Classification of Lac Insects

from a

Physiological Stand-point

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Lac insects in Mysore.

There are four scale insects (Coccids) in Mysore which at present must be classed under the genus Tachardia. Commercially speaking, the most important of them is the one to be found only on Shorea talura, N. O. Dipteroecarpaceae. Inasmuch as it is solely responsible for the lac industry in this state it might be looked upon as the Mysore lac insect.

Allied to it is another which usually forms its colony on Ficus mysorensis, a tree more akin to Ficus bengalensis than to F. religiosa. Perhaps, for partly two reasons, this insect is less localised in its geographical distribution. The host-plant F. mysorensis of the one, as compared with Shorea talura of the other, is well scattered all over the State. It occurs frequently along country-roads and is a regular avenue tree on some of the broad streets of Bangalore. The other reason for its being more commonly found is the fact that this insect is very cosmopolitan in its taste. In addition to its favourite food-plant, it thrives sufficiently well on Guazuma tomentosa, Anona squamosa, Ziziphus jujuba, Pithecolobium saman and others irrespective of their natural orders.

When specimens of stick lac from Shorea talura are compared with those obtained from Ficus mysorensis, it will be noticed in the latter case the length of the encrustation is remarkably small. If the former tree can be seen with almost all the branches covered
with lac and will appear conspicuous on that account, the branches of the latter tree will show a small colony of insects with pieces of stick lac usually, four to five inches in length, and very often with only one or two lac covered branches per tree.

It is due to the inability to form long encrustations of lac that this insect is not artificially propagated in Mysore. If, on account of the intense distribution of the insect colonies on Shorea talura we have called one the lac insect of Mysore, on account of the wide distribution of the insect on Ficus mysorensis we are inclined to look upon it as a wild or the commonly found lac insect.

The third insect of interest to us grows round about Bangalore on Pongamia glabra, an oil-producing tree of the leguminous order. It is mostly found on this host, possibly because, it takes its place along with Ficus mysorensis in being generally seen along the roads. This insect is identical with Tachardia minuta of Dr. Morrison, and my specimens were identified by him.

The last insect we have to consider grows most frequently on Ixora parviflora. This tree belongs to the order Rubiaceae and is popularly known as the torch-tree on account of the oily or resinous contents of the stems which, even when freshly cut, can be lighted or used as torches in a jungle. It is not rare in the scrub jungles round about Bangalore and especially in the Jakkur plantation, some seven miles north of Bangalore, there are several torch-trees infected with a new scale insect very closely allied to Tachardia minuta.

An apology.

The first two insects differ so considerably from the latter two that I am convinced these should be looked upon as pseudo-lac insects. When Dr. Kunhi Kannan was on deputation in America, he brought me in closer touch with Mr. Ferris, of the Junior Stanford University in California, with whom I was already in correspondence. I learnt from Mr. Ferris that from his own studies of lac insects he was of opinion that the present genus Tachardia embraces generically different insects and as such it is at present only provisional.
He was kind enough to inform me that as Professor Silvestri of Portici, Naples, was hoping to write a monograph on these insects, he had stepped aside in favour of this savant.

Afterwards I heard from the learned professor that he proposes to undertake such an investigation only when he has collected the necessary material from different parts of the world. As perhaps all may not be equally patient, I propose giving expression to my views on the subject. I do so not primarily to safeguard any claims to priority, but perhaps to draw the attention of the cut and dissect morphologist towards the living stage of the insects he is studying. To avoid all pitfalls due to a purely static study of systematic entomology it is best to take a kinetic or a physiological stand-point. It might be said with some justification that physiologists should not rush in where morphologists have not done the pioneering spadework, but, as will be explained later, I am of opinion these two aspects of study are mutually dependent and as unfortunately I have to step forward, a little prematurely, I do so in the interests of insect-physiology. I have this hope, however, that at least some of the views advanced here will be corroborated by a study of anatomical characters.

Lac resin: A physiological name.

The name lac insect should be sufficient to indicate that it was the physiological activity of secretion on the part of an insect, which has given rise to the present conception that lac is a generic name for resins of insect origin. It might be said that it is natural to remember things by their uses and, as lac was of some use to man, the insect producing it came to be known as lac insect. As an illustration we might be referred to the insect Gascardia madagascarensis which was called a lac insect and consequently scientifically classified under the sub-family Tachardinae, mainly because it secreted an alcohol-soluble resinous constituent. On the above assumption the word lac, being the name of the useful product, should be the older or the root from which the name of the insect takes its origin.
It is established, however, that the lac insect has been so called because the young larvae swarm, as it were, in hundreds of thousands, which figure means a lac.

A parallel instance is found in the derivation of the word thail meaning oil in general. Sesame oil seeds are called thil and this word is generically used for something small and dark since some varieties of sesame seeds are also dark in colour. A dark spot on the human skin like a mole or a beauty spot denotes an object something small and dark and hence the word thil, meaning sesame-seed, also stands as such for it. Thus it is clear that the word thil signifies small dimension and from the producers, thil seeds, was derived the name of the product thail. As sesame oil was the most popular oil the word thail was given the status of a generic term. In the same manner, from the name of the lac insect was derived the name of its product, lac, and by way of compliment to the famous Indian insect the word lac to-day has come to mean any resin of insect origin.

We are therefore safe in assuming that the first observers of the insect who gave it the present name were disinterested naturalists and our first view-point was physiological rather than morphological in character. It seems to me what is a natural point of view should be considered the most important of all.

Cardinal points of a physiological outlook.

For the purpose of illustration our view of lac industry may be compared to that of a butter refinery. Inasmuch as a farmer considers his animals as a source of milk secretion or butter production, we may likewise look upon our insects as though they were lac-cows. As a dairyman considers his best animals as suppliers of milk and distinguishes them from those that are bulky and fat, similarly, we should be interested, not in (1) the size of the insect, but primarily in (2) the capacity of the insect to produce thick layers of lac exudation. It may be worth while differentiating a piece of stick lac where a thin coat of resin may envelope large sized insects from another with a thick coat of lac covering insects of comparatively small size, specially, when the diameter of two such pieces of stick lac may appear the same.
We have also to consider as apart from the red dye or laccaic acid contained within the body of the insect, (3) the colour of the secreted lac. It is said that the yellow colour of the lac resin is due to erythrolaccin but either different proportion of this dyestuff occurs in different kinds of stick lac or some other bodies also find their way into the lac and produce the variation in colour found in different sorts of lac. The colour question has a great commercial significance as preference is given to those with the palest yellow colour. Eminent authorities like Sir George Watts have hoped that a white race of insects might be evolved in future and one day save the chemists all their drastic operations of bleaching.

Those that are engaged in increasing the raw material, or in propagating the insect are always hoping of getting a species which can thrive on all available trees. They are anxious therefore of knowing (4) the capacity, on the part of an insect, to adapt itself to trees other than its favourite food-plant.

It is also possible that of two insects, each given its most favourite host-plant, one might be more productive than the other. When such is the case it means that, (5) the reproductive power of one insect is higher than that of the other, for, the quantity of lac collected is as directly connected with the number of female insects as the out-turn of a dairy-farm produce might be proportional to the heads in a herd.

When an insect on its favourite host-plant gives a better crop of lac in one season than in another or especially when one insect, as compared with another, gives a better yield of lac, both insects being given the best conditions of growth with regard to climate and food-plant, it implies, among other factors, a difference in the ability to withstand enemies. There are climatic and constitutional factors which control the predisposition towards chalcid parasites and other diseases. Here we might generalise a little and say, (6) each lac insect may have its characteristic associated insects, friendly and otherwise.

Similarly, we might extend our observation to lower organisms and assume there are different micro-organisms associated with every
species of lac insect. Each insect might have a selective antiseptic product in its excretion which may prove sauce to a few and poison to many fungi. It is also possible that some bacteria might enter the alimentary canal of the insect through the plant sap. Some of these might be symbiotic with the tree, while others may be foreign to it, but in some way always associated with the attack of lac insects. From the point of view of the insect these bacteria might be compared on one hand to the pebrine germs among silkworms, where they are carried through unwholesome food and on the other to the lactic ferment in the intestines of cows. The former class of organisms are known to be pathogenic to their hosts and to some extent capable of being transmitted through the egg, while the latter, though highly beneficial and invariably present even in the intestines of newly born calves, are in no way hereditary. At the same time, there might be organisms actually in intercellular symbiosis with the lac insect. Inasmuch as different host-plants might have their characteristic lac insects, these in their turn might harbour special micro-flora associated with lac insects living freely and in symbiosis. It is possible the intercellular organisms might require the co-operation of others derived through the plant and only with the joint help of the food-borne and the inherited family friends, the delicate lac insect might be able to face its formidable and numerous enemies. It is of the greatest interest to find the physiological role these organisms play in the life of the insect, and to discover if the internal micro-flora is in any way associated with the insect-fauna injurious to the lac insect.

