the effects produced in dogs by this tick and those caused by the fowl tick *Argus persicus* (*A. americana*) in domestic poultry through the introduction of *Spirochaeta gallinarum* which causes fowl tick fever, Dr. Cleland and the senior author (while in Sydney in 1910) carefully examined blood from affected dogs, but failed to detect the presence of any spirochaetes. Considerable experimental work relating to this tick was carried out by T. L. Bancroft.† The effects are almost certainly due to the injection of some poison. Immunity commonly follows recovery from bites. Mr. W. Davidson has kindly forwarded information (16th October, 1918), relating to the establishment of such a condition in dogs in his district (Tambourine Mountain): "So far as I have observed with regard to dogs and scrub ticks after an experience up here of over 23 years, it appears that if you extract the first scrub tick from a dog before it has been fixed more than about 24 hours, no bad results follow; if later you extract the second tick that becomes fixed, before it has been in, say, 48 hours no bad results follow; and if on the third occasion you extract the tick just as it begins to assume a rather greyish swollen abdomen (the first signs of incipient engorgement) no harmful results are produced, and you may safely assume that your dog is immune. If you have a valuable dog this is by far the best method to adopt to protect him, but it means looking over him carefully every day. . . . Wild animals appear to be immune to the attacks of scrub ticks, *e.g.*, dingoes, iguanas and carpet snakes are generally more or less infested and never seem to suffer. I have

*T. L. Bancroft, *Queenslander*, 3rd Jan. 1891, *Brit. Med. Jour.*, 16th May, 1191. . . . also quoted in Neumann, *Parasites, etc.*, of domesticated animals (Engl. transl. by Fleming), 1892, pp. 103-4. . . .; H. Tryon, in *Ann. Reports Dept. Agr. Q'land*, 1911 (p. 80, fatal to calves); 1917 (p. 54, fatal to ducks); *etc.*; R.S.C., 1911, evidence by Pound (p. 23, dogs and fowls); and by Ramm (p. 2, foals, pigs, dogs, *etc.* ‡ 49, man, *etc.*); Editorial, *Cure for tick poison*, *Q.A.J.*, 22, 1909, p. 105-6.

†T. L. Bancroft, *l.c.*

reason to assume that the latter would never be affected at any time or under any circumstances."

Tryon* mentioned that a large cattle tick, probably *Amblyomma* sp., was reported as killing cattle in North Queensland, even when very few of them were present on the animals.

It is known that an anticoagulin occurs in certain ticks. Sabbatini† in 1898 isolated such a substance from *Ixodes ricinus* and found that certain symptoms followed its injection into various animals, dogs being especially susceptible, cats less so, while sheep and cattle were relatively resistant. Nuttall and Strickland‡ referred to the presence of an anticoagulin in the salivary glands and intestine of *Argas* and *Ornithodoros*.

Christophers** reported that the coxal secretion of *Ornithodoros savignyi* possessed anticoagulative properties. Kunssberg†† found that the anticoagulin was produced by certain gland cells in the salivary glands of *Ixodes* and *Ornithodoros*. Cornwall and Patton ‡‡ followed up Sabbatini's work and asked the question as to whether the salivary anticoagulin was the substance which caused the irritation following the bite of a blood-sucking arthropod.

We have carried out a series of experiments with *Boophilus australis* along the lines of those published by Nuttall and Strickland, and have found that an anticoagulin exists in the salivary and Gene's gland but that its action on human blood is much less pronounced than that of *Argas*. This is to be expected, owing to the difference in the feeding habits of the two ticks.

*Tryon, Ann. Rep. Dept. Agr. Q'land, 1915-6 (1916), p. 50.

†Sabbatini, Fermento anticoagulante dell *Ixodes ricinus*. Arch. Ital. biol. Turin, 31, 1899—abstract in Nuttall and Strickland, Parasitol. 1, 1908, pp. 303-4—also referred to by Cornwall and Patton, 1914.

‡Nuttall and Strickland, l.c., 1908, pp. 302-310.

**Christophers, S. Anatomy and histology of ticks. Sci. Memoirs Med. San. Dept., India, No. 23, 1906, p. 45.

††Kunssberg, K. Eine Anticoagulindruse bei Zecken, Zool. Anz., 38, 1911, pp. 263-8.

‡‡Cornwall, J. and Patton, W. S. Some observations on the salivary secretion of the commoner blood-sucking insects and ticks. Ind. Jour. Med. Research, 2 (2), 1914, pp. 569-593. (Argas, p. 583-4).

The fact that immunity becomes established in the case of some ticks is evidence that some substance is injected by the tick. It is reasonable to suppose that the material acts as an antigen stimulating the production of an antibody (anti-tick toxin) which can combine with the tick toxin and thus confer an immunity.

In many cases, a more or less marked eosinophilia is produced by the action of internal parasites*, and in the case of at least one of them (hydatids) the blood serum has become altered to such an extent that the precipitin reaction can be made use of to detect the presence of Echinococci in the patient†.

Zinsser‡ has given a list of the more important substances which, when on injection into the blood of an animal, lead to the formation of a specific antitoxin or toxin-neutralising body, one such substance being spider poison. It seems to us reasonable to expect that such reactions might be given by ticky cattle. It is proposed, with the assistance of Dr. H. B. Bradley, of the Bureau of Microbiology, Brisbane, to test the precipitin reaction, using the blood of cattle from non-infected districts (*e.g.*, N.S. Wales), from ordinary infested cattle and from strongly resistant animals. We must remember, however, that "the various antibodies are usually produced with more avidity by certain tissues than by others," and that "antibody formation may be of strictly local character depending upon the point where the antigen is injected."**

Should such a reaction be obtained from the blood, then one might consider the possibility of using an animal whose

*Stitt, Practical Bacteriology, Blood work and Animal parasitology, 1918, p. 264; S. Hawden ("Natural Occurrence of eosinophilias," Journ. Parasitol, 4, 1918, p. 135-7) has shown that the injection below the skin of juices obtained from Hypoderma larvæ which nourish themselves in the subcutaneous tissues of suitable hosts, causes an eosinophilia, the eosinophils apparently playing an important part in neutralising toxins from parasites.

†Welsh and Chapman, Austr. Med. Gaz., 27, 1908, p. 1 (Human); Weinberg and Veillard, Sur le diagnostic de l'échinococcus chez le dromedaire, Bull. Soc. Méd. Vet., 86, p. 50-1, Abstract in Jour. Trop. Vet. Sci., 4, 1909, p. 603 (Camel, sheep).

‡H. Zinsser, Infection and Resistance, 1918, pp. 86-7.

**C. Marshall, Microbiology, 1917, p. 699.

blood was strongly antitoxic to ticks, as a "bleeder" for providing blood to inoculate tick-infested stock and confer some degree of resistance—a passive immunity. The production of such antibody in the case of most ticky cattle is probably slow.

After mentioning that we may justly assume that natural resistance may be largely a matter of inheritance, Zinsser* goes on to say that natural immunity, unlike acquired immunity, cannot be passively transferred from one animal to another and implies therefore a fundamental cellular difference rather than a condition depending merely upon antibodies circulating in the blood.

Some graziers and dairy farmers maintain that if animals in fair condition be allowed to remain in ticky pastures without being treated in any way for tick infestation, such animals would become not merely habituated to ticks, but actually resistant. The cattle tick apparently reached Australia along with the Brahmin cattle introduced into the Northern Territory, and yet that particular breed is admitted to possess a marked resistance to *Boophilus*. Perhaps this resistance arose naturally in the manner just indicated. Marshall† points out that antibodies may be transferred from the mother to the young before birth, but only after foetal circulation has become established, being carried from the maternal blood through the placenta into the offspring.

It does not seem to be an unreasonable suggestion that, as a result of continued light or moderate infection, animals which manage to maintain condition, may eventually develop more or less resistance to tick infestation. It may be urged that the tick is an ectoparasite and not an entozoon, but the distinction between it and a haematozoon in regard to food supply is really very slight, since the mouth parts of the tick are as truly bathed in plasma as is the absorptive surface of an internal blood parasite. If this point of view be correct then the use of dips to free cattle from tick infestation, though admittedly valuable as a temporary measure, really prevents the establishment of more or less

*H. Zinsser, *Infection and Resistance*, 1918, p. 56, 58.

†Marshall, *l.c.*, p. 699.

permanent resistance to tick attack.* However, when once such resistance is firmly established, it is hardly likely that dipping would destroy or suppress it (provided the animal's condition be maintained) unless the arsenic which—as stated later in this paper—becomes to some extent accumulated in the subcutaneous tissues, actually interferes with the action of, or destroys, the antitick substances.

TICK RESISTANCE.

In speaking of natural resistance to bacterial invasion, Zinsser† referred to the very different results arising from invasion of different individuals by a given species of micro-organism whereas the same individual may be highly resistant to certain organisms but very susceptible to others; while “even in reactions with one and the same micro-organism, the susceptibility or resistance of the individual may be determined by variations in the physiological state, or by environmental conditions under which the two factors—invader and invaded—are brought together. . . . Within the same race or species, an epidemic sweeping through a community will kill many individuals, and leave others unscathed. Such differences point to variations in the defensive mechanism since the invader in these cases is the same.” There may be specific (*i.e.*, belonging to the species), racial and individual natural immunity. He points out‡ that in the case of human beings it is probable that individual differences in resistance are due, “not to any *fundamental* individual variations, but rather to such fortuitous factors as nutrition, metabolic fluctuations, temporary physical depression, fatigue, or chilling.” These remarks would apply equally to tick invasion, since we have already shown that cattle may become habituated to tick and we know that in many herds there are to be found one or more individuals which are markedly resistant to tick infestation.

*This statement must not be construed to mean that we advocate the abolition of dipping. We believe that, in the present state of our knowledge regarding tick control, systematic dipping, combined with a satisfactory rotation of paddocks, is the most efficient method of attacking, on a large scale, the problem of tick eradication.

†Zinsser, *l.c.*, p. 49, 50.

‡Zinsser, *l.c.*, p. 59.

There has been considerable notice given in the public press of Queensland and elsewhere as well as in official publications, to the statements of Mr. G. W. Munro Hull, of Eumundi, who claims to possess a herd of tick-resisting cattle. In an article in the *Queensland Agricultural Journal* of September, 1912 (pp. 294-6) he called attention to the presence amongst his cows of a certain number of animals which he claimed remained free from ticks, whilst other animals were infested. He there stated that such a tick-resisting condition was produced by vaccinating the animals with a "particular organism"—"a tick destroying microbe"—contained in "lymph from tiny vesicles" which appeared periodically on the escutcheon and dewlap of the first resistant cow he had noticed in his herd. "While untreated stock shewed the ravages of ticks on their necks and flanks, the treated stock grew sleek and clean-coated and although many of them have not been sprayed or dipped for the past 18 months they shew no signs of tick" (p. 294). Any ticks that adhered to such vaccinated stock had a very short life, larval ticks dying and falling off in a few days after attachment. Rarely a tick might mature on such beasts and eggs might be laid but none had hatched. He drew attention to the peculiarity that these vesicles should be apparent only on the escutcheon and dewlap, two favourite habits of the tick itself. Vaccinated animals had been turned out by him into open country for a couple of months at a time but always maintained their freedom from ticks, while wandering stock were heavily infested and some had actually died of tick worry and tick poverty, even though there was abundance of fodder. He claimed that in two cases he had "immune calves from vaccinated cattle. One vaccinated cow, her daughter and granddaughter all clean," but admitted that these cases were not enough to enable him to state whether the condition was hereditarily transmitted.

A little later Mr. Hull's claims were widened. The following list of those made by him for the cows Clover and Tinkerbelle is contained in Parliamentary papers, Queensland, 1914, Vol. 2, pp. 941-3; a report by Mr. C. J. Pound on these claims being also included in the publication (P.R. 1914):

1. These cattle never mature more than a few odd female cattle ticks during the whole course of a year.
2. They never require any attention as regards the tick.
3. They never need dipping and may be turned out on any country for indefinite periods without suffering any ill effects from cattle ticks.
4. They are regularly and heavily infested (or attacked) by millions of larval ticks.
5. With the exceptions mentioned above (No. 1) these infesting ticks die when still very minute.
6. Probably in the pupa stage (*i.e.*, nymph stage).
7. The cattle remain at all times sleek and clean in appearance, without blemish of any description.
8. That this peculiarity is transmitted in every case to their progeny.
9. That this peculiarity does not develop in their progeny until after the first year of their life.
10. That this peculiarity is transmissible by contact, *i.e.*, by natural infection, and by vaccination.
11. That the source of infection and vaccination is not a state of dermatitis produced by excessive tick worry.
12. That the few odd ticks found to mature on these cattle are not "survivors" but are such as have developed on ordinary cattle, have become displaced without mutilation, and have re-attacked these special cattle.
- 13, 14, and 15. Of no importance.
16. That regular trials, extending without a break for three years, to hatch the eggs laid by the few odd mature females found on these cattle have invariably been failures.
17. That no difficulty was experienced in hatching control eggs from ordinary cattle.
18. That during the winter months these cattle will mature more female ticks than in summer when ticks are most active.
19. That temperature tests made in winter with a ground temperature of 53 degrees F., showed that these cattle invariably ranged from one degree to $2\frac{1}{2}$ degrees higher than the ordinary cattle tested at the same time.

20. That when the tests were made ticks were wholly absent from ordinary stock, but were found in small numbers on all the special cattle under test (minimum 3, maximum 7).

21. That I estimate the total possible crop of female ticks per cow for the year to be from 50-100 only.

22. That if all the stock on a farm or in the State were infected with this peculiarity the cattle tick would be exterminated in a single season.

23, 24, and 25. Of no importance.

Mr. C. J. Pound, Government Bacteriologist, Department of Agriculture, Queensland, who had two of Mr. Hull's cattle, Clover and Tinkerbelle, under his control for some time, adversely reported on the claims in so far as they might be held to apply to these two animals specially selected by Mr. Hull as examples of tick resistant cattle.

Mr. Pound's findings were as follows:—

Claims, Nos 1, 5, 6, 21. The two cows were placed in a ticky paddock for 27 days and then removed to, and kept in, stalls for 25 days. During 23 days of the latter period 230 fully mature ticks were taken from Clover and 860 from Tinkerbelle while large numbers dropped off and were found on the floors of the stalls, these not being included in the totals.

Nos. 2 and 3. As a result of 27 days exposure in a ticky paddock these two cows became so badly tick infested and so suffered from tick worry that dipping and spraying would certainly have been justified.

No. 4. The degree of infestation depends entirely on the conditions of environment.

No. 7. On each occasion that the two cows were exposed to ticky pastures they became covered with sores while portions of the skin were denuded of hair.

No. 8 and 9. Clover's calf (13 months old in August, 1914) has been more or less heavily tick-infested since it was a few weeks old.

No. 10. A number of cattle, young and old, and of either sex, running with these two cows have not acquired the so-called tick-killing property, nor had he been successful in transmitting the alleged immunity by vaccination.

No. 11. The skin lesions referred to by Mr. Hull and from which he obtained his alleged vaccine, are caused by ticks, since if the cattle be kept free from ticks then no such lesions will develop.

No. 12. In one experiment the cows were kept free from contact with any other animal and yet developed ticks. It is only on rare occasions and with the greatest difficulty that mature ticks, after removal, can be made to reattach themselves to the same or other animal while with partly or fully engorged females this is an impossibility.

Nos. 16 and 17. Eggs laid by ticks taken from the two cows hatch out as rapidly at all seasons of the year as eggs of ticks taken from other cattle.

Nos. 18 and 20. There is practically no difference between the nature of the infestation of the so-called proof cattle and that of ordinary cattle during either the winter or summer months.

No. 19. Hull's statements in regard to increase in temperature were not borne out by Pound's observations.

No. 21. See No. 1.

No. 22. The statement is refuted by the fact that ticks will readily mature on the so-called proof cattle, since 135 fully mature ticks were recently taken off Tinkerbelle in one day.

Since we have not considered Mr. Hull's claims Nos. 13, 14, 15, 23, 24 and 25, as having any bearing on our subject we have not mentioned Mr. Pound's replies to them.

We recently asked Mr. Hull to inform us as to which of the "claims" above mentioned are still maintained by him. In reply (dated 17-10-18) he quotes Nos. 1, 2, 3, 4, 6, 7, 10, 11, 14, 15, 18, 23, 24, in their entirety; in regard to No. 5 the ticks do not necessarily die while "very minute" as some continue to live and grow, but the majority of these do not become engorged and as a consequence are not fertile; No. 8 is modified to the extent that he admits the possibility of some cases of apparently hereditary transmission being really due to "contact"; No. 9 needs amendment since in one case the exudate made its appearance in the first year of a calf's life (Tinkerbelle III)—a tick free animal; in regard to No. 21 the estimate is excessive in many cases.

Our observations as well as our consideration of such evidence as we have been able to obtain from published and other sources, have led us to agree with Mr. Pound's criticisms in regard to Nos. 4, 8, 9, 10 (in part), 11 (in part), 12, (13, 14, 15, not considered in this paper though we agree with Mr. Pound in regard to them), 16, in part only, 19,—Nos. 23, 24, and 25 were not considered by us.

We can readily understand that most of the remainder of Mr. Pound's findings would be correct, if only *intense artificial infestation* be taken into account. We must emphasise the fact that Mr. Hull claims that his cattle do not *mature* ticks like other cattle under *ordinary natural infestation*.

We agree with Mr. Hull in regard to No. 1, 2, 3, provided condition of cattle be maintained; 5, as subsequently modified; 7, approximately correct; 8 and 9, apparently true in many cases; 21, approximately correct.

To sum up: Our observations have led us to the conclusion that the animals which Mr. Hull has designated as being resistant and which we have examined, do not mature more than a comparatively few ticks per season under conditions of natural infestation, and as a consequence do not require any treatment to prevent tick worry.

In subsequent official reports (1914, 1915, 1916) Pound made further reference to the claims, his remarks and observations being referred to later on in this paper when dealing with statements regarding various cows. (See under Clover, Tinkerbelle and their calves). The 1914 Report is the most important. In it Mr. Pound states (p. 112) that the numerous experiments carried out at Yeerongpilly prove conclusively that Mr. Hull's claim that the tick-resisting peculiarity is transmitted by contact, heredity or vaccination, is without foundation.

Mr. Hull's dissatisfaction with the Departmental findings (Par. Rept. 1914; Pound, 1914) led to the appointment of a Select Committee of the Queensland Legislative Assembly, 1915, which examined amongst others, a number of persons who had had some experience with Mr. Hull's cattle. The evidence given proved conflicting and contradictory and this led the Select Committee to recommend

the appointment of a small committee (consisting of Messrs. Tryon, Pound, Cory, Johnston, Steele and a nominee of Mr. Hull) to supervise and direct further investigations and experiments (R.S.C., 1915, p. iii).

In giving evidence, Mr. Hull restated his main claims, adding that he believed that the application of an arsenical dip or wash temporarily banished the condition of tick resistance (R.S.C., p. 8). One of us mentioned the more important claims in his evidence (R.S.C., p. 56-8).

The new committee, under the chairmanship of Mr. H. Tryon, and consisting of those above named (except Dr. Steele) formulated a scheme of work, but owing to circumstances which need not be referred to here, found itself unable to proceed. Its report was laid on the table of the House, 22nd December, 1916, but was not printed as a Parliamentary paper (Tryon, 1917, p. 53).

The senior author has been interested in Mr. Hull's claims for several years but has been able to give only intermittent attention to them owing to pressure of other duties. He has, however, been constantly in touch with Mr. Hull, and has paid frequent visits of inspection (1915-1917) to his farm at "Cudgerree," at Eumundi. The junior author was able to stay there for a prolonged period during the past tick season, January-February, 1918, and has made subsequent visits. Mr. Hull has afforded every possible assistance and has placed at our disposal all his records relating to the matter under discussion. The statements contained therein have been compared as far as could be done, with those contained in letters received from him since early in 1915, and with the observations made by both of us during our many visits.

The work outlined by one of us (Johnston, in R.S.C., p. 58-9) might be summarised thus :

- (1) To ascertain whether the tick resisting condition actually existed, *i.e.*, whether his so-called resistant cattle when placed under conditions of natural infestation, would become tick infested and mature ticks to such a degree as to require dipping or other treatment to prevent tick worry.
- (2) If tick resistance be present can it be transmitted ?