**General physiological activity versus Major secretion product.**

Knowing what constitute the cardinal points of a physiological outlook, we may proceed to consider such points as do not see the phenomenon as a whole. To start with a concrete instance, we might ask ourselves the question already answered by others, viz., if any insect secretes an alcohol-soluble product, is it a lac insect? Having given an affirmative reply, they proceeded to state that since Madagascan lac contains such a constituent it is allied to Indian stick lac and therefore both these insects belong to the same sub-family. It
is worth while emphasising this fact for, it shows how systematic entomologists were diverted from their natural course and thought it worth while supplementing to their own some physiological reasons for classifying their insects. Applying the above kind of reasoning, it seems to me, if a sugarcane and a beet root both support the sugar industry, these plants should be classified together. If we should do justice to the physiological stand-point we should, in the first place, consider the general physiological activity of each insect and compare one with another as a whole. We should compare not only the major secretion products of both but also others. Thanks to the eminent researches of Professor Gascard of Rouen, we know that Madagascar lac contains 50 per cent. of a resinous body, but this lac has a nitrogenous constituent. The Indian lac contains 90 per cent. of alcohol-soluble portion but is free from traces of aminoacids. This is sufficient to show the great qualitative difference between the resinous constituents of the Indian and Madagascar specimens of lac and an equally great difference, quantitatively considered. If we should be so generous as to look upon these resins as identical, we should be prepared to assert the resin and turpentine from Boswellia serrata of the N. O. Burseraceae as identical with those derived from the pines proper of the order Coniferae.

When Madagascar lac is dissolved in alcohol, the insects look white on account of the coat of wax covering their bodies. Indian lac contains 5 per cent. of wax, while Madagascar lac contains 25 per cent. If, on the basis of previous kind of argument, we should call all insects wax insects, provided they secreted a waxy substance, Gascardia madagascareensis would be a proper wax insect, notwithstanding that it secretes twice as much of resin. Systematic study of this insect has proved it to be a Lecaniid, a genus allied to Ceroplastes or wax-producing insects. I understand that Madagascar insect does not contain a red dye. This fact of such great importance to us has apparently been entirely overlooked. A chemical investigation of Ceroplastes insect has not been undertaken, but, I am sure, when it is carried out, the products of this insect would be more allied to Madagascar lac than the latter is related to Indian stick lac.
We have seen our first outlook on the insect was objective and not subjective. Imagine that we are interested in the lac insect merely for the sake of its dye, which, as we all know, was actually the case just before the time when the aniline colours first came into popular use. From this stand-point we may classify the lac insect along with the Cochineal and the Kermes insects, especially as Professor Dimroth has shown that their dyestuffs have a distinct chemical relationship. The idea might strike some of us, if the Cochineal and the lac dyes were almost identical, why were these insects not classed together? One answer would be, at that time the lac insect was called Coccus lacca and the Cochineal insect, Coccus cactii, and hence physiological reasons for classifying them together could not have occurred. It must be said, however, that this classification was possibly the result of a broad morphological outlook, erroneous for having overlooked minor anatomical details and not on account of the consideration paid to their similar dye content. But I am sure, if Tachardia lacca could be classified along with Gascardia madagascarensis under the same sub-family Tachardinae, on account of their common resinous exudation when lac rather than the dye was the more popular in demand, there is every reason to imagine an entomologist, living at a time when the red dye was the more precious article of commerce, would have said with perfect conviction, "of course Coccus lacca and Coccus cactii belong to the same genus, they both give us a beautiful scarlet colour."

We may also consider an analogous case where, on account of a common product of fermentation, two organisms were given similar names. When grapes ferment into wine the decomposition is brought about by the action of yeasts proper, but later on other organisms, among others a bacterium and an yeast-like fungus, begin to feed on this alcohol. The former was once called Mycoderma aceti and the latter is named Mycoderma vini. The confusion in names was due to the fact that they both thrive on alcohol and they both produce acetic acid. The bacterium now called Bacterium aceti is usually employed in the manufacture of vinegar, while the species of yeasts named by Siefert as Mycoderma vini I. forms over
9 per cent. acetic acid, which quantity is sufficient to make good vinegar.

At the time when the great Pasteur began his work on biochemistry it was believed that these organisms were only mono-enzymic. For example, if there was alcohol present in a fermentation product, it was assumed that the organism producing it belonged to the yeasts proper or Saccharomyces. It was impossible to imagine that acetic acid could be the major fermentation product of organisms as different as an yeast and a bacterium, much in the same way, as an entomologist could not imagine lac to be a common secretion product of possibly two entirely different insects.

The micro-biologist, being accustomed to observe great variation amongst his organisms, is not inclined to pay much attention to the difference in the shape and size of Bacterium aceti and Mycoderma vini. It was not a deep microscopic research which later proved the real difference, but a better insight into the physiology of these organisms. It was found that their behaviour to different food constituents was different. Similarly, it is possible that a thorough chemical and physiological study is sufficient to show the difference in any two lac insects.

Low physiological activity.

An objection may be raised against a physiological point of view as a method of classifying higher organisms. The other day, Mr. Venkat Rao Badami, Agricultural Botanist in Mysore, showed me some striking cases of variation in his sugarcanes. He has been cultivating some varieties of canes, not from cuttings which is usually done, but from seeds. One of the types he obtained was a plant of puzzling appearance. My first impression was that it was a species of a tall grass and would prove rather good fodder for cattle. I was told it was a sort of degenerate cane and may possibly be the wild parent of the present day cultivated varieties. The question arises, if that plant contains no canesugar, how can it be considered as a sugarcane?—the physiological activity in this case being reduced to such a low ebb that it no longer affords a comparison with another
in full vigour. It seems to me, if an inactive species mocks at a physiological classification, the degenerate plant will be an equal puzzle to the morphologist. If a complete analysis of all these canes be carried out, there is no doubt the results will show a distinct relationship between them, though the similarity may not be with regard to sucrose content but may be due mainly to glucose. Judging canes by the crystalline sugar contents compares very well with the attempts to classify lower organisms by their major fermentation product, and this we hope to consider presently.

Perhaps, better than the physiological stand-point, is the viewpoint of a geneticist and it is hoped that a study of chromosomes will enable us to classify lac insects into species and varieties.

*Classification in ignorance of cross-inoculation experiments.*

The importance of a physiological study will be better appreciated when we have to explain the effect of food on these insects. It has been said "the lac obtained from *Butea frondosa* is rich in colouring matter and for this reason is commercially known as 'Rangeen', meaning "full of colour." The first idea would be that, since *Butea frondosa* yields a red gum, this forms part of the food of the insect and naturally affects the colour of the secreted lac resin. This would be further confirmed when we meet with the statement "the resin from *Ficus religiosa* is pale yellow in colour and is consequently used exclusively for the manufacture of low grades of shellac or mixed with *B. frondosa* resin to impart colour." My information has been that the paler the colour, the more desirable is the quality of lac and I have not been able to understand why the pale yellow lac resin from *F. religiosa* should not be used by itself. Apart from this little point, it is clear that *Ficus* lac is much paler than *Butea* lac.

The idea at once suggests itself that if *Butea* lac is "darker and redder," because the plant sap has a red gum, *Ficus* lac is of a pale yellow colour on account of the absence of such dark coloured food constituent. The word 'Rangeen' we might naturally associate with the colour of the resin. As a matter of fact, as mentioned by
Messrs. Lindsay and Harlow, 'Rangeen' is another name for the monsoon crop. It is used for "winter crop from trees other than Schleichera trijuga." My experience has convinced me that the monsoon crop is better than the one which develops during the drier portion of the year. The resinous layer enveloping the insects is however thicker during the drier season. Apparently, the dry climate helps the resin formation, while the moist weather helps the development of the insect. The large size of lac insects may be associated with the monsoon crop and it is the bigger insect which contains more blood and gives more lac dye. The dye content of the insect must not be confused with the colour of the resin secreted by the insect. The darkest coloured resin, I know, comes from the insect which grows on F. mysorensis and is apparently the same as found on F. bengalesensis in Hyderabad and the next darkest lac is the one collected from Shorea talura. None of these trees exude a dark coloured gum; Ficus trees yield a milky white product, while Shorea yields a glassy white vegetable resin of its own.

So much for the colour of the lac resin being derived from the colour of the food. It has been said that the insect which grows on S. trijuga degenerates on being introduced on Butea frondosa. The first such crop is called a bastard crop of lac and resembles the parental lac of S. trijuga. Lac introduced into Hyderabad at Nirmal on Butea trees has shown that the first crop is almost identical with the original S. trijuga brood obtained from Bagra, in Shoaapur Range, C.Ps. If it be true that, as the number of generations increase, the lac collected would resemble more and more the sort of lac naturally found on Butea trees, then both these insects must be looked upon as belonging to one species, but possessed with great powers of variation due to nutritional environment. However, inasmuch as S. trijuga trees are not supposed to take kindly to the Butea insect, we can only credit it with powers of degenerative adaptability. There is no scientific evidence to support this view, but to overlook the commonly held opinion and to classify insects without considering their powers of adaptation seems to me a serious matter. As a mycologist grows his fungii on artificial cultures, the entomologist can also, in the first
instance, convince himself of the stable characters of the insects by cross-inoculation experiments, as have been already suggested by the famous lac expert, Mr. Misra of Pusa.

**Common host-plants of lac insects.**

In order to compare two lac insects or one lac insect with a pseudo-lac insect I thought it necessary to find what I call the H.C.F. (Highest Common Factor) among the host-plants of lac insects. I am not sure if all these insects can grow on one and the same tree, and I am almost sure that a certain kind of predisposition on the part of the tree is necessary for the proper inoculation of lac insects. It is difficult to say if a certain insect would not grow on a particular host-plant or if that individual tree was not in a condition to receive the insects at that time. Positive observations have therefore been more productive of conclusions. Mr. Krumbiegel, Superintendent in charge of the Lalbag Gardens in Bangalore, has been exceedingly kind in permitting me to experiment with the trees in his charge. After vigorous experimentation in inoculations I find brood lac from Shorea talura grows very well on Nephelium litchi, N. O. Sapindaceae. It is equally well suited for the brood lac of F. mysorensis and all other commercial lac insects I have tried. It is also interesting to hear that a Ceylonese insect T. albizziae also thrives naturally on the Litchi tree. As the few Litchi trees in Lalbag were all inoculated with different lac insects, I have not been able to discover if the pseudo-lac insects will also grow well on this host. Guazuma tomentosa has proved to be the best tree for the study of the pseudo-lac insects. It is one of the common hosts of the insect on F. mysorensis; in three different localities it was found attacked by T. minuta of Pongamia glabra and in two other localities it had the same insect which is found on Ixora parviflora. On Sanatrum album I could see T. minuta in several places and on a single tree in another locality it showed the attack of the insect found on I. parviflora. Michelia champaca and F. cunninghami have each shown to be the common hosts between the lac insect proper on F. mysorensis and the pseudo-lac insect on P. glabra; F. benjamina has been similarly attacked by the lac insects of F. my-
sorensis and the pseudo-lac insect of I. parviflora. In spite of very vigorous search the lac insect on Shorea talura has never been found on any but its most favourite host. In addition to the Litchi it has been cultivated on B. frondosa and on Acacia farnesiana by my friend Mr. Srinivasayya. Since the first introduction at the commencement of the rainy season in May 1921 the insects have ever since been propagating themselves on these two hosts and have given five crops by now (May 1923).

As far as I can see, these insects are quite distinct from one another and have shown no sign either of degeneration or of approach to another in morphological or physiological characters. It seems to me, therefore, safe to overlook the question of adaptability as far as these four insects are concerned.

**Grades of colour among different sorts of stick lac.**

I find it more convenient to compare the lac insects proper first and therefore I hope to show later the difference between a typical lac insect and a pseudo-lac insect.

The most apparent difference between specimens of lac from Shorea talura and from F. mysorensis lies in the colour of the resinous encrustations. When the insects are healthy and living and somewhat nearly fullgrown, specially at the end of the monsoons, the fresh specimens on Ficus mysorensis look beautiful pink or rose-coloured. As the time for larval swarming approaches, it darkens a little assuming a chestnut colour with even purplish tint. Some of them appear red like the colour of ruby or garnet. When the young ones have evacuated the piece of stick lac and the bodies of the mother insects have dried and shrivelled, the resinous encrustation has a brown-red colouration, somewhat like a tea decoction. Whatever the original colour of the freshly collected specimen might be on keeping, until all the young ones come out, it has practically one and the same chestnut colour. If it is darker or looks covered with dust and fungus growth, it can be dissolved in alcohol and the colour of the solution compared with another which apparently is not thus soiled. Sometimes the rain gets to the dry insects through the minute pin-like pores in stick
lac. A little dye may be thus leached out and the surface of the stick lac be thus coloured from outside. With the action of the weather insect bodies may decompose, and ammonia may be liberated. This volatile alkaline substance will act on the dye already smeared on the surface of stick lac and further intensify the colour. Such specimens will be those that are collected so late as to show the action of rains and decomposition of insect matter. I have collected specimens almost coal-black in colour, while the usual colour of the dry specimens is like that of catechu or dirty chestnut. On the strength of the colour tests of the alcoholic solutions of the different specimens of stick lac I have been able to convince myself that a specimen of lac coloured coal-black, on Butea frondosa in Lingal, Mahboobnagar District in Hyderabad State, collected by me in July 1918, was identical with stick lac of the insect on F. mysorensis in Bangalore. Similarly, the insects found in Hyderabad on F. religiosa, F. bengaleensis, Anona squamosa, Guazuma tomentosa and Pitecolobium dulce are also of the same species though they may be of different varieties.

Mr. Green has been kind enough to spare me some of the type collection of his insect Tachardia ficii. The colour of the varnish from this stick lac was identical with that from Butea frondosa in Palamau and from Z. jujuba in Pakur, both being from the province of Bihar, from where T. ficii was also obtained. The lemon-yellow solution of the one was quite distinct from the dark tea-coloured solution of lac from F. mysorensis.

Next to this lac the darkest lac resin is obtained from Shorea talura. This is a little more yellow and less chestnut in colour. Next to it comes the stick lac from Indo-China. Specimens of this material were sent to me by the courtesy of the Director of Agriculture in Tonkin and the Consul-General for France at Calcutta. The host-plant was apparently some Dipterocarpus tree for the leaves looked very much like S. talura. My friend Mr. Gupta also procured for me some specimens of stick lac from Assam. There was no difference in the colour of the Assamese and Indo-Chinese specimens of lac. Their colour was yellowish chestnut. Stick lac from Sind on Acacia arabica came next and was more yellow than the Indo-Chinese lac. Sind lac
was not unlike the Indian yellow colour manufactured by Windsor and Newton for water-colour use. I was able to collect specimens of stick lac at Bagra in Sohagpur, C.Ps., with the kind help of Mr. Zamarud Hussain, in charge of that Range, from Schleichera trijuga and also with the courtesy of Mr. Mooney, the Divisional Forest Officer at Daltonganj, from Butea frondosa in Palaman when I visited these places in June 1922. There was little difference between their alcoholic solutions. The Butea varnish was much more transparent while the Schleichera varnish looked a little milky. Both gave lemon-yellow varnish; the latter specimen showed the presence of much wax and therefore it was clouded. Stick lac from the Punjab and Damoh on species of Zyziphus looks reddish, but as I have not studied these insects from any other stand-point, I shall not mention them further.

Size in relation to food and species.

When the size of the individual insect is taken into account, Shorea talura lac stands last as being produced by the smallest commercial lac insect in India. The insect on F. mysorensis compares well in size with those on Butea frondosa and others in different parts of India, but except in the case of S. talura which is very small, size is a very variable factor and, unless the largest specimens are compared, it is difficult to judge the species of lac insect by the average size in a colony. On Anona squamosa we often meet with cells growing individually and isolated from one another. I am of opinion they belong to the same insect which grows on F. mysorensis. When the insects grow together the fully developed adults have elongated pear-shaped bodies, but when separately found, they resemble some varieties of apples which, in comparison with others, have a short polar axis and a broad equatorial girth. The insects of the rainy weather generation are always longer and better grown than those that develop during the drier though longer period of their life-cycle. Size on the whole seems to indicate the nutritional environment. But as the best developed insects from S. talura do not approach anything near the longest specimens of F. mysorensis insects, we are safe in calling them different from each other.
Lac insects, like many other coccids that feed on stems, grow better on the lower side of a horizontal twig. It has been interpreted as indicative of an instinct on the part of the insect by which it avoids the light of the sun. When a branch is grown vertically the insects grow better at the basal portion of the stem. In the case of a branch which is curved, so that the convex side faces the earth, insects grow invariably on the lower surface and somewhat better than those on a similar side of a straight horizontal branch. If the concave side happens to face the ground, insects will be still on the lower portion of the stem but such insects will show very poor development in size, indicating that they were not well fed. In the cases of long branches, some 40 cms. and more, a sort of gentle spiral curve will be found. Even when it is apparently horizontal, shallow concave and convex curvatures will be discovered. This is due to the twisting of the stem in the course of its natural growth. If such a twig happens to be perpendicular a spiral-like twist will also be apparent in the encrustation of lac on it. If it should be somewhat horizontal the encrustation will be discontinuous and divided into blocks, as it were. The better encrustations will be those where the insects are not directly facing the ground but somewhat to the side showing, that the twisting action of the branch is also a factor in the distribution of insect food in the twig.