- (3) To ascertain whether the exudation mentioned by Mr. Hull is or is not merely that from an ordinary tick sore ; the relation, if any, of the exudation to tick infestation, climate, etc.; effect of dipping.

Does tick resistance actually occur ?

We have already brought forward evidence, when dealing with tick worry, that a certain degree of resistance is by no means uncommonly met with amongst cattle.

We propose firstly to examine the evidence available in regard to Mr. Hull's animals, viz., that collected by Messrs. Hull, Pound, Corser, Walker, ourselves and others who have had actual experience with such cattle ; secondly the experience of other Queensland farmers and dairymen in regard to tick resistance.

Tick resistance might be manifested by—

- (a) A failure to develop ticks or a particular species of ticks—really a tick immunity ;
- (b) A tendency towards light infestation when ordinary controls become heavily infested ;
- (c) A failure of female ticks to become fully matured (*i.e.* engorged) in such numbers as on controls under the same conditions of climate ;
- (d) A failure of such engorged ticks either to lay a normal number of eggs or to lay eggs showing a normal percentage of hatchings.

(a) We know there are many ticks which have very limited host relationships, *e.g.*, the cattle tick, *Boophilus annulatus*, with its several varieties or related species, including the Queensland cattle tick, *B. australis*, which is occasionally found in horses and sheep. Certain others prefer a particular host species but are not uncommonly found on other hosts, *e.g.*, some species of *Argas*, *Ixodes*, etc ; while certain others prefer a particular class of animals and occur only rarely outside that class, *e.g.*, *Aponomma* (on reptiles)—Still others seem to be indifferent as to the host, so long as it is an amniote vertebrate, *e.g.*, some of our Australian ticks. Some genera are practically restricted to certain classes of vertebrates, *e.g.*, many of those maturing

on Cheiroptera, birds and reptiles (*Eschatocephalus*, *Ceratixodes*, *Aponomma*). Then again many require to leave their hosts during certain stages of their development and must regain a suitable host (which need not necessarily belong to even the same order as the former host) for further development. However, the matter is simplified in regard to *Boophilus* since it passes through all its stages on one host animal.

We know that larval ticks may temporarily infest a great number of different hosts, *e.g.*, the larvæ of *B. australis* may be thus transferred by man, horses, cattle, sheep, marsupials, birds (such as quails, ibis, Charadriiform birds, etc.) Infestation by larvæ is then not a satisfactory criterion by itself. We will therefore discard it and use the remaining items for comparison.

Mr. Hull's resistant cattle.

We have endeavoured to collect information regarding these animals so as to be able to pass judgment on Mr. Hull's claims. The majority of the cattle referred to in this report have been subjected to the closest scrutiny by one of us for many weeks during the tick season, while in regard to them as well as other cattle formerly in Mr. Hull's possession, a number of casual inspections were also made (1915-1918).

Peony. The first cow which Mr. Hull claims to have noted as a "tick-killer" was Peony, resistance being observed in 1908. The offspring include Tinkerbelle and Poppy (*q.v.*).

Clover. A black and white cow was bought at Pinkenba in 1908. This was one of the original cows found by Mr. Hull to be tick resistant, and was selected by him as a suitable subject for experiment, being sold to the Queensland Government in December, 1912.

Tinkerbelle. Brindle cow, born 1908, dam Peony, became clean by contact with the above (according to Mr. Hull) and was sold with Clover for experimental purposes. Mr. A. H. Cory, who was in charge of the Yeerongpilly Experimental Station in the absence of Mr. Pound, concluded the arrangements and as an initial experiment had

the cows placed in a ticky paddock to test their resistance to natural infestation. About this time Mr. Pound returned from America and resumed charge.

On arrival at Yeerongpilly on December 19th, 1912, both cows were examined by officers of the Department and found "to be covered more or less all over their bodies with small sores, the result of the attacks of ticks. This condition was pronounced on the escutcheon, udder and dewlap." (Pound, 1914, p. 110). The cows with two controls were then placed in a tick-infested paddock, the property of Mr. Chambers, where they remained until January 21st, 1913. During this period of 33 days they were examined daily by Mr. Thorn and one of the assistants and on two occasions were seen by Mr. Cory who reported that "up to that period a few ticks which were developing, were found on the cows" (Cory, R.S.C., 1915, p. 51).

A letter dated March 29th, 1917, and signed by H. Chambers, Yeerongpilly, appeared in the *Brisbane Daily Mail*, and *Courier* in which the writer stated, ". . . I would like to place before the public certain facts which came under my notice, with reference to two cows purchased by the Queensland Government from Mr. Munro Hull for the Experimental Farm at Yeerongpilly. These cows were sent to my paddock on December 18th (20th ?), 1912, and taken away on January 20th, (21st ?), 1913. During that time an officer from the Experimental Farm and myself examined them almost every day, and a very few small ticks were found. These disappeared in a day or so. On April 14th, 1913, one of the cows before mentioned was again sent to my paddock and the other on April 24th. No. 1 was taken away on May 12th and the other was taken away on July 17th, or four weeks and 12 weeks respectively. During that time only two very small ticks were found on one of the cows, which disappeared as they had done previously. The two cows were again sent to my paddock on May 12th, 1914, and taken away on June 8th, no ticks were found on them. My cattle were running with them while they were in my care and mine were badly infested, so much so that I was obliged most of the time to wash every three weeks. I hold no brief for Mr. Munro Hull, and my sole reason for writing this is that I am quite convinced,

because I have had many years' experience with tick infested cattle, that Mr. Munro Hull has discovered a remedy which I believe would be the means of reducing the ravages of the tick to a minimum and be of inestimable value to farmers and others engaged in the cattle industry. In conclusion I would suggest that stock owners arrange with Mr. Munro Hull for, say, four head of cattle and have a thorough test by sending them to two districts where ticks are known to be most active and numerous."

On January 21st, 1913, the cows (*i.e.*, experimental animals and controls) were removed, examined and officially reported to have shewn evidence of tick worry and tick infestation. A number of fully-developed ticks were removed from the cows, presumably Clover and Tinkerbelle. The fertility of these parasites and the vitality of their offspring was found to be normal. The cows were then re-infested artificially with larval ticks (Pound, 1914, p. 110) which matured and likewise showed unimpaired fertility.

On May 12th, 1913, Clover was placed in a ticky paddock at Oxley: on June 14th she had a calf. On July 19th both animals were found on examination to be tick infested. In August, 1913, both cows were sprayed (Thorn, R.S.C., 1915, p. 29).

In February, 1913, Mr. Swayne, as Secretary of the Parliamentary Farmers' Union, wrote to Mr. White—then Secretary for Agriculture—suggesting that the cows be sent to Mr. Walker, M.L.A., and Mr. Corser, M.L.A. to see whether Mr. Hull's claim, that the cows remain free from tick infestation, would be demonstrated by a second trial in another district and under different conditions. In September, 1913, this suggestion was carried out, Clover being sent to Wetheron and Tinkerbelle to Traveston.

Clover. As the House was sitting Mr. Corser was away much of the time, but a local committee was formed consisting of members of the Wetheron Progress Association and one of the men on the place. This Committee was allowed to examine the cow at any time. Mr. Corser inspected her on every occasion he was home and at no time during the cow's stay at Wetheron was a developed tick found on her (Corser, R.S.C., 1915, p. 61). Larval ticks

were observed but it was noticed that by the time they assumed the size of a pin's head a small sore would start to form at the point of attachment and the tick would dry away. Clover was in fairly low condition on arrival and although she was milking all the time and never dipped, picked or sprayed during the five months she was at Wetheron, she left in good condition. Mr. Corser's own herd with which Clover was running, became very heavily infested with ticks and would have been in extremely poor condition had they not been dipped at intervals.

On March 14th, 1914, Mr. Pound wrote *re* Clover: "I have the honour to report that Mr. Munro Hill's cow Clover was untrucked here yesterday from Wetheron where she had been under the care and observation of Mr. B. H. Corser, M.L.A., since September. Immediately on her arrival, in very good condition, she was run straight into the crush and examined, and as a result Mr. Thorn and myself found numbers of cattle ticks in various stages of development, some of them past the second moult which takes place on the fourteenth day after first attachment." (R.S.C., 1915, p. 64). Later Mr. Pound wired to Mr. Corser asking him to visit Brisbane and stating there was one developed tick on the cow. Following Mr. Watson's investigations, Mr. Corser visited Yeerongpilly and saw a number of developed ticks on Clover as well as on Tinkerbelle and other cattle. Mr. Corser also saw a calf of Clover's with fully developed ticks on it.

Tinkerbelle. Mr. Walker had an independent committee formed consisting of five or seven local people who had authority to go into the farm at any time and examine her. They met every Sunday and discussed the matter and "during the whole period I do not think you could discover ticks on her." (Walker, R.S.C., 1915, p. 16). Mr. Pound (R.S.C., 1915, p. 14) admitted that three days before the cow was returned to Yeerongpilly he visited Traveston and after a half-hour's examination failed to find any ticks on Tinkerbelle, but he was not, however, satisfied that the animal was free from them.

On arrival at Yeerongpilly she was put into the crush and examined by Inspector Carmody who stated that he could have picked off 500 ticks up to a fortnight old.

(Carmody, R.S.C., 1915, p. 35). Three weeks later—on April 20th—she was examined by Messrs. Walker and Carmody and five small adult ticks were found on her (R.S.C., 1915, p. 15).

On May 12th, 1914, the cows Clover and Tinkerbelle were again placed in a ticky paddock belonging to Mr. Chambers for 27 days (see Chamber's remarks quoted earlier). On June 8th they were brought into the stalls and subjected to daily examination. Mr. Walker was represented at these inspections by Mr. H. B. Watson who reported to him on the subject every week. Mr. Corser was unrepresented. During a period of 25 days Inspector Carmody and Mr. Watson made 30 examinations, 860 developed ticks being removed from Tinkerbelle (Watson, R.S.C., 1915, p. 32) and 230 from Clover (Carmody, R.S.C., 1915, p. 38). During this period "both cows were so covered with sores of a vesicular and pustular character, caused by tick irritation, that under ordinary circumstances dipping or spraying would have been justified" (Pound, 1914, p. 110).

Inspector Carmody after having examined the cows at Eumundi, stated (R.S.C., 1915, p. 38) that "the vesicles on Clover had the form of variola or ordinary cow pox. The pus came out something like variola or cow pox."

On July, 1914, both cows were sprayed (Thorn, R.S.C., 1915, p. 29). In May, 1915, Clover and Tinkerbelle were sent to Maryborough. In October, 1915, the Secretary of the Wide Bay and Burnett Pastoral and Agricultural Society reported to the Under Secretary as follows:—

"I have the honour to report that since their arrival here in May last the two cows, Clover and Tinkerbelle, have been depasturing at Messrs. Butcher and Rex's, of Alford Dairy, Oakhurst, near Maryborough.

"They were placed among the dairy herd and treated in every respect, except dipping, in the same way as the herd, being regularly milked. Clover is in calf and now dry, whilst Tinkerbelle is drying off. The former has developed a few odd matured ticks but Tinkerbelle has never matured one, whilst the cattle they have been running with have been alive with ticks, and required constant dipping. The health of the cattle has been good and they are both in excellent condition."

On December 10th, 1915, these cows were inspected at Messrs. Butcher and Rex's farm by Mr. A. J. Jones, M.L.A., Mr. Dymock, Mr. Page, M.H.R., and Mr. H. A. Jones, Secretary of the Show Society of Maryborough. Mr. A. J. Jones (R.S.C., 1915, p. 69) reported that Tinkerbell was heavily infested with fully-matured ticks. Both Mr. Butcher and Mr. Rex stated the cows had not been dipped during the seven months they were under observation. Mr. Butcher is also reported to have said that Tinkerbell had not matured ticks until that week. Mr. Jones reported that "Clover was as clean as a table." He searched her very carefully and could find no ticks on her. He noticed that a yellow substance had been exuding from her skin. "Her skin was lovely. She was in good condition and clean." (Jones, R.S.C., 1915, p. 69).

There seems to have been some misunderstanding about the names of these cows. We have received the following note from Mr. Butcher *re* Clover :—"This cow we had from the Agricultural Department. She carried a few ticks while in good condition but she was an old cow and got fairly poor and became a living mass of ticks and died." This was during the 1915 drought.

Of Tinkerbell, Mr. Butcher wrote :—"Tinkerbell I failed to ever find a tick on, although we were milking her twice a day." We communicated again with Mr. Butcher pointing out this apparent contradiction. His reply was to the effect that he and Mr. Rex had confused the names and had given them to Mr. Jones wrongly, so that Clover must be substituted for Tinkerbell and *vice versa* in all his (Mr. Jones') statements.

Tinkerbell was subsequently returned to Yeerongpilly.

Two heifers, aged $2\frac{1}{2}$ years and 6 months, the progeny of Clover and Tinkerbell respectively, were reported to be maturing ticks on artificial infestation (Thorn, R.S.C., 1915, p. 28). Clover's heifer was kept in a stall for observation and artificially infested (Pound, R.S.C., 1915, p.28).

The evidence given above is sufficient to justify the statement that under conditions of ordinary natural infestation, these cattle did not mature ticks in sufficient numbers to require any treatment to prevent tick worry.

Our examination of Mr. Hull's resistant stock:— During January and February of this year (1918) one of us, while enjoying the kind hospitality of Mr. and Mrs. Munro Hull, carefully collected all the engorged ticks to be seen on the resistant cows. The latter in most cases were examined both morning and afternoon, with the exception of a few non-milkers which were usually inspected only once daily.

The total numbers of engorged female ticks collected from January 16th to February 11th (inclusive) from the following cows were:—Baby, 0; Fairy, 3; Kittiwake, 3; Peewee, 2; Primrose, 0; Rainbow, 4; Rosie, 13; Sprite, 0; Squib, 30; Sunset, 18; Wallum, 0; Yellow, 1. Nine were taken from Dot in 12 days; and 64 from Spot (classed as non-resistant) in the total period. Dot, Rosie, Spot, and Squib, are young cows; Sunset is the least strongly resistant among the older animals; from the remaining nine cows only 13 fully-matured female ticks were removed during 26 days. One might object that these figures were evidence of the scarcity of ticks at "Cudgerree," but such was not the case since control cattle were fairly heavily infested at the same time.

In addition to the record of our observations made during that period we are including some made in March and June of this year (1918) and also some notes made over two years ago by one of us (in June, 1916), as well as information, (which we herein indicate) extracted from Mr. Hull's stock book.

Baby, born March, 1914; dam, Jessamine. An Ayrshire—Illawara cross; red roan with yellow skin. (Extensive exudate was first noticed in February, 1916; free from ticks in the following month. Stock book). June 24th, 1916: clean except for presence of a few small immature ticks; exudate* present.

From January 16th-31st, 1918, this cow was examined daily by one of us (except on 25th, 30th, and 31st), during which time no fully-matured female ticks were observed though a few males and nymphs were always to be found on close examination and one fair-sized female was taken

*For an account of this exudation, see later in this paper.

on January 16th. Fresh exudate was seen on the 16th and 17th. On February 1st she calved and from this date to 11th was examined twice daily, but no matured females were seen. Fresh exudate appeared on 9th and 10th. From March 18th-24th she was examined five times, numerous larvæ being visible on the escutcheon but no fully developed ticks were seen. Extensive exudate appeared on 20th. On June 7th she was again examined when two fully-matured females were found, while males and nymphs were fairly numerous on the backs of the legs.

Beauty, bought from M. Bourke, Rosewood, 1911; clean, February, 1915; a few ticks present, May, 1915; clean, November, 1915; ticky and sprayed, January, 1916; vaccinated from Sweetbriar, 20th January, 1916; exudate present, March, 1916. Stock book).

June 24th, 1916: plenty of small ticks on escutcheon and axillae but none seen engorged though Mr. Hull stated that some do occasionally become engorged. Sold, 1917.

Betsy, bought at Gympie, 1913. June 24th, 1916: though referred to by Mr. Hull as a ticky animal, only a few small ticks were observed, also some tick sores. Sold, 1917.

Buttercup, born 1907; dam, Old Spot by Jersey Bull. Light yellow Jersey with yellow skin.

This cow had been running with a mob of milkers at Downey's in a rough and hilly paddock with poor grass since January, 1916. The cattle were poor and had been badly infested with ticks, they were dipped a week previous to examination. Buttercup had never been dipped and though only in fair condition had remained free from ticks. No ticks could be found on date of examination (at Downey's), February 3rd, 1918. June 7th, 1918, examined at "Cudgerie": small ticks were fairly numerous. Fresh exudate visible. Died, October, 1918.

Cherry, bought at Ripley, 1909.

June 24th, 1916. Examined immediately on her return from several months' stay in a neighbouring ticky paddock and found to be ticky. Sold 1917.

Dawn, born August, 1910, dam, Sunbeam,—sire, Peter Pan. A red Shorthorn-Jersey strain.

(Vaccinated from "Marty," 13/12/13; sprayed, December, 1915; infested, January, 1916 (condition low); sprayed, January, 1916; patch of ticks on escutcheon, March, 1916 (condition low); clean—no trace of ticks, 7/4/16; condition prime, slight exudate, 4/11/16: condition prime, no ticks, 9/1/17; condition prime, few mature females, 19/3/17; February 10th, 1917, applied larvæ from ticks from "Sunset"; February 19th, 1917, about 80 visible; February 20th, 1917, only 10 maturing ticks by natural infestation, excluding dead nymphs and males; May 4th, 1917, vaccinated on neck and rump with serum from Isis and Sprite; May 30th, 1917, ticks not attacking escutcheon, rest of body heavily infested and maturing in normal quantities; May 30th, 1917, vaccinated from "Kittiwake"; June 6th, 1917, body heavily infested, escutcheon clean; June 18th, 1917, free from ticks; December 11th, 1917, clean. Stock book).

Examined by one of us (24/6/1916) immediately on her return to Eumundi after several months' sojourn in an ordinary ticky paddock, and found to be apparently clean. Dawn had been running since December, 1917, with a heifer calf in Martin's paddock which previously carried ticky stock. Inspected 3rd February, 1918, only a few nymphs could be found. Calf also clean.

Dot, born October, 1914; dam, Starling; a black Jersey cow with fine short hair. (Slight exudate, October and November, 1916. Stock book).

June 24th, 1916: Several small ticks seen, none engorged. Examined twice daily from January 16th-25th, 1918: nymphs and males and half-bloated females seen on all occasions while nine fully-matured females were removed during that period. Fresh exudate appeared on January 24th.

Fairy, born September, 1911; dam, Vixen. A yellow Jersey, a very ticky animal until last season (1917). (Vaccinated from "Sweetbriar," 2/3/15; sprayed for last time, February, 1916; extensive exudate observed, 14/11/16. Stock book).

On 24/6/16 we found many small and a few engorged ticks, as well as numerous small tick sores resembling pinpricks. With the latter were associated ticks and a fluid resembling "exudate."

This cow was examined regularly twice daily from January 17th-February 11th (except on January 22nd and February 2nd), 1918. One fully-developed female tick was removed on each of the following dates: January 17th, Feb. 5th and 6th; larvæ, nymphs, males and a few unbloated females were observed on almost all occasions. Fresh exudate was seen on January 17th, 18th, 20th, 24th, February 1st, 3rd, 5th, 8th, and 9th. From March 18th-24th, Fairy was examined four times. Numerous males and nymphs as well as a few unbloated females, were noticed on the escutcheon while six matured but very small females were removed. Exudate had been breaking out all over escutcheon which was encrusted with thick yellow scales and hard black scabs. Calved April 1918. On June 7th she was again examined; males were numerous and a few fully-developed female ticks were removed. It was noteworthy that the escutcheon was free from scabs and ticks.

Greedy, born March, 1914; dam, Ladybird. Roan cow with yellow skin. (Tick infested, March, 1916; clean, shewing exudate, November, 1916. Stock book).

Clean, with a few typical exuding areas (24/6/16). Examined in paddock on six occasions from January 16th—February 11th, 1918.—Males and nymphs present but no mature females were observed. Fresh exudate was seen on January 16th and February 9th. March, 1918, very clean. Calved May, 1918. June 7th, much tickier than on previous examination, males and immature ticks numerous, few mature females. No trace of exudate.

Jockey, born 1915; dam, Old Spot. A red cow with yellow skin.

When 18 months old (24/6/16) she was examined and found to be clean except for the presence of some nymphs on the escutcheon.

This cow was running out in the paddocks and was examined on seven occasions between January 16th-

February 11th, 1918. A mature female tick was removed on 28th January and another on 9th February; extremely few ticks in any stage could be found. March 18th-24th, calved. No trace of ticks except a few larvæ. Exudate extensive. June 7th, still very clean but more immature ticks were noticed than in March and a few mature females were removed. This cow is very strongly resistant for such a young animal.

In October, 1911, ten heifers were purchased from M. Bourke, Rosewood, by Mr. Hull, who reported that they were all ticky on arrival at Eumundi and were turned into a small scrub paddock with Clover, Tinkerbelle, Peony and other dry stock, for nine months. During this time they were not dipped or treated in any way for ticks. The results of this experiment were as follows:—

1. Rosewood .. died, 1912.
2. Mulga .. became resistant, 1913; died, 1915 (drought).
3. Cuckoo .. became resistant, 1914; sold, 1916.
4. Beauty .. became resistant, 1915; sold, 1917.
5. Misery .. remained ticky, died 1916.
6. Starling .. became resistant, 1915; sold, 1915 (drought).
7. Stormbird .. became resistant, 1913.
8. Seagull .. became resistant, 1914.
9. Peewee .. became resistant, 1914.
10. Kittiwake .. became resistant, 1913.

For condition of progeny of these cows see genealogical tables.

The four last named are still in Mr. Hull's possession; of these Peewee and Kittiwake were milkers and were examined regularly by us during our stay early in 1918.

Kittiwake, bought from M. Bourke, Rosewood, 1911. A black Jersey with a very black greasy skin.

On 24/6/16 a few larvæ and nymphs seen; no engorged ticks present; yellowish crystal-like exudate; also tick sores associated with a number of which and partly buried in the lymph were ticks.

From January 16th-February 11th, 1918, this cow was examined twice daily (except on 27th-30th January, inclusive). Males, nymphs and larvæ were always more or less in evidence but only three fully-matured females were observed, one being removed January 16th and two on February 5th. Tick sores appeared from time to time;

while a typical exudation occurred on January 17th, 23rd and 24th. This cow shows tick blisters as well as the typical exudate. Calved on February 2nd. On March 21st and 22nd this cow was examined; the escutcheon was covered with larvæ and nymphs while three mature females were removed on 21st and 13 on 22nd. On June 7th, large tick sores were visible on escutcheon; small ticks numerous; fully-matured females fairly numerous. The tick resisting power of this animal apparently had undergone diminution.

Peewee, bought from M. Bourke, Rosewood, 1911. Black Jersey with white belly. (This cow was running with Finch's milkers (a ticky herd) from October, 1916-May, 1917, during which time she was never dipped and remained free from ticks. Stock book).

On 24/6/16 a few mature and immature ticks were seen on escutcheon; also some tick sores but no definite exudation; the body was free from ticks.

Although this cow was examined regularly from January 16th-February 11th, 1918, being a milker for the whole period, there is very little to report about her condition. She remained consistently clean throughout. Males and immature stages were occasionally seen, a few unbloated females were observed on the escutcheon on January 31st and February 1st, while a fully-matured female was removed on February 9th and another on 10th. There was no exudate visible during this period. March 19th-24th: this cow was examined four times, males, nymphs and larvæ being found but no mature females. Fresh exudate was seen on 22nd and 24th. June 7th, examination disclosed a few unbloated females scattered over the body.

Primrose, born May, 1909; dam, Spot, by Jersey bull. A light yellow Jersey with yellow skin. (No ticks, 1914; condition low, few ticks, December, 1915; sprayed, January, 1916; clean, condition improved; exudate, February, 1916; tick sores, March, 1916; exudate, March, 1916; exudate pronounced, May and June, 1916; remained clean and in prime condition. Stock book).

On 24/6/16 free from ticks; exudate abundant on escutcheon. Examined daily from January 16th-February

11th, 1918. No ticks of any description were found on her. Fresh exudate appeared only once, on January 17th. Calved, January 26th. March 18th-24th : a few tick sores were visible on the escutcheon but the animal appeared perfectly free from ticks. June 7th : one mature female tick was removed and a few immature ticks were visible. No exudate present.

Rainbow, bought from Luke, Eumundi, 1912. Black Jersey with yellow skin. (Clean, 28th February, 1915 ; condition good, exudate evident, January, 1916 ; condition good, no exudate, February-May, 1916 ; condition good, exudate, November, 1916 ; condition good, slight exudate, May, 1917. Stock book.)

On 24/6/16 free from ticks ; exudation present. Examined, January 16th, 1918. Calved, January 20th. Examined twice daily from 21st January-11th February. During this period four fully-matured ticks were removed. Males, nymphs and larvæ were evident on many occasions. Fresh exudate was observed on February 8th. Sold March, 1918, to G. B. Wells, Eumundi.

Redwing, born, 1914 ; dam, Snailie.

On 24/6/16 a solitary engorged female and a few young ticks were seen—neither tick sores nor exudations were observed. Sold, 1917.

Rhinca, born, 1910 ; dam, Jessamine. A yellow Jersey with a white face ; yellow skin.

24/6/16 : Two engorged ticks found, a few immature parasites present.

January, 1918 : this cow had been running in a large paddock (Mr. Finch's) opposite " Cudgeree " with ordinary stock for almost twelve months. She was in good condition and not being milked during January and February, 1918. Four examinations were made. On one occasion one poorly developed female tick and several nymphs were found on the ear and shoulder ; while on the other occasions no ticks could be found. Fresh exudate was observed once ; the dry scales were seen on two other occasions. On 24th January, a number of Mr. Finch's milking stock were examined and found to be grossly infested with ticks ; Mr. Finch had been unable to dip for over three weeks owing

to the continued heavy rain and as a result large numbers of ticks were maturing on the cattle. Two of his cows were noted as especially free from ticks. Sold March, 1918, to G. B. Wells, Eumundi, who reported (October, 1918), that neither this cow nor Rainbow had carried more than an occasional odd tick while in his possession, though both had not been dipped, sprayed or washed.

Rosie, born July, 1915; dam, Primrose, by Robbie—Jersey bull. A light red cow with yellow skin. (Clean, November, 1916; clean, February, 1917; exudate extensive, very ticky close to vulva, November, 1917; exudate slight, clean, December, 1917. Stock book).

24/6/16: No mature ticks seen, exudate absent. Examined twice daily from January 16th-February 11th, 1918. Males, unbloated females, nymphs and larvæ were always present in small numbers. Thirteen fully-matured females were removed during this period. Exudate appeared on the 20th January and the 10th February. March 18th-24th: immature ticks abundant especially on the escutcheon; a few mature females were removed each day and as many as 25 were collected on one occasion. June 7th: immature ticks fairly numerous, but condition as regards ticks had improved since March.

Seagull, bought from M. Bourke, Rosewood, 1911. A light brindle Jersey-Shorthorn strain, with a yellow skin.

24/6/16: Quite clean—exudation present. Examined several times in paddock from January 16th-February 11th, 1918, but no ticks were observed. March, 1918: in splendid condition, absolutely no trace of ticks. June 7th: condition unchanged in any way. Calved, September, 1918.

Stormbird, bought from M. Bourke, Rosewood, 1911. A dark brindle Jersey strain, with a dark yellow skin.

24/6/16: Examined at "Cudgerie" immediately on arrival there after having been for several months in a ticky paddock some miles away. Found to be free from engorged ticks. Examined in the paddocks on several occasions from January 16th-February 11th, 1918, no ticks were found. March 19th-24th: one mature female was removed from the escutcheon, otherwise very clean. June 7th: perfectly clean. Calved, September, 1918.

Spot, born December, 1915 ; dam, Brownie. A little light yellow Jersey with a yellow skin.

This young cow was by far the tickiest subject on the place, with the exception of some of the yearling stock and control heifers. She was not milking but came up each day with the milkers and was examined regularly from January 16th-February 11th, 1918. Males, half-bloated females, nymphs and larvæ could always be found on her, while from 2-3 fully-matured females were removed each day, the total number being 64. During this time no trace of exudate was observed. March 19th-25th : five examinations were made and 18 mature females were removed, numerous immature ticks were observed. The escutcheon was coated with a dry yellow substance resembling exudate. June 7th : small ticks were still numerous and a few mature female specimens were secured.

Sprite, born November, 1911 ; dam, Tinkerbelle. A brindle Jersey with a dark skin. (Allowed to run wild from birth as her calf has also been allowed to do ; neither have ever been treated for ticks, March, 1916. 1/2/16 : clean,—out on roads. No ticks found to date 23/1/18. Stock book).

June 24th, 1916 : Free from ticks—exudate present but somewhat blood-stained. During the January-February examinations, 1918, this cow was not a milker, being allowed to rear her calf, but was examined each day with a few exceptions. No ticks were observed on any occasion. Fresh exudate appeared on January 27th, 28th, February 5th and 10th. March 19th-24th : no mature ticks except two or three very poorly developed females were found. Larvæ were numerous on the escutcheon. On 22nd March, a clear yellow fluid was observed exuding from the part about some tick-sores on the escutcheon, while fresh exudate was also seen at the side of the escutcheon. June 7th : a few very small females were removed.

Squib, born May, 1915 ; dam, Rhinca. Ayrshire-Jersey strain : light red cow with white face, yellow skin. (Clean, November, 1916 ; clean, February, 1917 ; a few small ticks on escutcheon, April, 1917 ; few mature females, December, 1917. Calved, December, 1917. Stock book).

June 24th, 1916: A few engorged ticks present. This cow was examined daily from January 16th - February 11th, 1918. Males, half-bloated females, nymphs and larvæ were observed frequently. On the morning of January 18th, larvæ from tube II (hatched, 4/1/18) were applied to the escutcheon. The majority had disappeared on the following day. Mature females were removed from time to time making a total of 30, but from 8th-11th February when the artificial infestation might be supposed to be developing, only two fully-matured females were found. Fresh exudate was observed on 17th, 25th, 26th, 31st January, 8th, 9th and 10th February. March 19th-24th: Males and nymphs were very numerous and over 70 matured females were removed in five examinations; many of these were, however, extremely small. No fresh exudate was observed. June 7th: immature ticks fairly numerous, but infestation not so heavy as in March.

Snailie, bought at Tewantin 1913.

24/6/16: Tick-free, exudate present.

Sunset, bought from H. Bull, Tewantin, 1912. A red and white cow with rather long hair and white skin. (Very ticky,—inoculated from resistant animal. Clean 28/2/15; Condition good, clean, exudate, March, 1916. Stock book).

24/6/16: Examined immediately on return after several months stay in a neighbouring ticky paddock,—found to be free from ticks, exudate present. This cow was examined daily from January 16th - February 11th, 1918. Males, unbloated females and nymphs could always be discovered on close examination and fully-matured females were removed from time to time, making a total of 18 during that period. Fresh exudate was noticed on January 17th and February 9th. March 19th-22nd: traces of recent extensive exudation were observed on the escutcheon and several mature females were removed. Sold April, 1918, to H. Clem, Eumundi, who reported (October, 1918) that he had never dipped or sprayed this cow, since only a few small ticks had been noticed on her.

Sweetbriar, born June, 1910; dam, Bluebell, sire, Don (Jersey). A black and white cow, with yellow skin and short fine hair.

24/6/16 : No mature ticks found ; "tear-drop" type of exudation present. 1918 : This cow had been running with Mr. Fred Hull's milking herd at "Lonehand" for some months. Examined at "Lonehand" 25th January : only a few larvæ were visible. On 5th February, Mr. Fred Hull dipped his milkers with the exception of some five or six resistant animals of his own and five (including Sweetbriar), belonging to Mr. Munro Hull. No ticks were found on this animal and she was taken home and from 6th-11th February, 1918, was examined twice daily, but no ticks were detected on her. Fresh exudate was observed on 5th, 8th and 9th February. March 19th-24th : numerous larvæ were found attached to udder and escutcheon but no other stages were visible. Fresh exudate was observed on the 19th, 21st, and 24th. June 7th : Not examined carefully, but no ticks were apparent.

Wallum, born August, 1913 ; dam, Heatherbell. A dark brindle Jersey strain, with dark yellow skin. (Condition low and very ticky, December, 1915 ; perfectly clean, June, 1916 ; slight exudate, November, 1916,—clean ; slight exudate, May, 1917,—clean. Stock book).

24/6/16 : Examined on return from several months stay in a neighbouring ticky paddock—found to be free from ticks—dry exudate was present. This cow was examined daily from January 16th-February 11th, 1918, and no ticks of any age were discovered on her. Fresh exudate was frequently observed—on 16th, 30th January, 1st, 5th, 8th and 10th February. March 20th-24th : three examinations were made but no ticks were discovered ; fresh exudate seen on each occasion. Calved, April, 1918. June 7th : no fully-matured female ticks were observed but a fair number of immature ticks were noticed. No fresh exudate was seen.

Yellow I I, born 1912 ; dam, Yellow I.

24/6/16 : A few engorged ticks as well as a number of immature and maturing ticks. Substance resembling exudate present. Sold, 1917.

Yellow I I I, born, December, 1915 ; dam, Yellow II. A light yellow Jersey with particularly short hair and a

yellow skin. (Exudate ; condition prime, November, 1916, November, 1917. Stock book).

24/6/16 : Only a few immature ticks detected. This cow was examined regularly from January 18th-February 11th, 1918, but only one matured female was observed. A few immature ticks were noticed on several occasions. Fresh exudate was seen on 25th, 26th January, 3rd, 6th, and 8th February. March 19th-22nd : three examinations were made, only one mature female was discovered, fresh exudate was observed on 22nd. June 7th : a few immature ticks were seen but no mature females or exudate.

Zephyr, bought at Toowong, 1912. Remained ticky after vaccination. 24/6/16 : Examined immediately on her return from several months' stay in a neighbouring ticky paddock,—found to be ticky. Sold, 1917.

Trampas II, born, October, 1915 ; dam, Stormbird, sire *Trampas I*. Blue roan bull, reared on "Cudgerie" and has never been treated in any way for ticks.

24/6/16 : Found to be free from engorged ticks. January 16th-February 11th, 1918 : examined at intervals and found to carry ticks in all stages including fully-developed females, but the infestation was light and mainly on the flanks. March, 1918 : in the same condition as previous month.

Young Stock.

Bramble, born, November, 1916 : dam, Sweetbriar. A young Jersey bull. Five examinations were made between January 16th-February 9th, 1918. A few mature female ticks (1-7) were removed on each occasion, while patches of immature ticks and males were present on the hind parts and scrotum. Two red-legged ticks (*Rhipicephalus sanguineus*) were removed from this animal. No exudate was noticed.

Lotus, born November, 1916 ; dam, Isis. A Jersey heifer ; this young heifer was examined several times from January 16th-February 9th, 1918, but very few matured females were discovered ; immature ticks were present, but the infestation was not very heavy. Dry yellow exudate was observed on two occasions, while it was seen

in fresh condition on 9th February, 1918. In March, 1918, three examinations were made and several (2-5) matured females were removed on each occasion, while immature ticks, males and unbloated females were numerous on escutcheon, neck and ears. The escutcheon was encrusted with yellowish scales. On June 7th, 1918, she was again examined and a few ticks—mostly small, *i.e.*, immature—were present. The yellowish scales were again present on the escutcheon.

Nigger, born October, 1916; dam, Peewee. A black Jersey heifer. This heifer remained free from tick infestation throughout the January-February examinations. In March, 1918, she was noted as "fairly clean," carrying a light infestation of small ticks.

Sunrise, born August, 1916; dam, Sunset. A golden yellow Jersey heifer. This animal remained fairly free from ticks during the January-February examinations, only occasional mature females being removed from her. In March, 1918, she was still comparatively tick free. Sold, 1918.

Vixen, born July, 1916; dam, Fairy. A Jersey heifer. This animal was one of the tickiest under observation. Ten detailed examinations were made from January 17th-February 10th, 1918, and on each occasion males, half-bloated females and nymphs were abundant, especially on escutcheon, skirt and neck, whilst matured females were removed on each occasion, 26 being the greatest number found at one time. In March, 1918, Vixen was examined several times and 53 matured females were removed on 18th March, 1918. She calved a few days afterwards. Immature ticks and unbloated females were very numerous. On June 7th, matured ticks were less abundant, only a few fully-matured females being found though small ticks were present in fairly large numbers. It is thought that this heifer is becoming resistant as the proportion of fully developed ticks to the sickly yellow infertile variety is diminishing.

Donkey III, born December, 1916; dam, Donkey II. A brindle steer, in poor condition. Remained ticky

throughout the January-February and March examinations (1918).

Bally, born March, 1917 ; dam, Rhinea. A red heifer with white face. This calf was running in a small paddock during January-February, 1918, and remained quite free from ticks. In March, having been turned out into the large paddocks, a few mature females were removed from her, but she was in no wise badly infested.

Bluebell III, born October, 1917 ; dam, Sweetbriar. A blue roan heifer. Remained quite free from ticks during the January-February and March examinations (1918). During the winter she became poor on account of lung worm and was heavily tick infested. Died, winter, 1918.

Brindle, born July, 1917 ; dam, Pride. A brindle heifer. This animal always carried a few ticks : unblooded females could be found on all parts of the body, especially on the escutcheon, whilst odd mature females were removed occasionally. Died from lung worm, winter, 1918.

Bunting, born March, 1917 ; dam, Baby. A red and white heifer. Several (1-5) mature females were removed on each examination during January-February, 1918. In March a few mature females were found, while the escutcheon was thickly encrusted with yellowish scabs.

Banksia, born June, 1917 ; dam, Wallum. A brindle heifer carrying very few ticks during the periods of our observations.

Briar, born December, 1917 ; dam, Rosie. A red and white steer. This little calf was noticed to have a big patch of maturing ticks on the dewlap and odd matured females were removed from time to time. The rest of the body was practically free from ticks (January-February, 1918). Still fairly tick free in March, 1918. Died from lung worm, winter, 1918.

Cracker, born December, 1917 ; dam, Squib. A red and white heifer. Infestation on this calf was very similar to preceding (1918).

Crescent, born March, 1917 ; dam, Rainbow. A red steer, carrying abundant ticks during the January-February examinations. Became so heavily infested that washing with kerosene and light oil was resorted to to relieve tick worry ; hence fairly clean when examined in March, 1918.

Curlew, born March, 1917 ; dam, Seagull. A light red steer. Very ticky during January-February, 1918. Numerous matured females were removed from time to time. Washing was resorted to as in preceding case, but the fluid was applied only to hind parts. When examined in March the neck and sides were heavily tick infested. Died from lung worm, winter, 1918.

Peter Pan II, born May, 1917 ; dam, Fairy. A Jersey steer, carrying numbers of ticks. Numerous matured females were removed from time to time during January-February. This steer was also washed in March, 1918, and appeared fairly clean on examination later in that month.

Petrel, born February, 1917 ; dam, Stormbird. A blue roan heifer. Remained practically tick free during January-February, 1918. In March, she was fairly clean, a few ticks being found. A mass of yellowish scales was present on the escutcheon. Calved, September, 1918.

Snowy, born July, 1917 ; dam, Brownie. A white steer, carrying a few ticks, mostly immature, but odd mature females were removed occasionally, (January-February, 1918). Died from worms, March, 1918.

Stormy, born August, 1917 ; dam, Spot. A red and white heifer, carrying a fair number of ticks including matured females (January-February, 1918). Sold, 1918.

Tewantin, born March, 1917 ; dam, Sunset. A yellow and white steer. Ticky during January-February examinations. Washed with *Crescent*, *Curlew*, etc., and appeared fairly clean in March, 1918.

Tinkerbell III, born March, 1917 ; dam, Sprite. A red brindle heifer, remained practically free from ticks during the whole period of examination (January-February, March and June, 1918). A few immature ticks could be

found on close scrutiny and an occasional matured female was removed. On 28th January, 1918, and again on 10th February, some tiny dry patches of serum were found on the escutcheon. Mr. Hull had noticed exudate on this heifer previously, this being the youngest subject on which he has observed it.*

Rosewood heifers.

Six heifers were loaned by Mr. A. W. Johnston, Cowleigh, Thagoona, near Rosewood, as controls, their arrival at Eumundi being witnessed by one of us on October 18th, 1917. These animals ran in Mr. Hull's paddocks with the rest of his stock until June 17th, 1918, when they were returned to their owner.