On the whole, it would be found that geotropism is the best factor in the distribution of the insect-food and insects facing the ground or on the basal portion of a stem will be the most developed of all. It is not that the young insects swarm all over and settle anywhere on the stem regardless of geotropism, but that they apparently possess a food instinct and to begin with select the side of the stem nearer the ground. If there was a question of light repulsion those branches which may lie in the central portion of a tree, and more or less immune to the scorching light of the sun, might have shown growth of lac encrustation regardless of the force of gravity. Such is not the case; for, when insects do grow on horizontal branches, where direct light does not reach them, as might have been expected, they are never covered with lac all over. My observations tend to show that the rays of the sun have an indirect beneficial effect on the insect. A branch which
has been growing in full light, at least for four months, before the larvæ settle on it will show better growth of lac than the one growing in a less lighted portion of the tree. Pruning, so advantageous to lac cultivation, perhaps also helps the stems to grow in direct sunlight. As has been already observed by others, the young insects tend to move towards light and prefer shoots of fairly small diameter. If we assume that they instinctively avoid light and therefore settle on the darker portion of the stem, the above observation appears contradictory. There would be no explanation in this case for vertical branches being covered with thick lac.

For comparison of two sorts of stick lac specimens were collected from twigs vertically growing. It was impossible to find an ideally vertical twig and consequently a perfectly uniform size of insects all round the stem was not found in all cases. The side inclined towards the earth showed better growth of insects than the side away from the ground of a semi-vertical twig. Cross-sections were made of these twigs and sections resembling toy-wheels were compared with one another. It was apparent that the Shorea insect was smaller and its encrustation had smaller diameter than those on F. mysorensis. The diameter of the cross section of the Shorea encrustation of lac was smaller than that of stick lac from F. mysorensis, but the actual thickness of the layer of resin covering the insects was not proportional to the size of the insect. They seem to differ more in their size than in their ability to secrete resin.

Similar sections from Butea frondosa stick lac, from Palamau in Bihar, showed very fragile encrustation of lac and it was impossible to cut circular pieces of this stick lac.

The thickest layer of resin was associated with the insect on S. trijuga, specially those specimens of stick lac which were obtained from Raipur, C.Ps. The stick lac was the hardest I know and sections could be easily cut with a fine saw. The hard wax content also appears to be the highest in this case. I also imagine the ether-soluble portion of the resin to be likewise greatest in this case.
Food-plants and species of lac insects.

We may now take up the question of food-plants. The Shorea talaria insect has not been found to grow naturally on any other tree than its host. I have met with a small colony on a herb-like plant some eighteen inches tall which had encrustation of three inches in length. It had small leaves showing the advanced age of the plant and on being dug up showed attack of white ants and had a decayed root system. Seeds and flowers obtained from a similar plant were sent to Bombay where Professor Hallberg of St. Xavier's College kindly identified it as Rhyncosa cana of the Leguminous order. Two other plants, some three feet high, belonging to Diospyros tupra, N.O. Ebenaceae, showed small colonies but with good development of these insects. Both Diospyros and Rhyncosa were repeatedly inoculated with Shorea brood lac but without any positive results. The enrustations on these plants were seen at the end of the monsoon seasons in 1919 and 1920, and the exceptional favourable conditions of food which the lac insects found in these strange hosts must be attributed to the effect of moisture and also to a possible association of some pathological and other micro-organisms not naturally occurring in these plants. The locality, where these plants were found attacked with the lac insects was, Dursanipalya, some 12 miles south of Bangalore, where lac is being regularly cultivated on Shorea talaria for over 30 years. In addition to Litchi, Acacia farnesiana and Butea frondosa, this insect has been grown on Acacia concinna, Pithecolobium dulce, Z. jujuba and P. saman by Mr. Srinivasayya. The results in the latter cases, however, were only of scientific interest and not likely to tempt a practical cultivator.

Shorea brood lac was sent to different parts of India. It was introduced at Pusa by Mr. Misra on Z. jujuba; at Bagra, C.Ps., by Mr. Zamarud Hussain on S. trijuga; at Nirmal in Hyderabad State on Butea frondosa; at Pachmari, C Ps., by Mr. B. B. Osmoston also on Butea frondosa; and at Miani near Hyderabad, Sind, on Acacia arabica. The brood was not sent just before the commencement of the rains which is the best time for introducing lac and possibly for this reason
the experiments elsewhere were inferior to those at Bangalore. I myself saw the results of these inoculations at Bagra on *S. trifluga* in June 1922 and at Nirmal on *B. frondosa* in April 1922. I could not see any sign of life although the cells looked nearly full grown.

The host-plants of the insect on *F. mysorensis* are so many that I propose giving a complete list of such trees elsewhere. I believe the insect found in Hyderabad chiefly on *F. bengalensis* is identical with this. Professor Stebbing mentions a large number of trees attacked with lac and I wonder if most of them refer to this, his species. He mentions, however, that the lac encrustation on Ficus species is usually of a very pale yellow colour which is not the case in the South. The insect described by Mr. Green as *Tachardia ficii* also gives a pale lemon-yellow lac resin and, as mentioned, is different from the lac observed in our case.

**Reproductive activity of different species.**

Next to the food comes the question of natural propagation. The fact that lac is not artificially propagated on *F. mysorensis* should be sufficient to raise the suspicion that something is wrong with its lac insect. If specimens of stick lac from this source be examined, one cell growing rather isolated from the rest of the mass will be observed. It will show beautiful sculpture-like engravings on the outer surface of the resinous dome. There are six longitudinal stripes of such markings and the general appearance is not unlike that of a crown. The carvings to some degree recall the beautiful illustrations of *T. conchiferata* from Ceylon as given by Mr. Green in his standard work on the 'Coccidæ of Ceylon.' These longitudinal engravings are associated with six patches of pores of wax glands girdling the equatorial region of the insect body. I have seen two and even three such cells fused with one another and yet showing the external decorations clearly. Most frequently a piece of fresh stick lac collected in October will show at one end of the encrustation a single such crown-shaped cell. This cell would be invariably empty representing the mother of the present generation. Living insects in such cells can be found during the dry weather generation about May to June.
On tracing the history of these markings I could associate them with a female insect which had just completed its third or last moult or about the time when males have emerged. I could not find any trace of such markings in females before they reach the fourth or adult stage. I have evidence to show they were not malformations due to pathogenic organisms or absence of symbiotic yeasts to which reference will be made later. I have seen young ones crawling from such cells and therefore it proved them to be quite healthy.

I have collected living specimens enclosed within such parthenogenetic cells from F. bengalensis, P. dulce and G. tomentosa in Hyderabad and from S. trijuga from Bagra. I also collected dried specimens from B. frondosa at Nirmal. Specimens of stick lac from Sind on Acacia arabica and from Hoshiarpur in the Punjab on Z. jujuba showed such dome-shaped ornamental cells. Shorea talura differs from all the rest in not showing any such signs of parthenogenesis.

The insect on F. mysorensis, like most other lac insects studied so far, has two life cycles a year. One generation begins and ends with the monsoons, lasting from June to October, both being included, while the other continues through the drier period of the year from November to May. The larva that swarm about May to June from the dry weather crop of brood lac give rise to males during the monsoons at about August. The larva derived from the monsoon-fed crop give rise to males at about February to March during the dry season. Now there is a distinct difference between these males. Those that emerge during August are almost all wingless and not conspicuously more numerous than females, while those that emerge during March are invariably all winged and so much in excess over females that very often there is not a single female observed in a colony. It is during this generation that crown-shaped cells are formed. That means, winged males and parthenogenetic females are contemporaries. The few fertilised females and the majority of parthenogenetic females carry on the work of propagating the species and such individual cells give rise to small colonies of larvae which later on form small pieces of lac encrustation on F. mysorensis.
It seems to me, however, there is a distinct climatic factor influencing the formation of the sexes while the eggs are being formed during the monsoons. Apparently the same insect in Hyderabad produces large quantities of stick lac on *F. bengalensis*. In June 1922 I saw over two local maunds of 25 lbs. collected from one such tree in Hyderabad City. The drier climate in Hyderabad apparently prevents the formation of such polyandrous female population, but it should be mentioned that even there lac is only collected from Ficus trees when a good deal of it can be seen and no one takes the trouble to cultivate this insect artificially.

I have always entertained the hopes of introducing brood lac from *F. mysorensis* in Bangalore on to *F. bengalensis* in Hyderabad in order to study the influence of a drier climate. Even on *F. bengalensis* in Bangalore the insect during summer, produces an unhealthy excess of males and this, now and again, also occurs in Hyderabad.

Brood lac from Sind, received last November, similarly gave rise to a large number of male insects and I am inclined to believe the forthcoming crop next June is likely to be a very poor one indeed. I am hoping to hear that from August to October the river Indus flooded to such an extent that the trees growing lac in Sind were supplied with an excess of moisture.

*A trivoltine lac insect.*

The insect on *Shorea talura*, as distinct from all others, gives three crops of lac per year. There seems to be some hesitation on the part of some to give in to such an optimistic view. Some one has said "what I say thrice is right." I have once before given expression to my opinion and I like to reserve a third occasion for giving the dates of larval swarming observed by me. Even in this case the generation of larvae that swarm after the end of the monsoon season gives rise to the greatest number of males. There are four male larvae to one female but the death rate in the early stages among males is much greater than among females. Winged males among the Mysore lac insects are very rare but there is no evidence to deny their greatest
numbers occurring in the generation immediately following the rains. The larvæ as they are born can be distinguished as males and females. The presence of moisture in plants and increase in the osmotic pressure and other changes from August to October help the growth of mother insects but it also goes to determine, while in the egg stage, the greater ratio of males in the future generation. I imagine that the winged character is also predetermined but it has not been possible to differentiate among the newly born larvæ, those that are going to be winged from those that are to be wingless. So far, by external signs, I have been able to differentiate only the male and female larvæ. I have not been able to discover if the parthenogenetic character is also predetermined. It would be seen that the reproductive characters of these two insects differ considerably and this is sufficient to enable us to classify them into two separate species.

The possible influence of climate.

By way of comparative study it may be worth while mentioning here that the Mysore silk insect is the most prolific of its kind in India. Recently I was informed by Mr. Govinda Rao, of the Department of Sericulture in Mysore, who has recently returned from Japan, that the Mysore silk worm is identical with the one found in Canton, but it is also possible that the climate of South China may be similar, and this accounts why the Mysore silk insect is not reared in other parts of India. Dr. Kunhi Kannan has discovered that the almost international pest of the coffee plant, Lecanium viridis on having domiciled itself in Mysore has evolved itself into a new species. It has been named by him Coccus colemani in honour of the Director of Agriculture in the State. Like the Mysore silk insect and the Mysore lac insect, Coccus colemani is the most prolific of its kind and differs also in this respect from its sister species. It is plain that there is something in the climate of Mysore which helps the reproductive activity of insect life. But it must be confessed that it is not altogether the influence of climate, for we have the simultaneous occurrence of a trivoltine and bivoltine species of lac insects on Shorea talura and on F. mysorensis respectively.
Species of lac insects and associated insect-fauna.

We shall now proceed with the insect-fauna associated with lac insects. What we are seeking for is a kind of predisposition towards the attack of some parasites and at least a partial immunity from others. The question arises, are the parasites of lac insects common between them all, or are they specific of each lac insect?

As the Mysore lac insect forms large colonies it has many more enemies but it seems to me a great deal more wonderful that it is able to withstand hoards of them. Fresh stick lac on being removed from F. mysorensis, specially during October, might have thick and large encrustation, but on storing it for sometime it will be found that a large number of Eublemma amabilis moths have emerged from it. This appears to be one more reason why lac is not even collected from this source in Mysore. The caterpillars of this moth feed within the lac encrustation and practically destroy the whole colony. On Shorea talura these caterpillars have very effective enemies. Brasema annulicaudis and Bracon tachardiae keep the lac safe from Eublemma amabilis. None of these have been reared from lac on F. mysorensis. There seems to be a new chalcid which occasionally attacks Eublemma caterpillars feeding on F. mysorensis lac. It is allied to Elasmus articles described by Walker in 1843 from a specimen collected in Bombay and differs in having smoke-white legs instead of their being pitch-brown. In grateful acknowledgment of the help received from Dr. Coleman I propose calling it Elasmus colemani. This has also been reared from lac on Shorea talura. A beetle named Silvanus iyeri is a common enemy of lac, but it seems to feed on the dry skins of lac insects. However, its colour is usually almond-yellow. On Ficus mysorensis it is never found. On Shorea talura this insect does occur but of more common occurrence is another variety which is considerably more dark. I have never seen any of these dark coloured beetles from other Indian localities. Berginus maindroni, Trilobium ferrugineum and Cathatus adrena and two or three more beetles have been found along with Shorea stick lac but always absent from that on F. mysorensis.
Anatrachyntris falcataella is a sort of saprophyte feeding usually on dead lac insects. I have dissected its pupa from the cocoon of a chrysopa which is predacious on young lac insects. This moth, so common in Shorea lac, is absent from that on Ficus mysorensis. I have, however, reared it from lac on F. bengalensis in Hyderabad and specimens of moth sent to me by Mr. Edwards, Divisional Forest Officer from Karimnagar in Hyderabad State, proved to belong to this species. In one single case I have reared it from the pseudo-lac encrustation on Pongamia glabra and the moth looked dark chocolate colour while usually it is brownish yellow. I have other evidence to show that in the case of these predacious moths the colour of the insect on which the caterpillars feed have a direct bearing on the intensity of colouration. I have not understood yet why, if this moth attacks the lac insects on F. bengalensis in Hyderabad and lac insects on Shorea talura in Mysore, it should not touch the insects on F. mysorensis.

In the early stages of its growth the insects on S. talura are subject to the attack of the predacious larvae of the lace-wing fly. During the monsoons especially, this chrysopa destroys a good deal of the young insects and even when they are pretty well grown. Although it has been mentioned as a pest by Dr. Inms, the extent of its injury is not referred to. My observations are confined to Bangalore but I have seen remains of chrysopa cocoons on stick lac from Cochin-China and also from Sind.

Holcocera pulvera is found on Shorea but not met with in the case of Ficus mysorensis. Strathmoroda theoris has not been reared from lac in Mysore but a larva looking very much like the one of this moth was found on a piece of stick-lac which Mr. Bassappa, the Lac Expert in Mysore, had collected from Dursanipalya already spoken of.

As opposed to external parasites, predacious on living lac insects or saprophytic feeding on dead ones, we have internal chalcid parasites. During the drier portions of the year Ficus lac is attacked by a yellow insect which appears to be its main chalcid enemy. It is related to Lissencyrus, a genus founded by the late Mr. Cameron.
The male of this new chalcid has a very long club as in the antenna of the Apheline genus Eremocerus. For this reason I propose naming the new genus Ercencyrtus or a compound of Eremocerus and Lissencyrtus. In memory of the great insect physiologist, the late Professor Dewitz, I propose calling the insect E. dewitzii. This insect also attacks lac on Z. jujuba in Pakur and in Pusa. Lac insects on F. bengalensis in Hyderabad suffer most from the attack of this chalcid. This insect has never been reared from Shorea lac.

On Shorea we meet with a new species allied to Lissencyrtus troupi. It is easily distinguished from the last named by its greenish yellow eyes and an entirely orange-yellow head instead of dark eyes and a metallic-coloured head. As Professor Somerville of Oxford is a colleague of Professor Troup and as I have the honour of having studied under him I have much pleasure in calling this insect L. somervilli. This chalcid has been bred from S. trijuga lac obtained from Bagra, C. Ps., and from Butea frondosa lac in Jubulpore, C. Ps. During January 1923 Professor Fowler of the Indian Institute of Science, Bangalore, paid a visit to Jamshedpore, formerly known as Sakchi in Singhbum District in Bihar. He was good enough to bring along with him a few sticks of brood lac from S. trijuga. From this material a number of these insects were reared. I have never met with this chalcid on F. mysorensis in Bangalore or on F. bengalensis in Hyderabad. L. troupi does attack lac on F. bengalensis in Hyderabad but it is absent from lac on F. mysorensis in Bangalore.

The most common chalcid enemy of lac insects on Shorea is a black insect allied if not the same as illustrated by Dr. Imms in his Memoir as Fig. 35, Pl. VIII. It has not been described but it belongs to the genus Tetrastichus or to a closely allied one. I am hoping to receive some specimens reared by him, but provisionally in honour of its discoverer, I have named it T. immsii. This insect also attacks lac on F. mysorensis but to a very small extent and only when they are in the young stages. The males suffer more than the females during the dry weather generation. On Shorea talura during the monsoon crop these insects are at their maximum.
There is at least one chalcid which so far I have not reared from any other insect than the Mysore lac insect. It belongs to the genus Coccophagus and is black and lemon-yellow in colour. As far as I can see it is new and in gratitude for the suggestions and encouragement given by Professor Tschirch of Bern I have dedicated it to him and have given it the name of C. tschirchii.