One (Brand J.4.V.) died early in January. We found that the remaining five shewed varying degrees of infestation, becoming progressively cleaner in the following order :—

Brand T.3.O. No. 1 red and white	} ticky
„ T.3.O. No. 2 red and black	
„ R.O.8. No. 1 red	
„ R.O.8. No. 2 red and white	} comparatively clean
„ J.4.V. No. 1 red	

These heifers were examined from time to time (on 11 occasions) from January 17th-February 11th, 1918. With the exception of J.4.V., it was impossible to examine any of them thoroughly, the two branded T.3.O. being especially wild. The fact that there was no crush or facilities for handling such animals, made it impossible to collect all the mature female ticks present at any one time.

The two branded T.3.O. were ticky throughout the January-February examinations, shewing big patches of fully-matured females on escutcheon, shoulders and in the ears. March 18th and 22nd: these two heifers were carrying a large number of mature ticks. On March 25th the number of mature females was considerably less. June 7th: mature females were less numerous.

*Mr. Hull reports (11th Nov., 1918) that of the young stock mentioned above, Squib, Bally, Bunting, Banksia and Bramble are now resistant.

Of the two branded R.O.8. one remained consistently freer from ticks than the other. On one occasion (February 5th), 26 fully-matured females were removed from the escutcheon alone of the latter, while many more could be seen along the belly, sides of body and neck. Fully-matured ticks were occasionally seen on the other heifer (R.O.8. No. 2) but never in any great number. Three examinations were made from March 18th-25th, when both heifers were carrying more ticks but in the same ratio as before. Thirty-seven fully-matured females were removed from R.O.8. No. 1 on 22nd, while the shoulders, escutcheon and dewlap were fairly encrusted with small ticks. The escutcheon of this heifer was covered with yellowish white scabs, while the butt of the tail was scurfy. R.O.8. No. 2—the relatively clean animal—was also carrying numerous small ticks and yellowish white scabs on the escutcheon but the latter were not as plentiful as on her mate. June 7th: Both these heifers were carrying ticks, the one being more heavily infested just as on former occasions. In both, the escutcheon was coated with the whitish scabs mentioned above.

J.4.V. This—the odd—heifer soon became very tame and could be examined with ease. She remained practically free from ticks during the January-February examinations. On February 9th, about six tiny spots of yellow exudate appeared on the escutcheon. March 18th-25th: Carried many more ticks than on previous examinations. The escutcheon was quite covered with small immature ticks while about 12 mature females were removed on one occasion and 5 on another. Dry yellow granules were apparent on escutcheon. The ticks were practically confined to this portion, the rest of the body being almost free. June 7th: a few immature ticks visible.

Prior to trucking on June 17th, all these heifers were hand-picked and sprayed to comply with Stock regulations, though ticks were not numerous on them. In response to our request as to their condition, the owner, Mr. A. W. Johnston, stated (October, 1918) that one of the heifers—R.O.8. No. 1—had a few ticks on arrival at Rosewood and was still shewing some, though she had been dipped. None of the others appeared to have ticks nor were any of the

cattle with which these were now running, tick-infested. Particulars as to their condition during the coming tick season have been promised by Mr. Johnston.

Resistant cows at "Lonehand" (Mr. F. Hull's farm).

Five resistant cows, the property of Mr. Munro Hull, were sent as milkers to his brother's farm, Lonehand.

Isis, born August, 1912; dam, Buttercup—sire, Trampas I. A light red cow. (Clean, January, 1916; exudate, November, 1916. Stock book).

This cow was examined at "Cudgeree" on 24/6/16, when abundant exudate as well as typical tick sores were noticed. Examined at "Lonehand" on January 25th and February 5th, 1918, no ticks being discovered; on the latter date fresh exudate was visible. March 23rd: still absolutely free from ticks. June 7th: examined at Cudgeree. Only a very few immature ticks were seen. Fresh exudate was visible. Calved, September, 1918.

Pride, born August, 1912; dam, Clover. A roan cow. (Exudate, October, 1916. Stock book).

Examined at "Cudgeree," 24/6/16—very few mature ticks seen though plenty of small dead and living nymphs, etc., seen. Inspected at "Lonehand," January 25th and February 5th, 1918; and no ticks were found. March 23rd: escutcheon was covered with small ticks and one mature female was removed.

Donkey II, born 1912; dam, Donkey I. (Exudate, January, 1916. Stock book).

Examined at "Cudgeree," 24/6/16, and found to be quite free from ticks—abundant exudate present.

At "Lonehand," January 25th, 1918, a few mature females were removed from escutcheon; fair number of immature ticks present. February 5th: no ticks were found. March 23rd: no ticks observed. Calved, October, 1918.

Brownie, born May, 1913; dam, Spot, sire, Trampas I. Light red with white face. (Condition low, ticky, November, 1915; vaccinated, January, 1916, from Stormbird; vaccinated November, 1916; exudate, December, 1916. Stock book).

Examined 24/6/16, at "Cudgerie"—plenty of small ticks but extremely few engorged females and a few yellowish ticks present—no exudation.

January 25th, 1918 : examined at "Lonehand" and found free from ticks. February 5th : a patch of small ticks (larvæ and nymphs) on escutcheon. March 23rd : Brownie became so badly infested that Mr. Fred Hull washed her udder (which was principally affected) with dip fluid. This part and escutcheon had again become heavily infested, the rest of the body being comparatively clean. June 7th, at "Cudgerie" : Very few ticks, escutcheon coated with thick yellow mass (nature ?)

Evidence of others who have handled Mr. Hull's cattle.

Bluebell, born, 1908 ; dam, Clover.

This cow was one sold to Butcher and Rex. Mr. Butcher (July, 1918) reported that she developed a few ticks while in their possession. She was sold to J. W. Bates, Boompa, in 1915.

Ladybird, bought at Ripley, Ipswich, December, 1910, by Mr. Hull. She was vaccinated from Clover in 1912 and has never carried ticks since then. Sold to Butcher and Rex who had her for about 6 months. Mr. Butcher (July, 1918) wrote : "We *never* saw a developed tick on her," and although she was running with tick-infested stock they (*i.e.*, Messrs. Butcher & Rex) neither dipped her nor any other stock purchased from Mr. Hull. *Ladybird* also was sold to J. W. Bates, Boompa, in 1915, who wrote (January 28th, 1918) to the effect that of the two resistant cows one had been dipped three times in three years, and the other not at all since she never carried ticks. He did not mention the names of the animals but it seems likely that he was referring to *Bluebell* and *Ladybird* respectively. He is reported to have bought a third in 1915 but made no mention of it.

Poppy, born 1912 ; dam, Peony.

Poppy was clean from the time she was a calf. She was sold to Butcher and Rex, Maryborough. Mr. Butcher reported (July, 1918), that she had never developed ticks while in their possession. In 1915, *Poppy* was sold to Mr.

W. A. Bates, of Lakeside. When giving evidence before the Select Committee (R.S.C., 1915), on December 14th, 1915, Mr. Bates stated that he had had the cow under observation for several months and that only two or three mature ticks had been noticed on her. She had never been washed while his other stock had of necessity been treated several times. He had not noticed any exudate. In reply to a communication on this subject Mr. Bates wrote (January 28th, 1918) *re* Poppy " . . . In the two and a half years I have had her, she has never been dipped or washed and has been running with tick-infested cattle all the time. She carries a few ticks at times but they do not appear to develop to any size." He also mentioned that a calf from Poppy had not needed dipping up to the time of its death (at about 18 months old).

Pixie, born 1911 ; dam, Bluebell, sire, Peter Pan.

This animal was loaned to Butcher and Rex when a heifer. Mr. Butcher (July, 1918), wrote that he failed to ever find one tick on her during the whole time she was under his care. She calved just before she was returned to Mr. Hull. The calf (which he still had) had never been dipped for, like her mother, she never carried ticks.

Vanity, born 1912 ; dam, Bluebell.

Butcher and Rex also had this animal. Mr. Butcher wrote (July, 1918), "Vanity we still have, she is a cow that always did carry a fair amount of ticks, we never dipped her and she would clean up again in a short while. We had a steer from her but he was very susceptible to ticks and we had to dip him regularly. We also have a young steer from her but I do not know yet what his tick-resisting powers will be."

Communications were received from several persons in the North Coast district who had purchased stock from Mr. Hull, in answer to inquiries as to the condition of these animals as regards tick infestation.

Mr. S. Kelly, Billi Park, Eumundi, wrote (January 28th, 1918) that the one cow he had purchased had been dipped regularly and was regularly infested with ticks.

Mr. W. E. Noble, North Arm, wrote (February 2nd, 1918), that he had bought a Jersey cow from Mr. Hull : She had retained her resistance. Two other cows became

tick resistant this season and this Mr. Noble claimed to be due to contact with the Jersey.

Mrs. Bedington, Eumundi, wrote (January 31st, 1918), that she had bought two heifers from Mr. Hull, both of which carried ticks but did not become badly infested. They were dipped regularly.

Mr. R. W. Mealing, Butterfat, North Arm, wrote that of the three heifers purchased, only one had been retained. She was ticky and was dipped regularly. As this animal was ticky when sold and was from ticky stock this fact is not surprising.

For Messrs. B. H. Corser & H. Walker's experience see the account given for the cows Clover and Tinkerbell.

Information collected from other sources.

In view of the fact that one or more tick-resistant animals occur in very many herds and the utter impossibility of examining more than a small fraction of the total number, those who were interested in the subject were invited through the Agricultural Journals of Queensland and New South Wales (Johnston and Bancroft, 1918*a*, *b*) as well as through the local press, to send any observations they had made which might help in the investigation. Authentic observations under the following headings as regards tick-resistant animals were especially asked for.

1. Were such animals more usually of any particular breed ?
2. The length and texture of the hair.
3. The colour, texture and oiliness of the skin.
4. The general condition and stamina of the beasts.
5. The length of time the animals had been resistant, whether they had possessed the resistance from birth, or had acquired the peculiarity later in life ?
6. The transmission of this resistance to their progeny.
7. The nature of the country on which the animals were grazing.
8. Influence (if any) of food.
9. The effect (if any) of dipping such resistant animals.
10. Whether an exudate (which was described and differentiated from a tick sore) had ever been noticed on these cattle.

Information collected at other farms at Eumundi.

On January 24th, 1918, a farm owned by Messrs. Lewis and Finch was visited. This is situated on the opposite side of the road from "Cudgerree." There were about 40 head of milking cows which were dipped as a rule every three weeks, but owing to continued heavy rain they had not been treated for about four weeks, the result being an extremely heavy infestation of the majority. In many the escutcheon and parts of the udder were thickly covered with ticks in all stages; the fully and half-engorged females being of course the most conspicuous. Two cows—a Shorthorn strain and another of Holstein strain—were exceptionally free from ticks while another red Shorthorn was only lightly infested. One of Mr. Hull's resistant cows, Rhinea, had been running in this paddock for 12 months and remained free from ticks. It might be mentioned that about 200 fully-matured female ticks were removed in a few minutes from some half-dozen cows in the bails without making any special search.

On January 25th, we visited Mr. Sneezby's farm. The cattle had been dipped recently but one cow was pointed out which had never been dipped. A few mature females were visible and several small ticks were found on her.

On January 25th, 1918, a visit was made to Mr. Fred Hull's farm "Lonehand." The milking herd consisted of about 60 cows, five of them being the property of Mr. Munro Hull (referred to elsewhere). Approximately 20 others shewed tick resistance in a greater or less degree; these resistant animals have, however, usually been dipped with the remainder of the herd. Mr. F. Hull informed us that he had found it necessary to dip regularly during 1916; in the following year ticks were not so numerous on his paddocks and he had not dipped his stock since May, 1917.

On January 26th a number of dry cows and yearling stock were dipped; of the 30 odd animals so treated about one half were only very lightly infested. A number of clean yearlings were examined, also an exceptionally tick-free cow, Ubi.

On February 5th the milking herd was dipped, with the exception of certain animals. Very few fully-matured

female ticks were visible on the dipped stock but close examination revealed great numbers of small ticks. The following are some of the cows carefully examined on these occasions :—

Melba. This cow was one inoculated as a calf from a resistant animal. Another calf was treated at the same time and became resistant; the latter died last year. *Melba* was tick-free when examined on January 25th, 1918, while patches of exudate were visible. On February 5th a few larvæ were seen and exudate was again present.

Magpie, a calf of the first resistant cow owned by Mr. F. Hull. She had never been dipped and was practically free from ticks when examined on January 25th, 1918.

Wendy, Shorthorn-Jersey grade; this cow was fairly free from ticks when examined on January 25th, 1918; tiny scabs could be felt by passing the hand over the body. When examined on February 5th a few small ticks were visible while a certain lumpiness was evident on the escutcheon.

Daphne, a tick-free animal, was shewing dry scabs on the escutcheon. This cow was dipped regularly in order to ascertain if her resistant powers would be thereby lessened. She was still tick-free in June, 1918.

Bluebell II, dam, *Bluebell I*, was also examined on January 25th, 1918. This cow was ticky but the infestation consisted mainly of small ticks and unengorged females.

On February 3rd a visit was paid to Mr. Paton's dairy farm, where over 40 cows were milking. He keeps his stock free from ticks by rotation of paddocks and regular spraying. Mr. Paton shewed two cows which never carried ticks. Both were short-haired and of Ayrshire-Shorthorn cross. One occasionally exhibits the exudate. Both are regularly sprayed.

On the same day we also visited Mr. Duke's dairy farm, where there are 37 milking cows which are dipped regularly every three weeks. One roan cow was pointed out as being especially free from ticks. The remainder of the herd was lightly infested.

On February 7th an examination of Mrs. Lewis' milkers at Bartlett's dairy was carried out. There were over 50 milking cows of all breeds and grades—Shorthorn, Ayrshire, Jersey. They were dipped four weeks ago for the second time this season. Eight cows were noticed as specially free from ticks ; in four of these the Jersey strain predominated ; in all the skin was more or less yellow, in three it was markedly so. The majority of these showed the little characteristic scabs and lumps on the escutcheon and neck. Mr. K. Lewis informed us that some years ago they had from 20-30 resistant cows that were never dipped, some of which shewed an exudate similar to that occurring on Mr. Hull's resistant stock. After a while it was found too great a trouble to cut out the resistant animals and all were put through the dip. They now find it *necessary* to dip them. Mr. Lewis considered the dipping destroyed their resistance. He also vaccinated about three cows with some serum ; all "took," becoming clean a few months later and remaining so until dipped.

On February 7th, a visit was paid to Mr. Bevan's farm, where there were seventeen milking cows which had been sprayed recently and did not exhibit many ticks. One cow was shewn which it was stated never carried ticks.

Information obtained from Messrs. Inigo Jones, O. Jenner and other farmers, Crohamhurst, via Beerwah, North Coast Line.

On April 6th, 1918, one of us visited Crohamhurst and examined a number of Mr. Inigo Jones' tick-resistant stock. Mr. Jones has 40 adult cows ; of that number 18 may be considered resistant. During the last 12 months at least nine resistant animals were sold. Jersey and Shorthorn are the outstanding breeds. The resistant animals exhibited typical exudate as well as tick sores on many of them. Mr. Jones practises vaccination, his method being to scrape the escutcheon of a ticky animal with a clean knife until drops of blood appear, then to take a scraping from the escutcheon of a resistant animal, both pus from tick sores and serous exudate being included indiscriminately, and rub this mixture into the abrasion made on the ticky animal. In a large proportion of cases this method, according to Mr.

Jones, has proved successful, the animal becoming progressively cleaner, while some cows, however, remained unaffected by the vaccination. (See Vallonia line in genealogical tables).

A ticky Jersey bull was vaccinated on March 23rd, 1916, from a glycerinated "culture" (*i.e.*, scraping). Six weeks afterwards the first pustule appeared and the animal gradually became resistant. He was carrying a few odd mature ticks when examined by us.

We are indebted to Mr. Jones' kindness for the pedigrees quoted later on.

While in the Crohamhurst district we were enabled by the courtesy of Mr. Jones to inspect several other farms. On April 7th, a visit was paid to Mr. Owen Jenner's farm, a small but rich one, being composed entirely of scrub land carrying paspalum and clover. The cows were in very good condition. The milking herd consisted of about 40 head, the predominating breed being Shorthorn with an admixture of Jersey. Of the forty, fifteen were quite clean; another fifteen carried very light infestation, while the remainder of the herd were heifers which, though carrying more ticks, could not be said to be badly infested. The bull had a fair sprinkling of mature ticks, chiefly on the neck and shoulders. He was very ticky last year. Mr. Jenner considered the resistance became stronger as the beast grew older. He had never practised vaccination, and could only speak in a general way about hereditary transmission of the peculiarity, never having kept any records. He was of the opinion that it may be transmitted but that there was no regularity. He always had a few clean cows, but never took much notice of them until some three or four years ago a number in some way became resistant; this condition has apparently been spreading for now there are very few animals that require washing. The young stock were also remarkably free from ticks.

After leaving Mr. Jenner a visit was paid to the adjoining farm, the property of Moore Bros. The milking herd consisted mainly of Jerseys. There were four cows which never needed washing, but with the exception of two or three animals none of the herd became really badly infested.

The cows were washed only once last year and once this year. A black Jersey bull which never carries ticks was seen, one little vesicle being visible on this animal.

The inference seems to be that ticks were not plentiful that season in this particular valley at any rate. In regard to other valleys we were told that ticks were abundant.

On April 8th, a visit was paid to the farm of Mr. Collins, who had a herd of 27 milkers, four being Jerseys and the remainder Shorthorn. The majority of the animals examined were fairly free from ticks. Mr. Collins had only washed his cows once that season. These animals were allowed out on the roads and so had good opportunities to pick up ticks. Mr. Collins told us of three resistant cows he had purchased from an adjoining farm. An outbreak of redwater occurred among his stock three months later and these three animals were the first to die.

On the same date we visited Mr. Jackson's farm. His milking herd consisted mainly of Shorthorns and Jerseys. They were tick-infested. They had been dipped about a week previous to our visit. Both bulls were ticky. One red shorthorn cow reared in N.S.W., brought into Queensland five years ago, has not carried mature ticks and has never been dipped during the last three years while in Mr. Jackson's possession. She was shewing exudate when examined. Two Jersey-grade cows bought from Mr. Jones were retaining their resistance. They were dipped regularly with the rest. Two cows—a red Shorthorn and a black and white cow were vaccinated with the fresh exudate on the N.S.W. cow, but the result is not yet known to us.

On April 9th, several farms in the Ewan Valley were visited. In W. Gregor's bullock team two little Jerseys were pointed out as being resistant to ticks, one especially so.

At Mr. Walker's farm we were shewn a sleek, glossy black Jersey cow which did not mature ticks. She had been dipped three weeks before. No exudate was present, but Mr. Walker told us he had noticed it occasionally. He also had eight bullocks which were free from ticks and had not been dipped since May, 1917. No vesicles had been noticed on them. The rest of the stock had been dipped a few days previously.

Evidence received from various sources.

In a letter dated April 11th, 1918, Mr. W. H. Davidson, of "Wilmont," Tambourine Mt., wrote that he had had experience similar to Mr. Hull in possessing practically tick-free animals shewing vesicles on the escutcheon. These cows were "close-coated, short-haired, silky-skinned, red brindle animals in good condition, gentle tempered and when at their best giving up to 14 quarts of rich milk per day. They would belong to the class a dairyman would call "good doers," of Shorthorn-Jersey-Ayrshire cross."

Mr. Oxenford, of Oxenford, South Coast Line, called on May 16th and gave the following information regarding his experience with tick-resistant stock.

A cow of his escaped into the hills and when recovered some time later, both she and her calf, which had been born in the meantime, were found to be tick resistant.

His next experience was with a mob (16 head) of young stock, all of which were resistant, purchased some years ago from Mr. W. Lane, Wonga Wallen, *via* Upper Coomera. These animals were sleek-coated grade Jerseys. They stood the tick season and were never dipped. The majority were disposed of, but three were retained, all of which carried a few ticks but never became worried. They were dipped with the others. Nothing was known about their calves and an exudate had never been noticed.

Mr. Oxenford also informed us that Mr. Lane's method of raising resistant stock was to allow them to become tick worried for their first year. The latter considered that if cattle were once dipped their resistance was destroyed. He did not practise vaccination.

During an interview, May 9th, 1918, Mr. R. Cross, Graceville, stated that some five or six years ago he had reported the presence of tick resistant stock to the Agricultural Department, whereupon Mr. Cory visited his farm. A number had remained free from ticks for three years previous to Mr. Cory's inspection and had not been washed or dipped during that time nor were they so treated up till the time Mr. Cross sold his herd two years later. Others were very ticky in spite of washing. The first two resistant animals were Roany and Roany's daughter. Mr. Cross

did not know how the peculiarity began ; but from these two by vaccination into scratches and horn injuries on the ticky animals he increased the number of resistant animals to eight in 12 months. He had noticed that when cows became low in condition the resistance was greatly decreased. His resistant stock were all of mixed breed and various colours, some sleek-coated and some long-haired.

A resistant cow was sold by Mr. Cross to Mrs. Sonders, Sherwood. This animal was examined on May 16th, 1918, and was found to be a black Jersey of shiny sleek appearance. Mrs. Sonders had noticed a few full-blown ticks on the escutcheon a few days previously and rubbed that part over with grease and arsenic. The cow was then quite clean and shewed no trace of exudate. She had calved a week previously, which may have accounted for her temporarily lowered resistance.

In response to our request for information asked for per medium of the daily and country press of Queensland, a letter appeared in the " Queensland Grazier " 31st May, 1918, signed by W. G. Gray of Junggury, Ravenshoe (about 20 miles from Herberton and at an elevation of about 3,000 feet) in which the writer stated that he had in his possession three tick-resistant animals— a cow and her two calves. This cow is a Holstein-Shorthorn crossbred, purchased when 10 months old and from that time has carried very few ticks. A steer by a ticky shorthorn sire and a heifer by a Jersey sire had remained tick-free from birth and had never been dipped though running with ticky stock. Exudate had not been noticed.

A letter dated May 14th, 1918, was received from Mr. C. A. Ware, of Springdale, Bracewell, Mt. Larcom. Mr. Ware stated that he had a Jersey cow and progeny that had not required treatment for ticks for the last three years although running with several hundred head of ordinary ticky stock. The writer mentioned that his brother also had a Jersey cow and progeny that were tick resistant. Both the original cows were purchased from the same herd in the Isis district. Of four calves from the resistant cow two by Jersey bulls were just as clean as the mother while two by Hereford bulls carried ticks, but not to the same degree as the other cattle.

Mr. A. K. Henderson in an interview (November, 1915), stated that when farming on the Blackall Range several years previously he had had some experience with tick resistant stock. He had vaccinated nine cows with "a gummy substance" found exuding from one tick-free animal. Mr. Henderson had destroyed his records on selling the farm and could only give the results from memory. In about a week the first effect was noted, spreading slowly from the point of vaccination and taking some weeks to reach the shoulder. Of the nine treated, six "took" and from being tick-carriers they all had very few ticks. These cows were sometimes dipped with the rest. One cow, which Mr. Henderson retained on selling the farm and afterwards disposed of, became ticky some three years after treatment. From the slowness with which the effects of vaccination spread Mr. Henderson had formed the opinion it was not distributed through the blood but through the lymph. (See also R.S.C., 1915).

Mr. T. S. Rowbotham, of Springbrook plateau (on the N.S.W. border), who has a herd of about 90 smooth-skinned animals, chiefly Jerseys, informed us that he had found only three mature ticks during the 1917-18 tick season though he had milked 43 cows twice daily, the remainder being regularly yarded and examined for ticks but without further finds. No sign of tick irritation was observed. The greatest number of mature ticks collected by him during any one season since 1914 was six.

At the other end of the narrow horse shoe-like plateau redwater made its appearance each year. In May, 1914, he introduced 21 tick infested cattle into his property, 16 being dipped while the remaining five were left untreated in the hope that they might be the means of disseminating ticks and keep up an "immunity" from fever. The result was not successful as far as tick infestation was concerned.

On another occasion, May, 1917, he moved some of his herd to a neighbouring paddock where ticks soon appeared on the cattle, a number contracting tick fever and some dying in spite of several weekly washings in order to control the infestation. No subsequent treatment had been resorted to and the animals remained clean except for the presence of young ticks which however did not mature. He reported

that when ticks were present, then "tick scabs" like those found on Mr. Hull's cattle, were to be seen. He believed that his animals would become infested if placed in ticky country.

We think that the climate has a great deal to do with the control of tick infestation on the plateau, which is between 3,000 and 3,500 feet high and experiences cold winters and exceptionally mild summer weather. Mr. Rowbotham stated that the average summer heat, as recorded by him for several years, was between 50 and 60 degrees Fahr. at mid-day, and between 40 and 50 degrees at 9 a.m., while frosts were very common in winter.

Paspalum and clover were the chief fodder plants in the tick free paddocks as well as in the paddock in which the animals became infested, whilst rye was present only in the clean paddocks.

Through the courtesy of Mr. A. H. Cory, Chief Inspector of Stock, we have received a copy of a report, dated May 7th, 1918, from Mr. Jas. H. McCarthy, Stock Inspector, Beaudesert, *re* B. Birley, Tambourine, claiming to have tick resisting cattle on his farm. The report is as follows:—

"I have the honour to advise you that, when at Tambourine recently, B. Birley informed me that he had on his property a number of tick-resistant cattle. He particularly claims that there are three cows and a considerable number of young stock owned by him, and upon which ticks will not mature. Certainly I saw on one cow a number of immature ticks dead, and from what cause I do not know. I found also a number of full-grown ticks on one cow that Birley claimed was tick-resistant. This he said might occur to a limited extent, that is to say, that an animal may carry a small number of ticks and gradually the resistance increases until total immunity is reached. This immunity is yearly increasing in his herd, he claims.

"As Mr. Birley's claim is on the lines of the Munro Hull case, I promised that I would bring it under your notice for further investigation if thought desirable. Mr. Birley challenges either myself or the Department to take two or three of his cattle, which he will place at disposal free of cost, and run them on grossly infested country, to prove his contention. As these cattle are seventeen miles from my

headquarters, and day by day observation would be required, I can do nothing in the matter. If on the other hand you desire costless action arrangements can be made for removal of the three cattle to a centre for daily examination. Mr. Birley's claim is identical with the claims of Mr. Munro Hull."

Mr. Stanton, of Tingalpa, reported that three mixed Shorthorn Jersey cows belonging to his herd were tick-free whereas the remainder became infested. The former were smooth, clean-skinned animals. No sign or exudation was noticed.

Mr. James Woodward, of Terror's Creek, *via* Petrie, in a letter dated October 28th, 1918, related his experience of a tick resistant cow. This animal became crippled during the drought in 1915, and although heavily infested could not be treated for ticks except by hand-picking. Though previously a very ticky beast this cow is now strongly resistant to tick infestation. This animal is a grade Jersey with short fine hair; she has been in good condition since the drought and running on fairly dry forest and scrub country. Mr. Woodward considers that many animals could be rendered so resistant if not dipped for from twelve to eighteen months but that such a method is impracticable owing to the excessive tick worry to which the animals would be subjected.

On 27th May, 1918, a visit was made to Barrett's dairy, Rawlin's Street, Kangaroo Point, Brisbane, where we examined a red roan cow which, it was stated, never carried ticks. This cow was the only survivor of a number of calves turned out at Lytton about 13 years ago, the remainder dying of redwater. Exudate had never been noticed by any members of the family that were interviewed, though we were informed that an elder brother had seen vesicles on this animal.

EFFECT OF BREED ON RESISTANCE.

It has been a well known fact in America for many years, that Brahmin or crossbred Brahmin cattle shew very high tick-resisting properties. It was thought that these cattle were immune to tick fever but this was later proved to be incorrect, shewing that larval ticks must infest the

animals and actually attach themselves. Importation of Asiatic cattle into the United States was stopped in 1884 and the consequent breeding of the tick-free Brahmin strains with the susceptible European cattle led to a deterioration in the tick-resisting powers of the progeny. In 1906, Mr. A. P. Borden, Manager of the Pierce Ranch, Southern Texas, after complying with quarantine regulations was allowed to introduce 33 head of pure bred Brahmin cattle. He has since bred up a large herd of Brahmin and grade Brahmin cattle. These animals were carefully examined by the members of the Royal Commission and no ticks could be found on them while the Shorthorn and Hereford cattle were found to carry ticks freely. (Cowley, Pound and Chauvel, 1913, p. 10). "Brahmin crosses are remarkable resistant to tick infestation" (p. 14).

In some extracts from Mr. Froggatt's reports (Report of Under Secretary for Agriculture, 1907-1908, p. 26) reference is made to the crossbred Brahmin cattle at Pierce Ranch. These crossbreds have fine short hair and the suggestion is that the close short hair causes the larval ticks, when they moult, to drop off as they have nothing to cling to.

In Jamaica similar facts have been observed. "The almost total immunity of the Mysore cattle from the attacks of ticks of all kinds was most marked; this was especially the case at Shettlewood and other places, where this breed of cattle was used for draft purposes. Crosses between the Mysore and other breeds were also less subject to the attacks of these pests; while Shorthorns, Devons, Herefords and Creoles suffered most. Indeed ticks shew a decided preference for all cattle which have little or no Indian or Spanish strain in their blood; they have apparently a great dislike to animals with short, fine hair; hence probably the immunity of the Indian and Spanish races.*

Tryon (R.S.C., 1915, p. 46) pointed out that although the cattle tick occurs in India and Java, ticks are rare on the cattle and the gross infestation so common in Australia is never met with. *Freedom or comparative freedom from

*R. Newstead. Report 21st Exped. of Liverpool School Trop. Med. Jamaica—Medical and Economic Entomology. Ann. Trop. Med. Parasit., 3, 1909, p. 423.

ticks is also enjoyed by crossbreds with these native cattle. Mr. Tryon also quoted Dr. Nelson Mayo who stated: "An animal that has blood of the races of the East Indies named China or Brahmin holds less ticks than does an ordinary animal. This may be due to the excessive acid secretion of its skin, or to its short fine hair. The beast with short and fine hair is less affected by ticks than the densely clothed animal." Furthermore—"We have animals that are immune to ticks naturally. In a fully infested field it is frequently observed that some animals are not infested, or that other animals are very lightly infested." (R.S.C., 1915, pp. 46 and 47). Mr. Tryon suggests that what characterises the Indian cattle may occur in a few of the Queensland animals also, in which a little of their blood may persist.

In Algeria, experience shewed that the buffalo and the zebu (Brahmin strain) were also naturally resistant to disease. It was found impossible to breed the buffalo with domestic cattle but the zebu hybrids shared the perfect immunity to fever enjoyed by the Brahmin cattle. Similar conditions were experienced in Jamaica. (Q.A.J., vol. xiii., 1903, pp. 248, 249). This is directly opposed to the state of affairs existing in America where the Brahmin is susceptible to fever.

Gilruth (1912, p. 17) bears out the statements that buffaloes are free from ticks. He had occasion both on the mainland of the Northern Territory and on Melville Island, to examine freshly killed buffaloes and also fresh hides—the descendants of the Timor buffaloes, introduced in 1824-1828, and also the descendants of some Indian animals introduced in 1886. All were absolutely free from ticks, although grazing on country with badly-infested cattle. The same author found quite different conditions to prevail with the Brahmin cattle, since on the Adelaide River he examined several crossbred Brahmins which he stated "were well covered with ticks." This author has come to the conclusion that the cattle tick and the tick fever organism were most probably introduced with the Batavian cattle brought into the Northern Territory in 1872.

While tick-resistance in cattle in Queensland is confined to no one breed it may be fairly said that such resistance

is more common among Jersey and Jersey grade cattle than any other race. The fine short hair and the rather oily skin, which give many Jerseys their sleek, glossy appearance, are probably factors which help to determine tick resistance. Individual animals, however, of **Short-horn**, Ayrshire, Hereford or Holstein strain and crossbreds of these races have been found as strongly resistant as any Jersey.

EFFECT OF FOOD ON RESISTANCE.

The reputed beneficial effect of feeding sulphur to stock has frequently been mentioned in literature. Tryon (R.S.C., 1915, p. 49) stated that this sulphur administration is alluded to in the *Agricultural Journal of the Cape of Good Hope** as having been formerly favoured **there**. It is recommended by C. A. Barber in his article on the Tick pest in the Tropics,† and is also mentioned as being an Argentine remedy ‡

In their report on Tick Fever (1896, pp. 11, 13, 32) Dr. J. S. Hunt and Mr. W. Collins reported on the experiments of Dr. Nörsgaard on the internal administration of sulphur. The latter had noticed that cattle drinking from sulphurous wells were always free from ticks and that tick-infested cattle brought to such wells would after a few days lose all their ticks and remain tick-free, so long as they continued to drink such water. Efforts were being made to prepare sulphurous water artificially by boiling lime and sulphur. Dr. Nörsgaard was sanguine of success, though the results of his experiments had been negative up till that time. The members of the Commission stated they had seen tick-infested cattle which had access to sulphur-impregnated water. Ranch owners in Texas claimed however, that by feeding sulphur and salt they could to a certain extent relieve their cattle from infestation. These facts are also quoted by Tryon (R.S.C., 1915, p. 49). Hunt and Collins considered that this treatment seemed worthy of further trial as it had been favourably reported on from the Argentine Republic, although experiments witnessed in America had failed.

*Vol. viii., No. 16, p. 421.

†Nature, 1895.

‡"Pastoralists' Review." 1896, p. 344.

Ransom* found that there was no difference in regard to tick infestation when animals were experimentally supplied with sulphur in addition to ordinary food. This was supported by Klein (1907, p. 16).

Circumstantial evidence can be quoted to the effect that lucerne confers tick-resisting powers on animals. Lignières (1901) mentioned the fact that tick infested animals from Northern Argentine when placed in the richer pastures of the South became tick-free and did not set up fresh centres of tick fever. This he attributed to the action of lucerne and also mentioned that the substitution of lucerne for natural grasses leads to the establishment of tick-free areas. Tryon (R.S.C., 1915, pp. 47-48) also quoted Lignières to this effect.

In an editorial article (Q.A.J., vol. x., 1902, p. 96) there is the record of a cow at Samsonvale which became clean on being turned into a lucerne paddock and was never thereafter troubled with ticks. In the same journal (Vol. xix, 1907, p. 142) green lucerne feeding is reported to have considerably reduced ticks on some holdings in the Blackall Range. Walker (R.S.C., 1915, p. 51) stated that lucerne feeding had been tried extensively by individual farmers and that it failed in every case.

Tryon (R.S.C., 1915, appendix, p. 71) pointed out that experiments carried out at several agricultural stations in U.S.A. have conclusively shewn that there is a peculiar association between lucerne and sulphur. Chemical analyses have proved that lucerne contains a high percentage of sulphur. "Accordingly" Tryon concludes, "if sulphur when in the animal's system confers an immunity from tick-infestation, we should expect the same result to follow the ingestion of lucerne or any other similar sulphur-containing herbage."

Various other plants are reputed to have the power to confer tick resisting properties on stock. Tryon (R.S.C., 1915, p. 48) mentioned the statement in a West Indian Agricultural paper that "when cattle were allowed to graze on pasturage in which certain grass predominated they

*Ransom, in "The eradication of the Cattle Tick." U.S.D.A., B.A.I., Bull. 97 1907, p. 72.

ceased to be continually tick infested. This grass was one of the *Andropogon* family, the members of which are, in some cases, noted for containing essential oils." Further on the same page he stated that he had a paper by Dr. Nelson S. Mayo, Cuba, 1906, in which the latter mentioned certain plants that contain specifics which are fatal to ticks.

A. K. Henderson (R.S.C., 1915, p. 43) stated that for many years his farm on the Blackall Range, 6 miles from Nambour, was free from ticks. This he attributed to the presence of white clover. However, on going to Maleny, several hundred feet higher, he had seen some exceedingly ticky stock although white clover was growing luxuriantly there. After this experience he had not placed much reliance on the clover theory. It is stated (Q.A.J., vol. xix, 1907, p. 142) that it has been found on the Blackall Range that in paddocks properly cleared and laid down with *paspalum*, ticks do not breed to the same extent that they do in rough uncleared country.

Notice appeared (Q.A.J., vol. iv., 1899, p. 498) of a particularly ticky cow in the Cairns district being rendered tick resistant by feeding with saltpetre and salt. P. R. Gordon (same issue) stated that the matter had been investigated by Sir Horace Tozer and quantities of saltpetre were tried on cattle without the slightest effect.

In several communications and in an interview Mr. L. G. Jones stated his conviction that food plays an all-important part in an animal's susceptibility to tick infestation. Whilst animals graze on lucerne or *paspalum* (*P. dilatatum*) they remain resistant to the tick until they are turned on to a poorer pasture. Mr. Jones pointed out the impracticability of substituting artificial grasses or lucerne for natural grasses on a large scale. He furnished us with a copy of analyses of *paspalum* and ordinary pasture shewing the higher percentage of inorganic matter contained in the former. The percentage of sulphates and chlorine and soda was approximately twice as great, while that of ferric oxide and potash was from 3-4 times as great in *paspalum* as in ordinary grass. Mr. Jones gave us the result of some observations and experiments performed on sheep in N.S.W. which point to the efficacy of certain iron ore and salt mixtures in helping sheep to withstand the

inroads of worms and fluke (Q.A.J., 1918, p. 48) and is of the opinion that similar treatment would be beneficial to ticky cattle. Stewart (1906, p. 1156) mentioned that cattle suffered more severely from tick worry when fodder was dry and scarce, such as during periods of drought; and that a liberal allowance of green succulent fodder invariably aided them in their fight against the tick.

In consideration of the possibility that the tick-resistance enjoyed by Mr. Hull's cattle, had been developed and maintained by them eating some plant peculiar to his property, a collection of all the more evident plants was made both from Mr. Hull's paddocks and from those opposite, where the cattle were ticky. The specimens were kindly identified for us by the Government Botanist, Mr. C. T. White. None of those submitted were rare, the majority being the common scrub and forest plants found all along the North coast. The fact that Mr. Hull has frequently had his resistant animals running in neighbouring paddocks with tick-infested stock, without any reduction in their resistance, also negatives this suggestion. The creek water was not found to be unduly charged with mineral salts.*

EFFECT OF LOCALITY.

Tick resistant animals occur in very many districts in Queensland. We have records of animals exhibiting such resistance from the following places:—Springbrook Plateau; South Coast district—Tambourine Mt.; Brisbane district—Graceville and Kangaroo Point; North Coast district—Terror's Creek (*via* Petrie), Crohamhurst, Mooloolah and Eumundi; Mt. Larcom and Ravenshoe (Atherton tableland). In almost every case the animals were running on scrub country.

Ticks develop most freely in a moist warm climate. Cold retards their development, while an intense dry heat destroys the eggs, thus the tick has never established itself

*A remarkable "remedy" for tick fever and also alleged to be efficacious in ridding beasts of the ticks themselves in the Transvaal is cited by the Editor of the Queensland Agricultural Journal (Q.A.J., vol. xxii., 1909, p. 104). The treatment consists of making an incision in the dewlap and inserting a piece of garlic bulb. Garlic is said to be an old remedy used by the Dutch for their horses when these became badly tick-infested.

in the hot dry interior. (See Stewart and others, 1915, pl. I. for tick infested areas of Queensland and N.S. Wales).

Altitude—along the coastal belt—has little effect upon the activities of the parasite. On the Atherton tableland 2,500-3,000 feet above sea level, cattle become tick-infested as they do on the Blackall Range, *e.g.*, at Maleny and Crohamhurst. Ticks appear periodically (apparently as reinfestations) on the Springbrook Plateau, but the winters are too severe to permit the pest establishing itself.

EFFECT OF ARSENIC ON RESISTANCE.

As already mentioned, Mr. Hull claims that if a resistant animal be treated with arsenic, either by spraying, dipping or washing, the resistant condition becomes at least temporarily suppressed and that such animals then carry ticks (R.S.C., p. 3, 8, 57).

He informed us (7/6/1915) that he had applied arsenical solution to a part of the hide of a resistant cow and the part so treated matured abundant ticks while the rest of the skin remained free from them. On another occasion he wrote (20/12/1915) stating that some milking cows were sprayed a few weeks previously and subsequently became tick infested so that spraying was again necessary. At the time drought conditions prevailed locally, food was scarce, and those cows which were being milked were in a very poor condition, whilst the dry stock, whose condition was much better (since they were not subjected to the task of producing milk), maintained condition and were tick-free. We think that it was the poverty of condition and not the application of dip fluid which brought about a lowering of resistance and permitted tick infestation to occur.