It would be interesting to compare it with a similar black and yellow apheline of this genus named C. seutatus by Dr. Howard. It is parasitic on a Kermes insect. A comparative study of parasites bred from the Cochineal may also show a similar Coccophagus insect. In this case it would be interesting to find the connection between the Coccophagus parasites and the symbiotic yeasts. Professor Pierantoni has found that there are yeasts in the Cochineal and I am inclined to believe the same would be true of the Kermes. If yeasts be absent, then the red dye would have something to do with the Coccophagus parasites.

I inoculated different broods of lac on the same Litchi tree and took care to see that insects derived from Shorea talura were growing near those from F. mysorensis. T. immusii seems to make the least discrimination between them. The male lac insects between the 2nd and 3rd instar of the dry weather generation were mostly, if not entirely, attacked with this chalcid. To a very small extent C. tschirchii also attacked the male larvae derived from Ficus brood. But in no case was E. dewitzii bred from such Shorea derived insects.

Thus it is clear from experimental evidence that some parasites have a distinct inclination towards their hosts, and by a general study of parasites it has been possible to differentiate between the lac insects on Shorea talura and on F. mysorensis.

Finally it may be mentioned that the Mysore lac insect seems to show the greatest number of parasites. This I attribute to the insect being the most prolific of its kind.

Associated micro-flora as specific of each lac insect.

It has not been possible for me to study the symbiotic micro-flora in any detail. A few points may be mentioned as being of general
interest. If a full grown female lac insect is crushed and the blood-
smear examined under a microscope, even under a low power, refrac-
tive bodies will be observed. They resemble yeasts in shape and
especially look like *Pseudosacchromyces apiculatus parasiticus* of
Lindner. To my friend Mr. Narasimhan, Mycologist to the Govern-
ment of Mysore, I owe my knowledge of staining the organisms and
with this help I have been able to study the symbiotic yeasts in different
sorts of lac insects. They can be cultured on fructose agar and on
prune-juice agar. In artificial media the cells do not possess the original
citron shape and hence they are not *apiculatus* species for they look
elliptical without the terminal projections. Giant cells also occur
and even mycelium formation. Major De Mello, now Professor of
Parasitology at the University of Oporto, kindly studied these for me
and came to the opinion that they belonged most probably to the
genus *Mycoderma*. Professor Buchner of Munich, who is the greatest
authority on symbiosis, has been kind enough to inform me that a
certain mycologist is studying some of the European symbiotic
organisms and is about to publish his researches. According to him
some of the so-called symbiotic *Sacchromyces* are fruit bodies of
new fungi. It is hoped that on consultation of this work the
classification of the lac yeasts will be a comparatively easy task.
At present I consider the lac yeast as a species of *Monilia*.

Bechhold, in his masterly treatise on *Colloids in Biology and
Medicine,* looks upon an organism as a system of colloids. Similarly it
may be said that the different lac insects represent different worlds of
symbiotic life. On clinical examination patients have been pronounced
as suffering from consumption but bacteriological tests have shown the
absence of Koch's bacilli. Major De Mello has recorded cases where the
malady was due to yeast-like organisms. In this light each lac insect
becomes, as it were, a habitat for certain species of micro-organisms;
and, if a tumour can be known by the bacterium associated with it,
the lac insect should be judged by the organism in intercellular
symbiosis with its host. Anatomists give dental formulæ to animals
and by the different arrangements of molars and premolars they
distinguish, for example, a cow from a horse. The biochemist can, if he
likes, ascertain the different enzymes secreted by his microbes and give his organisms enzymic formulae. In the same manner it is possible to obtain a physiological formula for each lac insect which will really imply all the potentialities of the microflora within it. Maladies due to pathogenic yeasts have been known to have pronounced symptoms during the wet season of the year. This may also explain why lac grows best during the rains and even though it takes longer in other seasons of the year in Mysore, the other two crops of lac are not to be compared with the monsoon fed crop. The climate of Mysore as directly effecting the symbiotic yeasts, discovered by Mr. Narasimhan in Coecus colemani, may also explain the superior reproductive character of this insect as compared with its ally Lecanium viridis. It is possible that the yeasts in the Mysore lac insect and in C. colemani give rise to a better formation of nucleic acids. Before the close of this subject it may be said that one day I hope to convince myself that each lac insect has its specific associated micro-organism.

Pseudo-lac insects and the colour of their encrustation.

Having compared the lac insects proper on F. mysorensis and on S. talaria we may proceed with a comparison of the two pseudo-lac insects on P. glabra and on Ixora parviflora with each other. The former insect, as already mentioned, was identified by Dr. Morrison as T. minuta. It was so called because at the time he received it from the Philippines, it was the smallest insect of its kind. The insect on the torch-tree is even smaller and when both are fully grown this is nearly three-fourths in size of T. minuta. The next visible difference between them lies in their colour. The cells on Pongamia are dark chestnut in colour with a distinct tinge of purple. At the marginal projections of the exudation a brownish blue colour is distinct. The Ixora insect is more orange-coloured than chestnut, while the fringe or the border line of the cell shows clear yellow colouration. In an earlier stage of development, cells on I. parviflora have a beautiful golden colour much more brilliant-yellow than is the case even with lac insects proper. Alcoholic solutions of their encrustations bear out this difference with regard to the colour of their cells. One solution would be chestnut, verging on to purple, looking
like a tincture prepared from the fruits of *Eugenia jambolana*, while the other would be like a dark orange-coloured lac varnish.

As already mentioned these two insects have two host-plants common between them. One is the sandal-wood tree, the other is *Guazuma tomentosa*, both being found in Bangalore. The possibility of the food effecting the colour of the insect-secretion or the climate in any way influencing the same insects differently, is therefore out of question.

*Parthenogenetic cell.*

*T. minuta* shows only one kind of female cells. On the other hand the torch-tree contains two kinds of such cells, one looks like a miniature cell of *T. minuta* when both are full grown, except for the colour, the other form, even when fully developed, bears resemblance only to immature cells of the insect on *Pongamia*. The first kind of cells is smooth and elevated with only small projections in front, while the latter has two long finger-like projections instead. This is distinctly more flat, bears a rough and folded surface and on the whole looks larger than the other sort of cell but not larger than the full grown cell of *T. minuta*. I suspect this rugged looking cell to be parthenogenetic.

*Only winged forms of males.*

Both the pseudo-lac insects have only winged males. It has been pointed out already that winged males and parthenogenetic females arise from the same generation of larvæ, and this further strengthens the assumption that the *Ixora* insect does show signs of parthenogenesis. A new insect on *Acacia sundara* from Travancore, also a pseudo-lac insect, shows no signs of wingless males.

*Life cycle.*

The life cycle of the pseudo-lac insects seems to last nearly ten months. Larvæ may be seen crawling in every season of the year though not in every month. Similarly males do not possess any special time of emergence. Brood sticks from *Pongamia glabra* were-
put on *Michelia champaca* on which species of trees *T. minuta* had been previously known to thrive. This was done on 12th October 1921, and the next larval swarming occurred on 15th August 1922. Observations made on the *Pongamia* tree which had supplied the brood sticks showed profuse larval swarming about August and this together with the fact that *T. minuta* does thrive on the champaca trees excludes all possibilities of a deferred larval swarming.

Next to size and colour, the most obvious difference between the insects on *Pongamia glabra* and *Ixora parviflora* is with regard to the symbiotic organisms. As a bacteriological test is superior to a clinical examination, the easiest method of deciding, which is the young insect of *Pongamia* and which is the adult insect of *Ixora*, is to observe the blood smears of both under a microscope. The presence of chains of bacteria will prove that the insect was derived from the torch-tree. In the case of *T. minuta* we do find some coccii-like organisms but since they have not been cultured, it is impossible to say if these bodies are micro-organisms or granular substances of the insect blood. Yeasts and chains of bacteria are similarly absent from the Travancore insect. From the information given so far, it is possible to identify the insect on *Ixora parviflora* and, as it is new to science, I intend associating with it the name of the great authority on scale insects and insect parasites, I mean Professor Silvestri. I feel this is an humble way of recognising the help and suggestions he has been giving me from time to time. *Tachardia silvestri* is not the only insect which has been described without going into anatomical details. In their monograph on Indiana scale insects, Morrison and Dietz mention that the Kermes insects apparently show only a broad difference in the shape of tests and their classification is not based on anatomical details.

**H. C. F. among parasites of lac insects.**

My first interest in the pseudo-lac insects was due to a remark of Dr. Imms, where he has suggested the enquiry, "Do these parasites and predators in the absence of *Tachardia* utilise other species of coccids in order to maintain their existence?" To solve this problem adequately involves an investigation of all likely coccidae occurring
within lac producing areas and breeding parasites therefrom. Such information, as we have been able to collect, is too scanty to warrant any conclusions being drawn but the problem is one that needs to be kept in view." If there be common or inter-racial parasites, the host insects allied to one another are likely to show such parasites. I have also reared parasites from scale insects occurring on Shorea talura. My experience seems to be very optimistic and beyond the physiological basis, which predisposes the lac insects towards their enemies, there does not seem to be much danger from any other account, as for example, from mere association with other scale insects. Experiments with breeding parasites have fortunately not brought out the danger which was feared by Dr. Imms. *Tetrastichus immicida* possibly is the only enemy common between the pseudo-lac insect on Pongamia and the Mysore lac insect proper. The *Pongamia* insect, however, is not chiefly attacked by this parasite.

In the very early stages of growth, and mainly when the insects are grown in unnatural environment like on the Litchi in Lalbag, they seem to have one inter-communal parasite. This insect is a species of *Perissopterus* and has been reared from all broods of lac grown in Lalbag and also from *T. minuta* and *T. silvestri*. It has been also reared from the Travancore insect. Other coccids apparently also seem to suffer from its attack. This has never been bred from lac grown at Dursanipalya or from *Ficus* species. Beyond this evidence the parasites of so closely allied insects as *T. minuta* and *T. silvestri*, when compared with true lac insects, show entirely different parasites, and also among themselves. The polish barons, they say, were very shy of new bankers and each had, what he called, his family jew. These parasites have similarly parcelled out the lac insects between themselves and each seems to exercise a strict monopoly over its host. On the whole, when their parasites are taken into consideration there seems to be evidence of racial antagonism, rather than of any signs of physiological approach between the different lac insects. To me the associated insect-fauna seems to be only indirectly connected with the lac insects. These hosts are, as it were, cultures of certain organisms. If we consider the attraction of the chalcid parasites to smells,
we have also to take into account the volatile esters of fatty acids that might be secreted by the yeasts. The entire absence of yeasts would make an insect immune to those parasites which are attracted only by the unhealthy activity of certain organisms. Here seems to me to be a physiological link between the parasitic insect-fauna and the symbiotic micro-flora.

*Lac and pseudo-lac insects.*

Having compared two lac insects and also two pseudo ones we can proceed to consider the generic characters of each as a class.

We have to tackle the old question, "what is really meant by lac?" In the absence of any chemical investigation of the encrustations of *T. minuta* and others it is not absolutely safe to decide the matter but until we can satisfy ourselves perfectly on that point, there seems to be other evidence pointing to a clear difference between stick lac proper and a pseudo-lac encrustation.

Lac insects proper give rise to exudation which has a resinous lustre. There is an appearance of a yellow-coloured frosted glass and sometimes distinctly translucent and glasslike. The encrustations of pseudo-lac insects look leathery or parchment-like, specially that of *T. minuta* can be cut easily with a knife without a fracture and looks like hardened gelatine rather than crystalline or a brittle resin. The cells of a lac insect proper often show fracture on the resinous dome and sometimes drops of lac are seen projecting outwards from the cell which is never the case with pseudo-lac. Stick lac proper melts with heat and it is possible to draw long and fine threads of shellac with the point of a hot needle. This is not possible in the case of encrustations of pseudo-lac insects. In Ceylon there are three indigenous insects which have been called lac insects, *T. conchiferata, T. albizziae* and *T. minuta*. The Indian lac insect has been introduced there only recently. It is of great interest to find Mr. Green not mentioning *T. minuta* being ever employed in Ceylon for any commercial purpose. He has positive information with regard to the products of *T. albizziae* and *T. conchiferata*. He says, "the former is known to Matale lac
worker as *Kepptiya laccada* and to those of Tangalla as *Kon laccada*, while the latter is considered to be superior and is greatly valued by the lac workers of Matale and Tangalla, who distinguish it by the name of *Tela Kiriya laccada.* No such mention is made with regard to the encrustation of *T. minuta* and this further shows that this product does not melt with the application of heat in the sense that shellac does. On placing a hot needle on the cell of this insect it emitted a shellac-like pleasant buttyer odour and melted without much sign of being stretched into a fine thread. It may be mentioned here that, when shellac is over-heated or dissolved in alkali and precipitated with an acid, it sometimes becomes rubber-like, no doubt due to an alteration of the ether-insoluble portion. This rubber-like lac does not melt, nor does it dissolve in alcohol. *T. minuta* encrustation leaves a large residue in alcohol. When lac insects proper are dissolved with their encrustation in an insufficient quantity of alcohol the varnish would be very syrupy and viscous, but the bare bodies of insects would be distinctly visible. It must be owned, however, that there does occur a very delicate membrane enclosing the entire insect which does not seem to dissolve in cold alcohol or in a cold caustic alkali solution. When pseudo-lac insects are placed in alcohol their encrustation first begins to swell and when more of the reagent is added a large insoluble residue is left. This material does not dissolve in caustic solution either. The behaviour of these two sorts of encrustation in alcohol reminds very much the manner in which gum tragacanth swells enormously in water without properly dissolving and of gum arabic which always forms a homogeneous solution, highly viscous, if the quantity of water is poor. Pseudo-lac insects are by no means spheroidal in shape. They are somewhat triangular in outline when seen from above; besides, they are ventrally flat or on the side in contact with the twig and arched only on the dorsal side. They are distinctly flatter when compared with lac insects proper. The true lac insects are egg-shaped or pear-shaped when they grow near one another but if they grow isolated they are more spherical or apple-shaped. Pseudo-lac insects have lobed projections and their body outline consists of straight arcs and corners. Lac insects proper would have a circular girth, without any sign of forking.
Honey-dew.

When pseudo-lac insects are observed on a tree it is very rare to find ants attending on them. Leaves of such trees look dark due to a sooty growth of fungii; which evidently develops on the excreta of these insects. When living insects are observed under a microscope, a tiny drop of liquid is seen excreted by them. Inasmuch as ants do not feed on their excreta, it is possible that it may not consist of any sugars, but, instead, may be composed of glycerine or some fat decomposition product. It is certainly some material on which the fungii can thrive but which is not the food of ants. The absence of ants in this case must be taken as an indication that the honey-dew given out by pseudo-lac insects differs both quantitatively and qualitatively from the excreta of lac insects proper. Honey-dew from the Mysore lac insect has been collected in a sufficient quantity to test for its sugar contents; but this is impossible in the case of T. minuta and other pseudo-lac insects. The test for sugars was carried out by my friend Mr. Srinivassayya. It may be mentioned here that the form in which scale insects get rid of their nitrogen has not been studied. We hear of the honey-dew and of its sugar content but never of its containing nitrogenous bodies. In the case of Mysore lac insects I suspect some aminoacids in their honey-dew. It is a problem of great physiological interest and the presence of sugars seems indirectly connected with their nitrogenous metabolism.

Anal hairs and variation in structure as indicative of a difference in function.

The anal process among lac insects is free and can move up and down through a hole provided for in the cell. The terminal portion is very well chitinised and on top of such a band are ten anal hairs. These hairs are very well developed showing the hard work to which they are put by the lac insects proper. In contrast with these the pseudo-lac insects have very delicate anal hairs, which correspond with the actual difference in the excretion of honey dew observed in the living insects. Mr. Green has excellent illustrations of the anal hairs of these two kinds of insects and a glance at his figures will convince any one of the difference referred to above.
Significance of wax exudation.

The production of sugars and the secretion of wax seem to have a close physiological relationship.

It is so in the case of honey bee as is generally known. The larvae of lac insects proper are pinkish due to their body colour being masked by a dust of white wax, which exudes from all over the skin. The mother insect is also responsible for a soft wax which is powdered over the young ones as they are born. This pink-white appearance of larvae has not been brought out clearly by previous observers. Their beautiful colour illustrations give one the impression that the young ones were first dissolved in alcohol or in xylool and by this treatment the white wax was washed away. Mr. Misra's latest figure (Report of the third Entomological Conference at Pusa) for the larva of S. trijuga lac insect is the best I have seen and shows the pink rather than the scarlet colour of the young one as it appears to the eye. As opposed to red larvae, Sir. G. Watts mentions the possibility of evolving a white albino race of lac insects; for, he says, according to some observers, even white young lac insects have been observed. These, no doubt, refer to such larvae, which were heavily dusted with a white wax powder. The larvae of pseudo-lac insects are absolutely free from such white appearance and look clear orange-red.