He believed that there exists just below the skin of resistant cattle some substance which is detrimental (or may we say distasteful) to the tick, but that such substance becomes destroyed by the action of the arsenic absorbed by the skin.

There is some difference of opinion as to whether arsenic from dip fluids does actually become absorbed. Graybill*

*Graybill, H. The action of arsenical dips in protecting cattle from infestation with ticks. U.S.D.A., B.A.I., Bull. 167, 1913, p. 19.

thought it possible that certain of the ticks used by him in some of his experiments were affected by arsenic absorbed by the skin. Brunnich and Smith* believe that the poison enters the tick partly through its own skin and partly through the host tissues, *i.e.*, that absorption of arsenic by the skin of cattle actually occurs. Watkins-Pitchford† has shown that the poisonous effect of arsenic on ticks though quite local, is not due merely to a deposition of arsenic on the surface of the skin, since if a patch of skin of a habituated animal be closely shaved and carefully washed free of all deposited arsenic, together with the hair and surface epithelium, ticks subsequently applied die just as if such precautions had not been taken. He also found that ticks placed on an animal *after* dipping, died. Cooper and Laws‡ confirmed the latter observation, and have stated that experimental inquiry tends to prove that the poison is imbibed by the tick while feeding on its host.

They endeavoured to answer the question as to whether the tick takes up arsenic from the blood or from the skin of the dipped host, and found that neither the feeding of arsenic to such cattle nor the subcutaneous injection of the poison into the blood stream caused the death of ticks. Consequently ticks did not take up a lethal dose from the host's blood** though the blood may contain enough arsenic to exert a toxic action on hæmoprotezoa††. "The epidermal cells possess a special affinity for arsenic and once this arsenophile proclivity is satisfied, the excess of arsenic is available for absorption by the blood. It is obvious that the *total* amount of arsenic in the general blood system cannot be very great since the general health of the animal is not interfered with in any way. But a consideration of the amount of arsenic applied every week (*i.e.*, in regular dipping) . . . and especially the appearance

*Brunnich and Smith. Factors influencing efficacy and deterioration of cattle-dipping fluids. Q'land Agric. Jour., 1914, pp. 81-92.

†An illustrated pamphlet on tick destruction, etc. (p. 50), 1911, Maritzburg, quoted by Cooper and Laws. Some observations on the theory and practice of dipping. Parasitology, 8, 1915, pp. 190-217 (p. 196).

‡Cooper and Laws, *l.c.*, p. 196-7.

**Cooper and Laws, *l.c.*, p. 199

††Cooper and Laws, *l.c.*, p. 202, 203.

exhibited by the inner surface of the skin of an animal which has been dipped in a solution only slightly too strong, would lead us to suppose that the amount of arsenic present in the blood circulating in the *most peripheral vessels of the skin* would be very considerable. . . . It is quite conceivable that . . . this peripheral blood containing a large quantity of arsenic would be immediately diluted by the general mass of blood from the internal parts of the animal so that the total amount in general circulation would not be excessive."

In experiments where arsenic was injected subcutaneously, only those ticks in the immediate vicinity of the puncture were killed, those a few inches away being unaffected (Cooper and Laws, p. 208-9). These authors, along with Watkins-Pitchford, believe that "arsenic is cumulative in its action and that the quantity absorbed by the tissues of the skin is augmented by each subsequent dipping until a certain maximum is reached," the excess being absorbed into the blood stream and eliminated into the urine by the kidneys (p. 200). Analyses of the skin of animals dipped at short intervals has proved that arsenic does accumulate as a result of repeated application, penetration of the poison taking place as a result of osmosis (p. 201).

If Mr. Hull's observation, that dipping suppresses resistance, be correct then one might explain it by assuming that the arsenic absorbed as a result of one or of a few dippings, is sufficient to alter the anti-tick quality of the blood or lymph and thus convert the resistant cow into an ordinary cow so far as tick infestation is concerned. Since the protective effect of arsenic lasts only for a few days after dipping,* one would have to assume that the influence of the arsenic as a tick destroyer does not persist as long as its influence in suppressing the hypothetical anti-tick quality in peripheral blood.

We are not satisfied that arsenical dipping by itself will suppress tick resistance since loss of condition would probably afford a sufficient explanation in the cases mentioned by Mr. Hull.

*Graybill. U.S.D.A., B.A.I., Bull. 167, 1913; Watkins-Pitchford in Cooper and Laws, *l.c.*, p. 201.

The majority of cattle owners who have interested themselves in any way in this subject, are of the opinion that dipping makes no difference; but several persons in the South Coast district, however, hold with Mr. Hull, that the effect of dipping is to induce an animal to carry ticks.

Information obtained by us from Mr. Henderson (R.S.C., 1915, p. 41) was to the effect that a cow which had become resistant after vaccination relapsed to a ticky condition three years later. This animal had been dipped but Mr. Henderson was not prepared to say whether loss of resistance was, or was not, due to dipping.

Actual facts observed by us seem to be overwhelmingly in favour of the view that dipping has no appreciable effect on resistance. In February, 1918, Mr. Fred Hull undertook to dip regularly one of his clean cows—Daphne; in June last she was still free from ticks. In almost every herd examined a few (1-8) tick-resistant animals were noticed. These are usually put through the dip with the rest of the cattle, cutting out individual animals giving too much trouble, while in cases where a dip is not used and spraying or washing is resorted to, resistant animals are treated if ticks are noticed on them, without apparent diminution of their tick resisting property.

The experience of Messrs. Jones and Jenner, of Crohamhurst district, both of whom have a large number of resistant animals which are occasionally treated with an arsenical solution, supports this view.

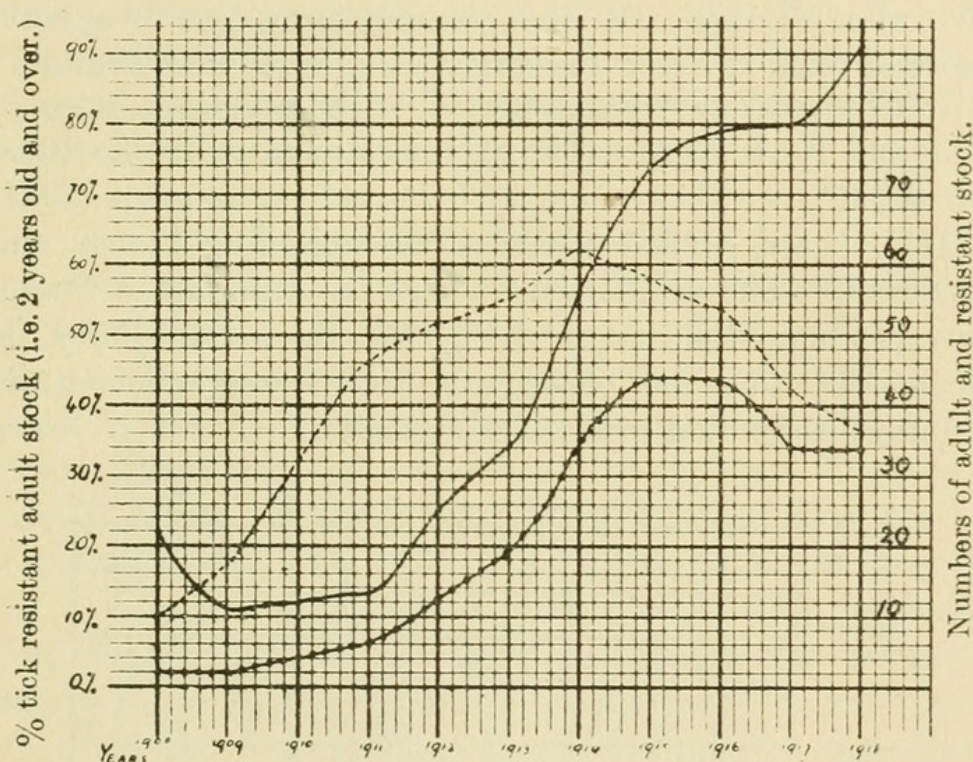
PERSISTENCE OF RESISTANCE.

Tick resistance may be lessened by (1) low condition brought about by drought or prolonged milking and poor feed, (2) by subjection to unnatural conditions, *e.g.*, stalling and rugging. In animals living under favourable conditions, *i.e.*, as regards food and water, resistance may persist from birth, or from whatever time the animal acquired such resistance. Strongly resistant animals may, if able to maintain their condition, withstand tick infestation even during unfavourable circumstances.

On February 11th, 1916, Mr. Hull reported that two days previously he had brought in 28 head of cattle from relief country, where they had been running for three months

during the drought. Of these, four were heavily tick-infested and in poor condition ; ten were lightly infested and in fair condition, while the remaining fourteen were in good condition and absolutely free from ticks, eight of these showing exudate.

As examples of persistence of resistance in individual animals in the same locality, the cows Sweetbriar and Primrose may be mentioned. The former has been clean since birth in 1910, and the latter since she acquired resistance in 1914. These are amongst the most strongly resistant



The lightly dotted lines refers to the actual number of adult stock, the heavily dotted line to the actual number of *resistant* adult stock carried each year at Cudgeroe, Eumundi.

animals on Mr. Hull's property. Resistance may persist when an animal is removed to another locality, *e.g.*, Poppy, born in 1912, remained tick-free at Eumundi up till 1915, while since that year she has been at Maryborough and Lakeside in both of which districts she has remained strongly resistant.

For further instances, one might consult the accounts given earlier regarding individual cows.

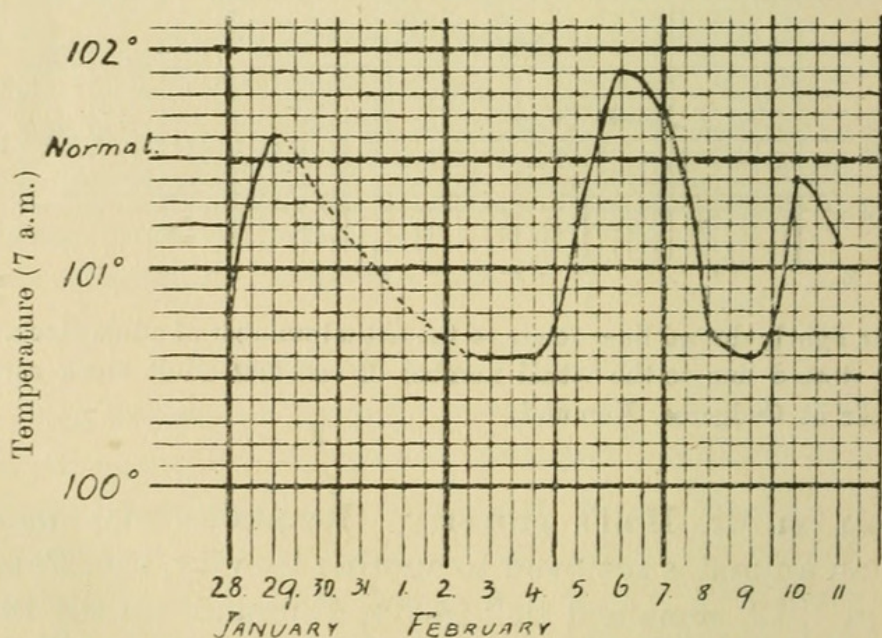
The heavy infestation of Clover just prior to death may

be accounted for partly by old age and partly by extreme poverty of condition as reported to us by Mr. Butcher.

The rate of spreading of the resistant condition amongst Mr. Hull's herd may be readily noted by consulting the graph (p. 289). The drop in the percentage, 1909-1911, is partly accounted for by the addition of a number of non resistant animals to the herd.

TEMPERATURE OF RESISTANT ANIMALS.

As regards the temperature of resistant animals, tests made during January and February, 1918, failed to shew any abnormality. Of the temperatures per vaginam recorded from thirteen resistant cows, most were found to fall within the normal range of variation—*i.e.*, between 100.8 and 101.6 degrees, the extremes obtained being 100.4 and 102.3* ; we thus agree with Pound's statement (1914, p. 111), based on his observations regarding Clover and Tinkerbell. The temperature chart for a period of fifteen days (January-February, 1918), for the cow Fairy is appended.† We are of opinion that observations made during winter would give similar results.



Temperature chart of cow Fairy.

*Dodd (1908, p. 11) mentions that a variation of several degrees in temperature from the normal 101.5 may be met with in healthy young cattle during our summer.

†W. Osborne. Elements of Animal Physiology, 1909, p. 64, gives 101.5—102°F. as the normal temperatures of a cow (per rectum).

“ *Winter Ticks.* ”

Mr. Hull repeatedly claims that his resistant animals mature more ticks in winter than in summer. We think that this is probably due to the fact that the cows which are under closest observation, are the milkers. During the winter, milking cows frequently fall into somewhat low condition, which, as is well known, brings about a diminution of their tick-resisting properties. Resistant cows when dry, seldom become tick infested.

We might mention that occasionally during both summer and winter, we received specimens of *Rhipicephalus sanguineus* taken from cattle and from a horse (Eumundi), while Mr. Inigo Jones forwarded during last winter a number of ticks (*Hæmaphysalis* sp.) which he had collected from his cows (Crohamhurst).

IS RESISTANCE TRANSMISSIBLE ?

Mr. Hull claimed that the peculiarity is transmissible, (1) hereditarily ; (2) by vaccination ; (3) by contact.

Mr. Pound (1914, p. 110) published a statement prepared by Mr. Hull, giving a list of his resistant cattle (31st March, 1913) under the headings, (a) resistant by vaccination, 6 ; (b) by contact, 7 ; (c) by heredity, 6 ; while the rest of the herd (38) were at the time all more or less infested.

1. *Transmission by Heredity* :—Mr. Hull maintains that the progeny of resistant animals become resistant, though such quality does not usually manifest itself until after the first year of life. The occurrence of some cases of animals showing a strong resistance to tick infestation from birth seems to support the hypothesis.

Mr. Pound has reported adversely, mentioning that Clover's calf and Tinkerbelle's calf were just as liable to tick infestation as an ordinary animal (1914, p. 111, 112, ; 1916, p. 90 ; R.S.C., p. 21 ; Corser, R.S.C., p. 64 ; Thorn, R.S.C., p. 28). Clover's calf was two and a half years old and the other six months, in October, 1915. In March, 1915, one of us visited Yeerongpilly and was shown a young calf from Tinkerbelle as well as Clover's heifer, both of them markedly infested with fully engorged ticks as well as others in earlier stages. Information was given by Messrs. Pound and Thorn that these ticks were applied as larvæ in February. Infestation in this case was artificial as it was in 1917

(Thorn, R.S.C., p. 28). The only fair way to test resistance is—as has been emphasised by Mr. Cory, Chief Inspector of Stock, Queensland (R.S.C., p. 53, 54)—to place such animals on natural pastures where ticks are known to be present and then note whether the parasites *mature* on those cattle.

On one occasion the strongly resistant cow Peewee, and her young calf (five months old) were running with ticky cattle elsewhere for some months. On their return to Eumundi the former was clean while the calf was tick infested.

So that the relationship of the various resistant animals belonging to Mr. Hull's herd might be more easily seen, we append a genealogical table (pp. 293-5). In the case of Peony it will be noticed that the peculiarity has persisted to the fourth generation.

Tick resistance appears to us to be a quality capable of hereditary transmission but like many other qualities it may or may not be inherited. We know nothing regarding the tick resistant qualities (if any) of the male parents and consequently it is impossible to discuss the tables satisfactorily.

We know that natural immunity to disease is a hereditary quality both in animal and plant life.

It is likely that some strongly resistant animals which are known to occur in many herds are to be regarded as a mutation in so far as this particular character is concerned, and if such be the case then its inheritability is to be expected. Before concluding that a resistant calf from a resistant parent (no matter how such resistance were attained) has inherited such quality, one must remember that it has been proved in the case of resistance to bacterial invasion, that anti-bodies formed in the maternal blood may be transferred through the placental circulation to the blood of the offspring, the latter thereby becoming resistant or immune to such invasion for a period of some months after birth, but subsequently losing such resistant power. Before such loss occurred, it might be possible for the animal to have acquired protection naturally, *i.e.*, to have elaborated its own anti-tick bodies in response to continual stimulation by larval tick attack, so that the immunity becomes an active one.

Pedigree of resistant animals.

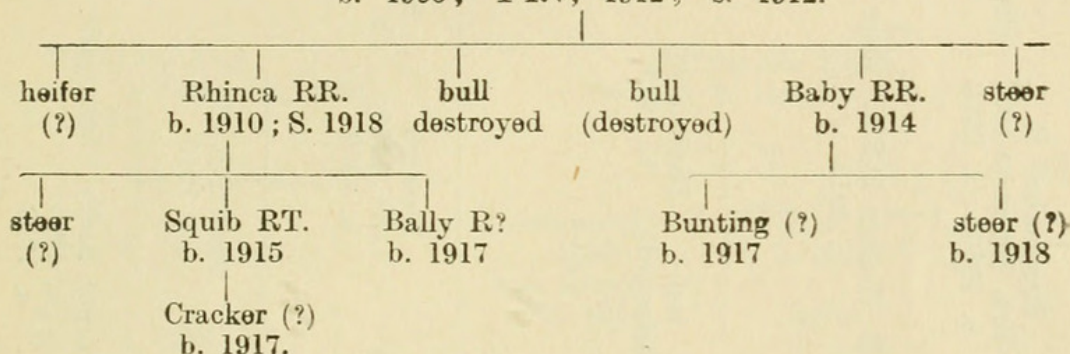
Signs used (adapted from Mr. I. Jones' tables).

b. born; d. died; R. resistant; RR, strongly resistant; R?. apparently resistant, but too young for us to be certain; Rwt. redwater case; RT. resistant generally, but occasionally ticky; s. sold; T. ticky; T°. slightly ticky; TT. very ticky; T-R. ticky, but became resistant; T-RV. ticky, but became resistant after vaccination; TT-RR. very ticky, but became strongly resistant; TV. ticky, and remained ticky after vaccination.

MR. MUNRO HULL'S HERD.

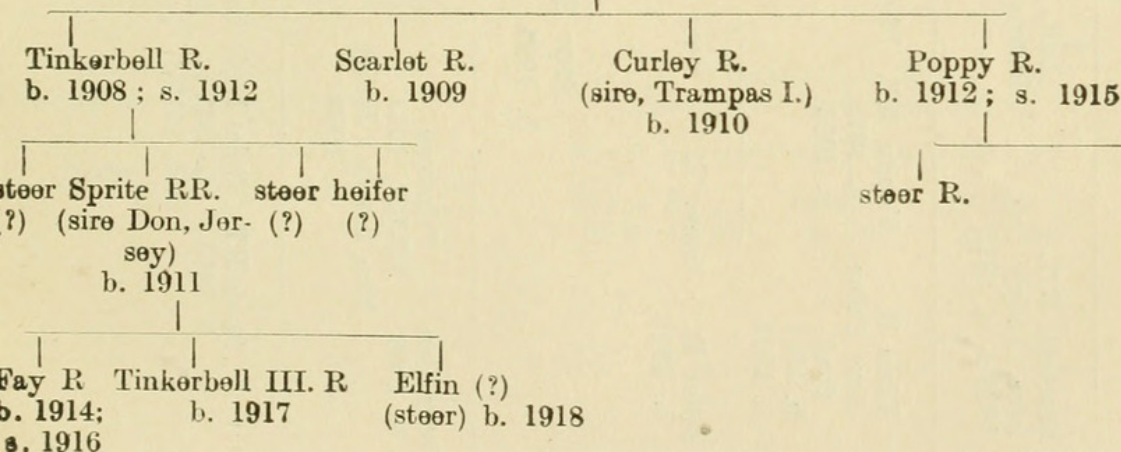
JESSAMINE (bought from Geo. Story, Runcorn).

b. 1906; T-RV, 1912; s. 1912.



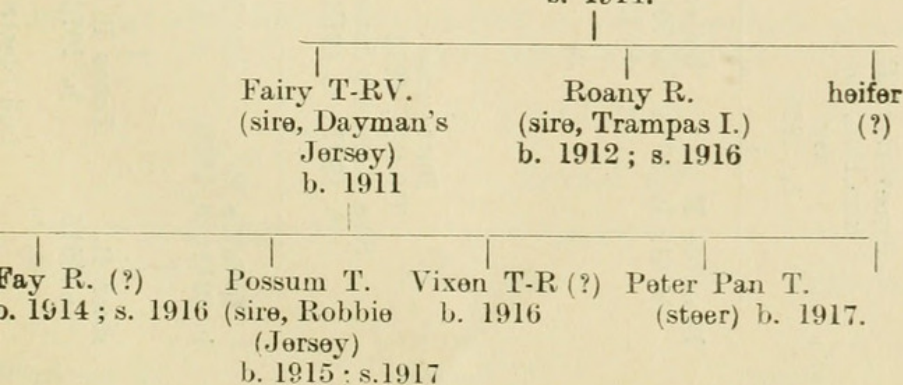
PEONY (bought at Toowong).

b. 1904; s. 1912.



VIXEN TV. (bought at Eumundi, 1910).

s. 1914.



YELLOW I. TT-RV
(bought at Yandina, 1913)
s. 1914.

Yellow II. T-R
b. 1912; s. .

Yellow III. T-RR.
d. 1917

DONKEY I. R.
(bought at Yandina, 1913)
s. 1914.

Donk y II. T-R
b. 1912

Steer T. heifer (?)
b. 1916 b. 1918.

STARLING T-R.
(bought at Rosewood, 1911).
d. 1915

Dot R.
b. 1914; d. 1918

steer
b. 1917; s. 1918.

STORMBIRD T-RR.
(bought at Rosewood, 1911).)

Trampas II. R.
(bull)
sire, Trampas I.
b. 1915

Petrel R. steer (?)
b. 1916. b. 1918.
heifer
b. 1918

PEEWEE T-RR.
(bought at Rosewood, 1911)

Nigger R.
b. 1916

SEAGULL T-RR.
(bought at Rosewood, 1911).

Sulky R. Steer T° heifer (?)
b. 1913; s. 1916 b. 1917 b. 1918

MR. INIGO JONES' HERD.

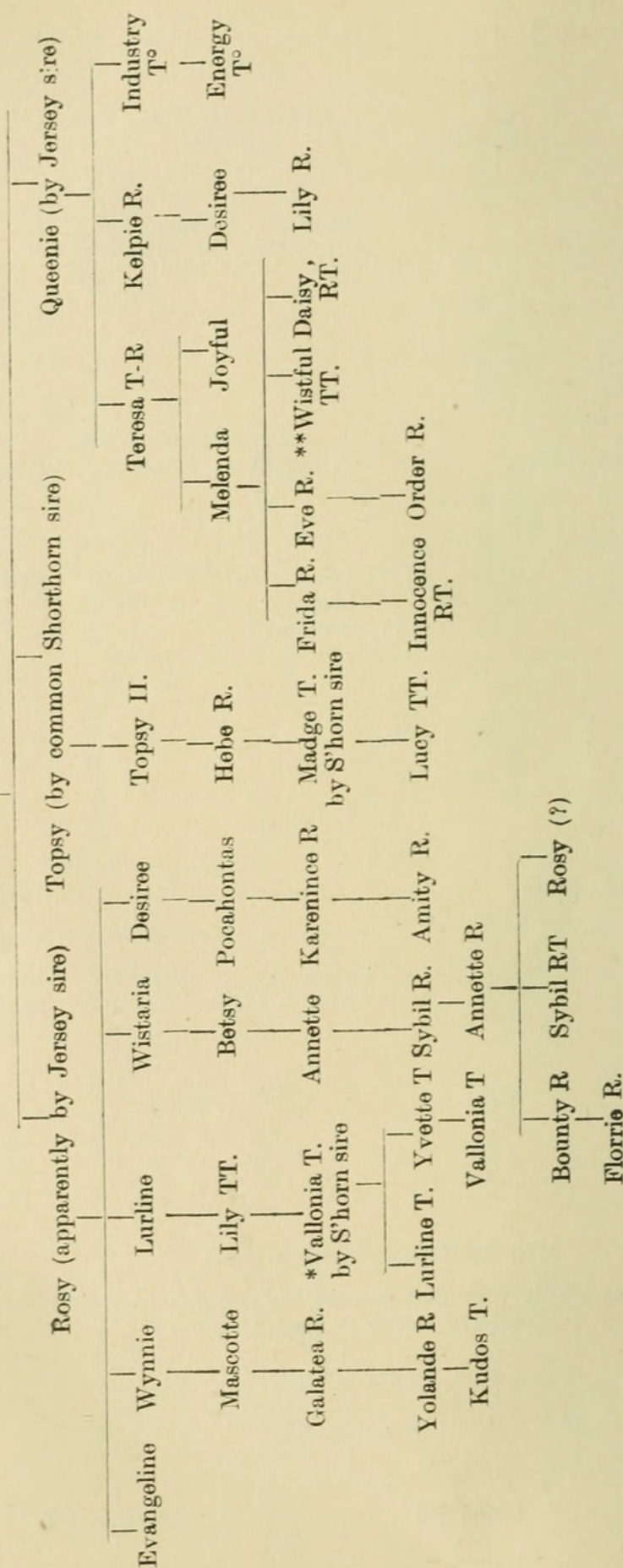
Mr. Inigo Jones has kindly provided us with the pedigree of some of his animals a copy of which is here given :—

XENIA TT-RV.

Erminie RT.

Xenia	Chloe RT.	Queenie RT.
Prudence T.	Rachel T°	Quality T. Gazelle T°

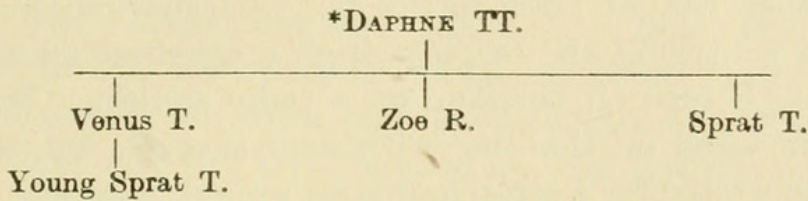
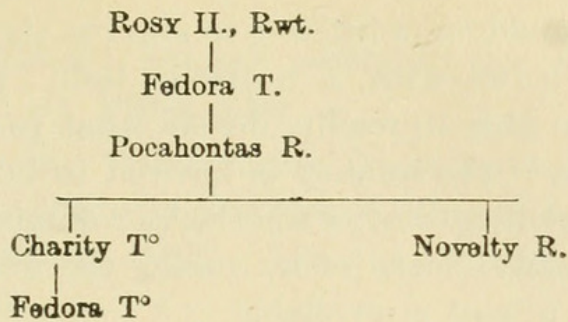
OLD DAISY, d. 1898.



. All are by Jersey bulls unless stated otherwise.

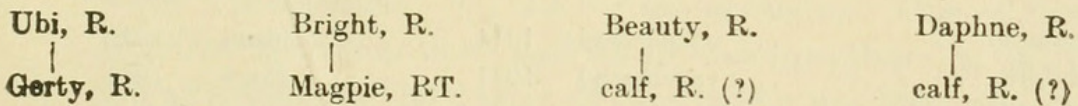
*This line will not take the vaccination,

**Wistful died of tick worry.

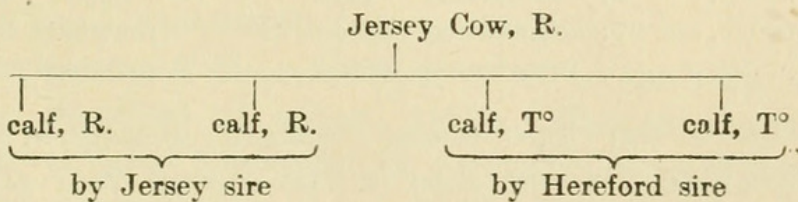


*"This line will not take, but Zoe associated with Novelty, and perhaps became clean in that way." (I. JONES).

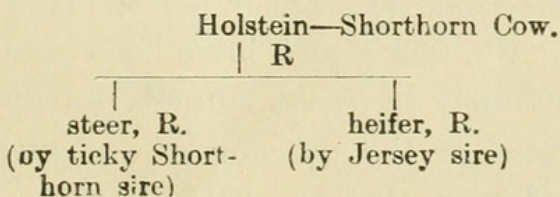
" LONEHAND COWS " (MR. F. HULL).



INFORMATION SUPPLIED BY MR. C. A. WARE.



INFORMATION SUPPLIED BY MR. W. G. GRAY.



It should be of interest to observe the result of mating resistant cows with a resistant bull. By so doing one should be able to readily decide what part heredity plays. Moreover, if the quality be proved to be inheritable from either parent, no matter whether as a dominant or a recessive, then a ready means of increasing the number of resistant cattle in a herd is available.

2. *Transmission by "vaccination"* :—There is a considerable amount of evidence in favour of the view that resistance can be transmitted by "vaccination," i.e., by taking a little of the exudate from a resistant animal and rubbing it into an abrasion on a ticky subject. Mr. Hull experimented on this line with some success, but since at first he waited for a scratch or horn wound to appear on the ticky animal at the same time as fresh exudate was available, his progress was necessarily slow. Later he performed the scratching with a clean knife. During the last few years he has given up vaccination since he considers the animals become tick free naturally if left alone. The results of vaccination of the following ten animals were :—

Jessamine	..	..	vaccinated	1911	..	..	clean	1912
Ladybird	..	..	vaccinated	1911	..	..	clean	1911
Woodbine	..	..	vaccinated	date ?	..	..	clean	date ?
Fairy	..	..	vaccinated	1915	..	..	clean	1916
Maudy	..	..	vaccinated	1913	..	..	clean	1914
Betsy	..	..	vaccinated	1913	..	..	clean	1915
Prettyface	..	..	vaccinated	1914	..	..	clean	1915
Brownie	..	..	vaccinated	1916	..	..	clean	1916
Holly	..	..	vaccinated	date ?			remained ticky	
Zephyr	..	..	vaccinated	date ?			remained ticky	

Eight out of ten thus became resistant, usually in the following year and in one case in the second year after vaccination. As a contrast of this apparent success one may consider the case of the 10 heifers purchased from Rosewood in 1911; these were never dipped nor (with one exception, Beauty) were they vaccinated, yet eight out of nine survivors became tick resistant in periods varying from two to four years; the four which have been retained are some of the most strongly resistant animals on the place.

Positive evidence of the efficacy of vaccination was given by Mr. Henderson (R.S.C. 1915, p. 41). Of nine

animals so treated six became resistant, the peculiarity developing about six weeks later.

Mr. Inigo Jones, Crohamhurst, practises vaccination, his method being described elsewhere. He has found that some animals will not "take" but that the treatment is usually efficacious.

Mr. R. Cross, Graceville, is another adherent to the vaccination theory (*see* statement already given).

Pound reported against such mode of transmission (1914, 1916), as also did Thorn (R.S.C., p. 29). One of us endeavoured to "vaccinate," using "exudate" sent down to Brisbane by Mr. Hull on various occasions. The substance when sent dry was pounded up with glycerine or else "extracted" with glycerine and after carefully cleansing the skin with alcohol, was placed in cuts made on the hind quarters of animals.

In January and March, 1917, owing to the kindness of Mr. D. A. Rooke, we were enabled to test the effect on a number of his cows at Caloundra. Three ticky animals were "inoculated" on the former occasion. One of these, together with four cows and a bull, was inoculated in March. No alteration in the degree of infestation has been observed to date, those which were vaccinated being neither more nor less infested than the rest of the herd.

A small herd of Jersey and Shorthorn crossbreds in Brisbane was also utilised (November, 1915-June, 1917). One was "vaccinated" once, and two twice, but there was no appearance of an exudation up to the time that they were disposed of (June, 1917). Though attempts were made to infest these with larvæ artificially and though some ticks were present in the paddock, they remained practically free, as did also the three control cows. These animals, which are now the property of Mr. Jacobson, Mooloolah, were examined in March last. Five of them which were running with dry stock, were all very lightly infested, while another was perfectly clean though its companions in the milking herd were quite ticky. The last named was one of our control animals, while three of the former group had been "vaccinated." The results of our experiments, then, are negative.

3. *Transmission by contact* :—By this Mr. Hull means that the resistant condition is “picked up” naturally, *i.e.*, that larvæ which hatch from the eggs laid by the few ticks maturing on resistant cattle, convey “something” derived from such animals to those which they infest and thereby set up resistance. We have already stated our inability to find any organism in smears of the exudation. Larvæ from ticks taken from resistant animals were applied in considerable numbers and on several occasions to cattle in Brisbane during 1916. The latter did not show any difference from the controls in regard to tick attack, all being very lightly infested. The application of larvæ to animals which had been “vaccinated” did not meet with success.

Two batches of larval ticks, one lot being the progeny of four engorged females taken from Rosie, the other the offspring of six taken from Sunset, were sent on 3rd April, 1918, to Miss M. Walker, Woollooga, who replied on 18th June, that on two or three occasions, after applying these larvæ to an experimental heifer, there appeared in the vicinity of the anal and genital region of the latter, about two days after application, tiny yellow blisters which, on being squeezed, exuded a drop of clear yellow fluid. In July, another letter was received in which Miss Walker stated that quite similar blisters had appeared on the animal after the application of ordinary larvæ.

A number of heifers were brought from Rosewood to Eumundi and allowed to remain in Mr. Hull's paddocks for a certain length of time to ascertain whether they would acquire resistance. They were not subjected to vaccination and were treated with an arsenical solution only at the time of leaving Eumundi for Rosewood. Their condition while at Eumundi has been noted elsewhere in this report. We are awaiting observations as to the effects noticed during the forthcoming tick season.

Our examination of Mr. Hull's records reveals the fact that of the stock which never acquired resistance while on his property—young animals (*i.e.*, calves and yearlings) excluded—four remained there two years without acquiring it; two, three years; four, four years; nine, five years; one, six years; and one, seven years.

Our experiments in regard to "vaccination" and "contact" have given much the same result as that reported by Messrs. Pound and Thorn. We would like to point out however, that we used only glycerinated material. Perhaps the employment of fresh exudate may have led to more satisfactory results.

In this connection we would like to emphasise our remarks made earlier in this paper (see under section "Tick poison") when dealing with the question of tick poison, the production of anti-tick bodies and the possibility of using an animal with blood rich in such substances, as a "bleeder" for supplying material for inoculation in order to obtain passive immunity.

Mr. Hull forwarded the following account (19th February, 1916), of his experiments in regard to transmission by "vaccination" and "contact."

I. *Blood* from Clover inoculated into three cows and three calves.

Result:—One cow re-acted for piroplasmosis. The three cows remained liable to ordinary tick infestation until disposed of. Calves exhibited no abnormal conditions until disposed of at two years old.

II. *Exudate* from "tick sores" on Clover *vaccinated* into nine young cows obtained from different districts.

Result:—Five re-acted by exhibiting a serous exudate on escutcheon, close to vulva, and developed resistance, requiring no treatment as regards ticks. Close observation revealed presence of abundant dead larvæ and occasional fully-engorged females, the latter increasing in number in the winter months. This condition was maintained until cattle were disposed of several years later.

III. *Inoculation* by exudate from "tick sores" on Clover into five young cows.

Result:—Three re-acted and maintained similar conditions as in Experiment II.

IV. *Contact experiment.* Ten young cows from 12-15 months old obtained from Rosewood—inoculated without loss by A. E. Cook, of Eumundi, against piroplasmosis.

These ten heifers together with a number of the subjects of previous experiments (including Clover) were run on an isolated paddock of about 30 acres, leased for this purpose, whereon no stock had been running for a considerable time and which was practically surrounded by standing sub-tropical scrub and at some distance from any public road. After some nine months these heifers were brought home and closely watched.

Result:—One subject, Rosewood, died during the following winter, cause not known. One subject, Misery (so named from its persistently poor condition) matured innumerable ticks, and is in this condition to-day (Feb., 1916), after dropping her second calf.

The balance re-acted similarly to subjects of previous experiments, showing at variable periods during the summer months the clean serous exudate on escutcheon, with occasional fully-engorged females present, but retaining full immunity as regards necessity for any special treatment against cattle-tick.

Of these subjects seven are alive to-day (Feb., 1916) on this property, viz. Kittiwake, Seagull, Peewee, Cuckoo, Stormbird, Beauty, Misery; the two cows Starling and Mulga succumbed under drought conditions obtaining at the end of 1915. All living subjects have dropped their second calves.

Of the progeny of these there are extant Starling's heifer, Dot; Stormbird's bull, Trampas II., all other having been destroyed or died through stress of drought conditions last year (1915).

V. *Vaccinated by glycerinated virus* from tick sores on Tinkerbelle into two calves at "Lonehand," the property of Mr. Fred Hull.

Result:—One subject extant to-day as a fully-matured cow, on third calf, showing similar conditions as regards resistance.

VI. *Contact experiment.* Two calves, Brownie (dam, Spot, a very ticky, aged cow) and Wallum (dam, Heatherbell, out of Clover) were enclosed in company from birth until nine months old without contact with other calves or

grown cattle. The object in view was to ascertain if the resistant qualities enjoyed by the daughter of Clover would be conveyed to the progeny of a very susceptible subject.

Result :—Both calves retained resistance while running free with ordinary cattle until the summer of 1915, when, owing to drought conditions, they became poor and emaciated, maturing fully engorged ticks to such an extent that treatment became necessary. Both are still under observation to ascertain whether, with improved conditions, this resistance will become established. The calf of Brownie (Spot) is still living and will be used to determine whether the resistance enjoyed by its parent (and possibly obtained by contact from Wallum) has been transmitted.*

VII. Isolation of nine calves on ten acres of grass land, heavily infested with ticks, six being the progeny of ordinary tick susceptible cattle and three being the progeny of "proven resistant" stock.

Result :—Three of the controls succumbed to extremely heavy infestation. Two had to be destroyed subsequently, having failed to recover. One recovered but showed no resistant qualities when disposed of.

The three resistant stock suffered but light infestation and rapidly developed into clean-coated heifers.

Two of these are identical with the mature cows Donkey and Yellow now registered as resistant, have passed their first period of lactation, both showing serous exudate on escutcheon.

(Signed) MUNRO HULL,
February 19th, 1916.

FERTILITY OF TICKS TAKEN FROM RESISTANT CATTLE.

A number of ticks taken from twenty of Mr. Hull's resistant animals during the past three years (1915-1918) have been watched by us in order to determine whether their fertility has become diminished. Ticks from ordinary controls have also been tested. For a considerable time Mr. Hull was not able to raise larvæ from such ticks, while

*Wallum has fully regained resistance and is to-day quite tick-free while Brownie has been carrying a few ticks all throughout the period. 10th July, 1916. M. Hull.

specimens forwarded by him regularly to Dr. Porter, Cambridge University, laid eggs from which larvæ hatched but lived only for a day (R.S.C., p. 12), investigation failing to reveal the cause of such widespread destruction.

Pound (1914, p. 110) stated that ticks picked up naturally by Clover and Tinkerbelle as well as those applied artificially, eventually laid eggs which hatched normally, the progeny being in no way impaired. In his report for 1915-1916 (1916, p. 90) practically the same information is given.

One of us found that there was little difference (if any) in regard to the laying and hatching of eggs of ticks taken from a resistant cow and from a ticky control animal (R.S.C., p. 59). In some cases no hatchings were obtained, but these were due to climatic or other conditions—chiefly drying.

Fertility tests were carried out at Eumundi with ticks obtained from November, 1917, to February, 1918. These ticks, 55 of which were from the following eleven resistant animals, Dot, Donkey, Fairy, Jockey, Kittiwake, Peewee, Rosie, Rainbow, Squib, Sunset and Yellow; and 42 from seven non-resistant animals (mostly calves) were placed in loosely stoppered tubes and kept in a fairly cool, moist place on the easterly side of the house. These observations were concluded in Brisbane in February and March. The results were:—

	Ticks from (a) resistant.	(b) non-resistant animals
Normal fertility (i.e., ticks of whose eggs 80 % or over hatched)	54 % (approx.)	78 % (approx.)
Partial fertility (i.e., under 80 %— usually about 50 %)	42 % (approx.)	17 % (approx.)
No hatching	3 % (approx.)	4 % (approx.)

Tests carried out by Mr. Hull during 1917 afforded very different figures. He supplied us with full details of these tests. His results were based on observations of 113 ticks removed from 11 resistant animals and 138 ticks removed from 10 ticky animals during the period February-November, 1917.

	(a) resistant.	(b) non-resistant animals.
Ticks from		
Normal fertility ..	4 % (approx.)	19 % (approx.)
Partial fertility ..	13 % (approx.)	38 % (approx.)
No hatching	83 % (approx.)	42 % (approx.)

These ticks were kept in match boxes and in a rather hotter and drier part of the house than that used by us.

During the period 1915-1918, Mr. Hull sent down engorged ticks from various cows, both resistant and non-resistant, whose names were indicated by him.

Of course one found many ticks that did not lay, also many which laid few eggs and many which laid a normal number of eggs from which no larvæ hatched, but there were quite enough normal hatchings in the case of eggs of ticks from resistant animals to justify the above remarks. On several occasions we noticed that, though under exactly the same conditions, there was a very marked difference in the activity of larvæ, those whose parents were taken from ordinary cattle being much more lively and living much longer than those from resistant animals. This may perhaps be an individual matter as far as the parent ticks were concerned.

We have, then, had plenty of opportunity to test the fertility of such ticks. We have already emphasised the fact that extremely few ticks mature naturally on such animals. In regard to such engorged ticks, we found that the percentage of those with normal fertility was less than in the case of ticks from control animals. The percentage of those whose eggs did not hatch was practically the same in the two sets. The same statements apply to the "winter ticks" spoken of by Mr. Hull—*i.e.*, cattle ticks taken by him from resistant animals during the winter.

Mr. Hull carried out the following experiment. A solitary engorged tick was found (11/12/16) on a resistant animal (Sunset). There was normal egg-laying and hatching, the larvæ being applied on 10th February, 1917, to another resistant cow at the base of the tail. The infested area was observed twice daily. The larvæ became attached especially in creases of the skin. On 19th February only 80 nymphs could be counted. Next day several males and two nymphs were to be seen. Only one female reached maturity.

We carried out a similar experiment (January and February, 1918) the results of which (detailed under cow Squib) agree with those stated above.

We would like to draw attention to the results obtained by Bishopp and Wood (1913, pp. 176-178), who applied large numbers (700-1,500) of larvæ of *Dermacentor*

albipictus to cattle, but only a few engorged females were developed from them.

Fairly frequently one may meet with undersized yellowish female ticks in which the malpighian tubes appear to occupy a great deal more than the normal space. Such ticks apparently are nearly always unable to engorge. They occasionally lay a comparatively few pale eggs which in every case failed to hatch, although from eggs from three specimens of such ticks (December, 1915), larvæ were developed but failed to emerge. It may be objected that such ticks have not been fertilised but those which have been dissected have contained abundant spermatozoa. Such ticks have been taken from a number of resistant animals and also from certain cows which are at present classed as non-resistant. At least one of the latter, viz. Vixen, is regarded as "cleaning up" as far as tick infestation is concerned. Mr. Henderson (R.S.C., p. 41) referred to this type of tick as occurring on his "immune" stock.

In this connection we might draw attention to the following observation by Dr. Wynne (1896, p. 40): "*Ascites of female tick.* One morbid condition of the adult female tick is worth noting though I am unable to offer any explanation. Very rarely and apparently only on certain animals the ticks look like miniature white grapes, almost transparent, of a pale greenish yellow. . . . They are little bags of fluid, in the interior of which the various internal organs can be seen lying. It appears to be a true dropsy of the peritoneal cavity as on dissecting the tick the condition of the organs recalls vividly the appearances seen in ascites of man."

The ticks referred to by us are certainly not like "bags of fluid" but are somewhat shrunken.

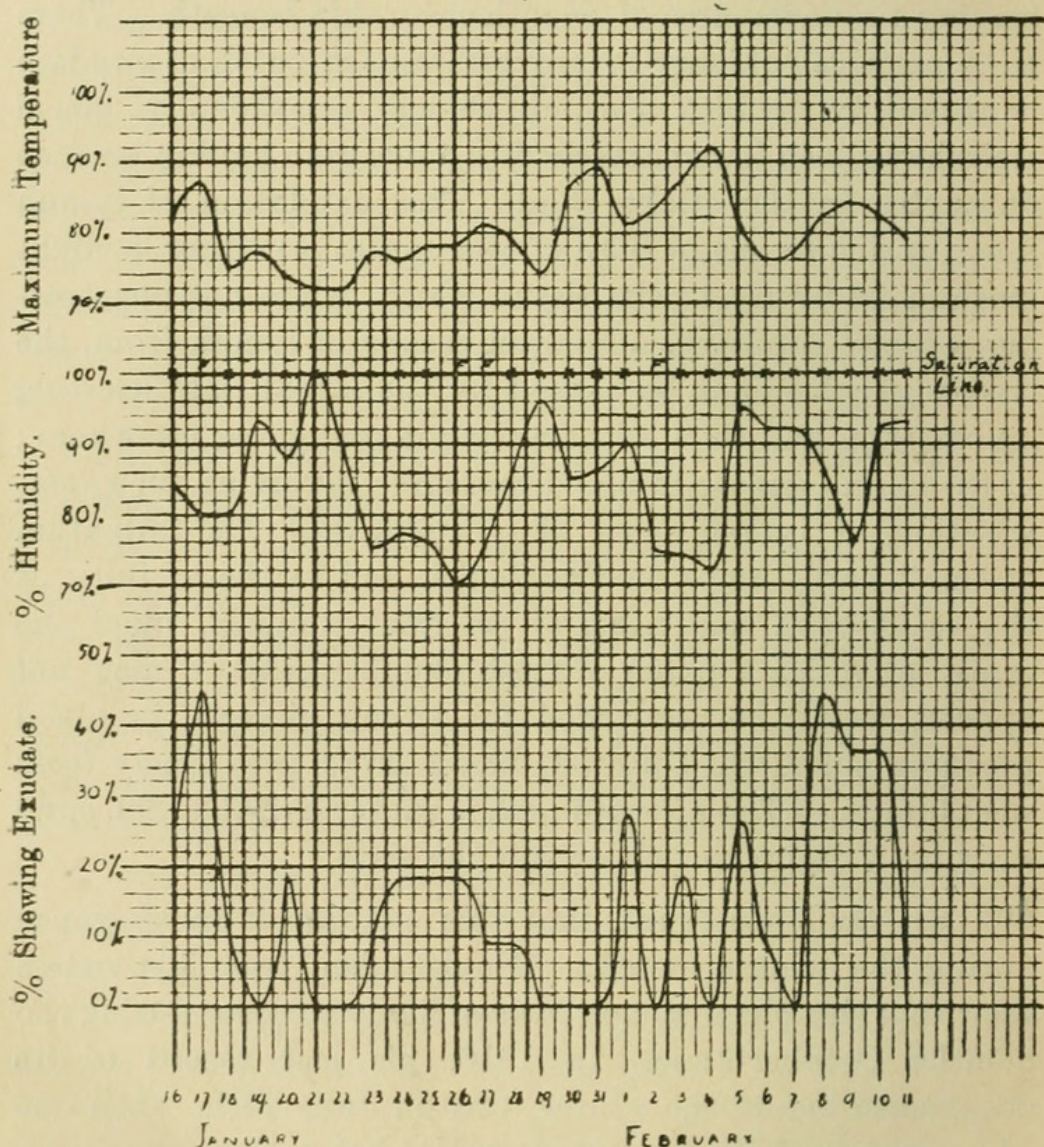
EXUDATE.

Associated with tick resistance may be an exudate. This exudate, or so-called serum, has on many occasions been referred to by Mr. Munro Hull, who was, as far as we know, the first to bring it under public notice in Australia. It consists of drops of a clear yellow fluid, which appear on the skin on various parts of the body, neck, dewlap, butt of tail and escutcheon, notably on the last-named, where

it is more evident owing to the shortness of the hair. These drops become thick and sticky, ultimately forming little granular masses or thin flat yellow scabs, according to the size of the original drop. The largest patches seen were about the size of a sixpence or slightly larger. In some animals these little masses of exudate are perfectly clear, the skin appearing through them quite uninflamed. In others some blood may be present, then the resultant scab is discoloured. When dry these scabs are readily flaked off leaving a rounded area of smooth clean skin beneath. There is no positive evidence to prove that each patch of exudate is caused by the bite of a tick, though, occasionally, larval ticks have been found attached to a dry scab having become entangled in the sticky fluid. This exudation of lymph must be due to one or both of two causes (1) either a slight mechanical injury to the tissue which, while not penetrating a blood capillary, allows an escape of lymph from the tissues; such might be caused by the larval tick inserting its rostrum, and then withdrawing it and going elsewhere; or (2) to an increase in blood pressure, involving an extravasation of lymph from the capillaries. The formation of small hard lumps on the flanks, and in the vicinity of the escutcheon and neck of resistant animals, upon the centre of which a patch of fresh exudate may or may not appear, would be accounted for by an increase in blood pressure, since when scored, blood flows very freely from such lumps. The affected area is rather irritable, the cows shewing a desire to lick or rub the part.

Mr. Hull has found that this exudate is in abeyance during the winter months. Notes taken from his letters shew that this phenomenon is most likely to occur during the months October-June. In 1916, his last record of its occurrence before the winter, was on June 24th, when one of us examined the animals, exudate being then abundant. The first record of it in the following spring was on October 20th, when exudate was present in small patches. In the beginning of the next month, during some humid weather, it appeared abundantly. The cows were in splendid condition and no ticks had been noticed on them. Records of the occurrence of the exudate came to hand from time to time up till April 28th, 1917, although little or none

appeared during the first few months of 1917. Its first appearance in the following spring was on October 10th, 1917. The condition continued to be shewn by various cows at intervals during January, February and March, 1918 (see details regarding different cows). On April 6th, Mr. Hull reported that no exudate was apparent. On May 2nd he wrote that Baby was shewing heavy exudate, while the same condition, but far less pronounced, was



The days on which more or less rain fell, are indicated by a cross on the saturation line. F represents the days on which there was no rain at all.

visible on Wallum. On June 7th, inspection revealed only one cow—Buttercup—with fresh exudate, but Brownie, Isis and Baby shewed evidence of extensive exudation a day or two prior to examination.

Evidence of the effect of the weather on the "lumpy" condition already referred to, is afforded by the following notes taken from Mr. Hull's letters. On January 9th, 1917, he noted that nine of his resistant cows were shewing a lumpy, knotted condition. Next day a sudden change in the weather occurred. The barometer fell and a westerly wind sprang up, the lumpy condition subsided without any extravasation of lymph.

An attempt has been made to correlate the daily temperature records taken during January and February, 1918, with the exhibition of exudate. The accompanying graph shews the results obtained by plotting maximum temperature, humidity per cent. and per cent. of animals shewing exudate, against each day. It appears that there is a rough correspondence between the three curves, the humidity per cent. being an inversion of the other two. The exudate appeared more abundantly on days of fairly high temperature accompanied by less humid conditions. The humidity was very high throughout—as might be expected during the rainy season, so that the term "less humid" is only a relative one, meaning that there was less moisture in the atmosphere than when it was actually raining. Although some rain fell on practically every day, the mornings were frequently fine, warm and sultry (conditions favourable to the exudation), becoming stormy or showery in the afternoon.

Mr. Inigo Jones, Crohamhurst, however, finds that the exudate appears on his cows in winter as well as summer.

At the end of July, Mr. Jones undertook to examine several resistant cows at regular intervals throughout the winter and note especially the presence (or absence) of ticks and exudate. On September 23rd, he forwarded his report. The four selected cows, Erminie, Queenie, Pocahontas and Frida were examined on July 15th and 30th, August 15th and 30th, and September 15th. The exudate was visible and normal on all occasions, and owing to the severity of the winter and consequent low condition of the cattle a few ticks were observed on each occasion. On August 15th, he reported that a calf, Rosy V., aged eight months, the daughter of a resistant cow, showed a typical exudate for the first time. She was apparently tickless. Erminie

calved on 15th August, 1918; Queenie on 6th October, 1917; Pocahontas on 29th April, 1918; Frida on 18th July.

The condition just described appears to graduate into a type of tick-sore, so far only noticed on resistant animals. The scab formed over such a tick sore consists of two very distinct parts—an outer ring of a clear yellow substance, apparently composed of exactly the same matter as that spoken of above, surrounding a dark blood-stained core, on the upper surface of which there is a pit, where the mouth parts of a tick have been inserted*; very often the tick is still present. Development up to the adult stage occurs in such ticks but the females are unable to bloat and remain stunted, sickly-looking individuals, eventually dropping off with the scab. The under surface of this hard black core, surrounding the rostrum of the tick, is tipped with pus. When such a scab is removed a corresponding pit is seen in the skin of the beast. The distribution of ticks, tick sores and exudate on the skin of a beast is very irregular. For instance, a fold of skin three by two inches on the escutcheon of the cow Fairy was carefully drawn to shew such distribution. About two-thirds of the area was occupied by small dry yellow granules and six larger hard red scabs, while one nymph was present; the other third contained two pairs of ticks—adult and female (unbloated)—each pair being attached to an inflamed area of skin. In close proximity were an adult male and a nymph creating no disturbance. An area of similar size, was examined on another cow, Baby; several dozen larvæ (apparently just attached) were visible, but, while the larvæ were concentrated at two points, dry yellow granules were just as abundant in the intervals as around the larvæ. Three typical tick sores were present as well as some hard dry scabs. Such instances could be multiplied indefinitely.

A type of tick sore quite distinct from that described above, is found on certain cows, notably Kittiwake. These might be termed tick-blisters, as each forms a little rounded excrescence on the skin, filled with lymph. These seem to form usually round the point of attachment of a larval or nymph tick.

*W. Herms (Jour. Parasitol., 2, 1916, p. 140), has given an account of the tick sores produced by *Ornithodoros coriaceus*. He mentions the presence of lymph exuding from the wounds.

Little whitish sores containing pus are also formed in response to tick irritation. Thick, whitish scurf may also be formed from the same cause, notably at the butt of the tail and in the ears.

With regard to the appearance of an exudate on Clover and Tinkerbelle, Pound (R.S.C., 1915, p. 20), stated that such vesicles as did occur on them, were the result, purely and simply of tick irritation. On arrival at Yeerongpilly in December, 1912, and again during the stalling experiments of June-July, 1914, these cows are reported to have been covered with sores of a vesicular and pustular character (Pound, 1914, p. 110). Further on, however, in the same report he mentioned that bacteriological examination was made of "the serous exudate." Several kinds of ordinary skin bacteria were found; while such pyogenic cocci as *albus* and *aureus* were observed in the pustules, but no other organisms were detected that could be regarded as fatal to the cattle tick. Pound (R.S.C., 1915, p. 20), also stated that no such vesicles occurred when the animals were kept on non-infested country.

Smears of blood and exudate taken from a number of resistant animals during the period 1915-1918, failed (on examination by us) to reveal the presence of any organisms other than those which one might expect to find as a result of contamination.

Cultures were made of some exudate sent down in capillary tubes. These were submitted to Dr. Bradley, Microbiologist to the Health Department, Brisbane, who reported as follows:—"The plate culture submitted shewed several types of colonies. The types of these were such as usually occur from air or water contamination. None resembled known pathogenic organisms, except a few which may have been varieties of Staphylococci (commonly found in the skin of men and animals). Many of the colonies were apparently dead as no growth occurred on sub-culture of the smaller types. Gram stained film shewed gram positive cocci and gram positive bacilli."

Cultures made in agar slopes were incubated at 37 degrees C. for several days; several shewed a growth of mould but no organisms other than those noted above were detected.

Only one definite reference to such exudate is to be found in literature. In the conclusion of a paper on the "Biology of some North American ticks of the genus *Dermacentor*," Bishopp and Wood (1914, p. 179) made the following statement: "Three of our bovine hosts used in experiments shewed such a tendency to immunity. As stated in Table VI. (Infestation No. 8), no females became engorged on a Jersey calf used as a host in comparison with a bull (Infestation No. 9). This calf as well as two other animals were tested several times without a single specimen developing to repletion. It should be mentioned that these hosts showed marked resistance to the attack of other species of ticks. This resistance appears to be due largely to an unusually strong tendency to form scabs at the point of attack, thus healing the wound, and throwing off the tick with the scab. On all hosts scabs are usually produced as the result of the insertion of the mouth parts of the ticks. When the larvæ first become attached a translucent yellowish exudate is thrown out at the point of attack. The subject of resistance will be discussed at greater length in another publication." This is also mentioned by Tryon (1916, p. 50). We have been unable to find further reference to this other publication, which may throw greater light on the problem.

Schroeder (1905, p. 57), stated that "When ticks are numerous it has been observed that a sticky substance frequently accumulates on the skin of cattle: this may be either an exudate from the irritated skin or an accumulation of the discharges from the ticks. After a while this substance hardens into dark, granular flakes and peels off. It is best seen in the creases of the skin. Whether it exudes from the skin or is discharged from the tick does not alter the fact that its original source is the body of the cow or steer. If it exudes from the skin it is strong evidence that the skin is extremely irritated" The same author also describes the effect of a tick bite on the skin of an animal—"When a cattle tick is detached from the skin of a cow, a small circular spot, sometimes partly denuded of hair, and slightly reddened, is seen, with a minute, barely visible puncture in its centre, from which a drop of blood may ooze. When examined under the microscope the skin

in the narrow circle about the puncture is found to be densely packed with infiltrated cells." This "sticky accumulation" does not exactly correspond with the exudate observed by us: the former is found to occur when ticks are numerous, whereas the latter is most marked on cattle on which few or no ticks are present.* With regard to the suggestion that it is a discharge from the ticks, it has been noticed that certain ticks of the genus *Ornithodoros* when feeding "become surrounded by a clear fluid which comes from their malpighian tubes and coxal glands."†

Although we have failed to find even larval ticks in the great majority of the patches of exudate examined by us—even after using the microscope, we believe they are a direct result of larval tick attack on certain cattle, *i.e.*, cattle which possess some individual physiological peculiarity. Such animals are resistant and apparently the small quantity of tick toxin—perhaps even the mere mechanical stimulus of the rostrum—is able to so increase the local blood pressure that there is an exudation of lymph. We have already stated our opinion that the blood of resistant animals will be found to possess certain differences in regard to its biochemical composition.

It may be objected that this exudate makes its first appearance each season before the presence of ticks is noticed, but we must point out that larvæ begin to infest cattle some little time before their occurrence is noted by an ordinary observer.

SUMMARY.

The cattle tick in Queensland may cause tick fever and tick worry.

There exists a degree of resistance to tick fever and this is largely influenced by individual idiosyncrasy, age, sex, and general health of the animal as well as by food and other conditions.

Tick worry is at present a more serious complaint than tick fever in Queensland. It is apparently due, at least in part, to the injection of a toxin by the tick.

*See also Herms. Jour. Parasitol. 2, 1916, p. 140.

†Patton and Cragg, Medical Entomology, 1913, p. 639

Many cattle become habituated to tick infestation and this, in individual cases at least, leads to some degree of resistance. Such resistance is probably due to the formation of anti-tick poison bodies by the blood of the animal.

Tick resistant cattle are known from a number of Queensland localities. Asiatic breeds are tick resistant. Of the various breeds commonly met with in this State, Jerseys appear to be less affected than others by ticks.

Tick resistance seems to be influenced by food only in so far as the latter affects the general health of the animal.

The effect of the application of arsenical solutions to resistant cattle has not been satisfactorily determined. Perhaps the use of arsenical solutions prevents the realisation of such resistance.

Tick resistance persists, provided the resistant animal's health be maintained.

The temperature of resistant animals appears to be normal.

There is good reason to conclude that the resistant tendency is hereditarily transmissible.

Although there is considerable positive evidence of the transmissibility of resistance by vaccination, we have not succeeded in proving it.

In many cases the condition has been acquired naturally. We think that habituation is a step towards resistance which seems to us to be a physiological reaction to the introduction of a tick toxin.

The comparatively few ticks which mature on resistant cattle appear to have their fertility, as a rule, somewhat impaired.

Associated with tick resistance in many animals is an exudation of a lymph-like substance on the skin. This condition is quite distinct from the typical tick sore, though it is apparently a response to tick attack.

In conclusion, we desire to express our appreciation of the assistance we have received from many individuals whose experiences have been quoted in our paper; the Under Secretary, Department of Agriculture, Queensland,

for permission to utilise certain paddocks for our experimental animals ; and to Mr. D. Rooke, for allowing us to use his cattle for experimental purposes.

We would like to acknowledge particularly the help afforded us by Messrs. Inigo Jones and Munro Hull, especially the latter, who has allowed us full access to his records and to whom we are indebted for hospitality on many occasions.

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