At the time when the larvae are about to swarm, if the resinous vault be carefully broken without rupturing the skin of the mother insect, its body would be found dusted with a white powder. In the case of true lac insects this is always the case, but it is altogether absent in the case of pseudo-lac insects. Before the larvae are born, the body of the mother contracts and thereby the anal process, which is always free, is drawn inside the cell. The mother insect remains attached to the ceiling of the dome-shaped home by means of the anal spine as will be explained later. At the extremity of the anal process are the ten hairs spoken of above. These surround the anal aperture. Each hair has a circular glandular plate and beneath it lie glands responsible for the secretion of cotton-like filaments of wax. Ordinarily these filaments arise outside the cell but, at the time when young ones are
about to swarm, this wax is secreted within it. As the body contracts more and more, the original pear-shaped body becomes gradually flat on one side and this increases the body surface to be dusted with the white wax. Finally, when the contraction is at its maximum, the shape of the body looks like a pear longitudinally split, as has been figured by Mr. Green for *T. lacca* in his standard work. The young ones at this stage would have all left the mother cell. It would be clear that the white surface gradually increases in proportion as the body contracts.

It is a device resorted to by artists, when it is desired to give bright effects to their pictures, that they give a white background before they put on the actual colour desired. With a background formed by the white wax that portion of the cell, which is directly above it, will appear conspicuous; the rest of the cell will look reddish due to the colour of the insect which is beneath it. The portion of the cell between the observer and the wax-dusted skin looks golden-yellow, being the original colour of lac resin intensified by the white background. There is also an air space between the background and the yellow colour of the resin. As the entire cell is not uniformly brightened but only in portions, it looks as if it has acquired a yellow tip. This is considered a sign of the approaching larval swarming. No 'yellow tips' ever occur in the case of pseudo-lac insects, for, in them the anal process does not exude any soft wax.

I have not met with any previous explanation of how the 'yellow tips' arise. Sometimes the resin is exuded in drop-like projections and these also look like amber tips. I am, however, thoroughly convinced of my explanation of the above phenomenon.

From the living insects filaments arise from three spots on the outer surface of the cell. One corresponds to the anal process spoken of above; the other two represent the upper surfaces of stigmatic processes. At the base of these processes lie the posterior spiracles. The wax filaments from the stigmatic processes are supposed to keep these spiracles in free access with the atmosphere and prevent lac from exuding and choking the spiracles. If a stigmatic process be compared.
to a tower, the spiracle would not correspond to its roof but to a door at its foot. Around the actual spiracular opening there are wax pores which exude soft wax around it. This material may be spoken functioning as keeping the spiracle free. The filaments that are conspicuous outside the resinous vault arise from the roof, as it were, and therefore cannot act as protectors or in keeping the resin at bay. It is quite imaginable for the resin to block the spiracular opening and yet permit the wax filaments to continue their development. The fragile nature of the filaments and the geographical position their seat of origin occupies with regard to the spiracle, contradict the explanation offered by previous writers with regard to their role. The wax which constitutes them is very soft, melting below 60°C, as has been correctly found by Mr. Puran Singh. This has been contradicted by Mr. Hoseason who evidently was unaware of such a soft substance, and mistook it for the hard wax embedded within the mass of lac, and which arises in the form of pencils from the equatorial region of the insect body. The melting point of lac resin is higher than 78°C, or 174°F; so that, if heat is to have any effect, the soft wax near the spiracle would melt before the resin and would be the first to block the passage so essential to the lac insect. I feel that, before any of the products of secretion can ever melt, the insect would suffer from tissue dehydration, and respiratory troubles of a purely physiological nature would set in long before there would be any possibility of the insect being choked to death by such external and mechanical means.

When entomologists have suggested the above sort of explanation it is not without some basis. During summer ants are scarce as they take shelter under ground. In their absence honey-dew accumulates and these drops collect together until they look like large shot or small pills. These are seen entangled in the mass of filaments. The honey-dew, being so rich in sugars, forms excellent food for the growth of micro-organisms which transform it into a viscous and gum-like substance. Possibly this material may block the spiracular passage. During summer or rather during the drier period of the year the transformed honey-dew may prove detrimental to the growth of lac insects. The danger from insanitary accumulation of honey-dew, however, will be
greater during the rains, specially, as a moist weather is more conducive to the devolvement of micro-flora. Such saprophytic organisms feed first on the sugary excreta and later even attack the lac resin. Very often they form a felt-like growth and I have seen cases, where the mother insects were alive, but the young ones could find no exit to come out.

If a drop of water be allowed to fall on the surface of a clean glass, it would spread flat, but if grease or even fine dust be smeared on to it, the drop would collect like a pill. The spherical drops of water are naturally more easily blown away with the wind. Stick lac is usually greasy and prevents any drop of rain adhering to it. But invariably its surface, by virtue of uneven growth, is rugged and becomes a receptacle of fine dust. Now if this rough and dust-covered surface be continuously powdered with a soft wax, any liquid falling on it would collect as round shot and with the slightest breeze can be blown off. The anal hairs are sufficiently well provided with muscles to eject honey-dew at a great distance, and the wax filaments function as a further safeguard in the upkeep of a general sanitary condition of the lac colony. It is to serve such a hygenic purpose that the filaments arise from the uppermost portion of the stigmatic processes and not from near the spiracular openings.

In the case of pseudo-lac insects the stigmatic processes give rise to silken filaments instead of their being cottony. These silken filaments seem to be less fragile and are probably constituted of a harder kind of wax. The growth, however, is so poor that an authority like Mr. Green has been led to state with regard to T. minuta "all these three orifices appear to be sealed up and do not emit the curling white filaments that are so conspicuous in T. albizziae and several other species." Similar silken fibres also arise from the stigmatic processes of T. silvestri and the Travancore pseudo-lac insect. From the anal process, however, some true soft wax arises but in such insignificant quantity that it deserves just a word of mention and no more.

Significance of the spinoid and stigmatic processes.
Systematic entomologists have not yet found the function of a spine they have discovered on the back of the insects belonging to the
sub-family Tachardinae. They attach a great deal of importance to it now, since they came to grief for not having paid much attention to its absence in the case of Gascardia madagascarensis. A structure really ought to be taken as a silent witness of a physiological event. The difference in anatomical details ought to signify a variation in physiological activities due, not only to difference in species, but also to changes in weather, food and other environment. In this light these morphological observations become more interesting records than are likely to be in the hands of pure entomologists. If we can derive any such lesson, it is essential to come to some definite idea with regard to the role the spine plays in the life of lac insects. It will be seen that the insects we are considering, the lac insects proper and the pseudo-lac insects, have a very delicate skin. A comparison with Ceroplaastes ceriferus will at once convince one on this point. I feel sure that the Madagascar lac insect similarly possesses a thick chitinous skin. The one reason why Tachardinae secrete a thick exudation product is to overcome such a deficiency. But a thick coat means pressure from without and resistance on insect body in growing freely. In the early stages of growth the Tachardinae secrete only a thin exudation and we may imagine that the insects are not pressed by their products of secretion. During this period, or until the larvae molt for the third time and become mature, they are devoid of the dorsal spine. For this reason Mr. Green supposes it to have a sexual function. I do imagine such a possibility, but any such role must be considered secondary, for, if it were meant only as a guide to males to indicate the sexually mature females, the spine would tend to disappear, as soon as it has served its purpose. On the contrary, the spine grows with the development of the female insect. After fertilisation the insect becomes, as it were, a miniature factory for the production of lac; and the thicker the coat, the less room it has for free development. To overcome this trouble it has adopted a device which is explained in the following lines. At three spots the insect fixes itself into the ceiling of its vault. Two are the stigmatic processes which are loosely attached to the dome and the third, which is "boxed up within the hard resinous cell," as Mr. Green describes it, is the spinoid process.
Let us imagine a dish-like pedestal supporting a ball and from the equatorial region of such a sphere six arched beams projecting upwards forming a skeleton over it. Now imagine the entire structure filled with a concrete so that it now looks like a regular dome. This would give a rough idea of the lac cell. The central ball would be the full grown insect. The dish-shaped pedestal would be a plate of hard wax secreted from the ventral surface of the insect body; the six arched beams from the sides would be the pencils of hard wax arising from six patches of pores girdling the waist of the insect, and referred to earlier, when mention was made of the parthenogenetic cell. The concrete is made up of two materials, the ether-soluble portion and the ether-insoluble resin. Throughout the under surface of the skin there are dermal glands. They have long chitinous ducts and with these they look like toy balloons. The origin of the ether-soluble portion is not clearly established. If the caudal end of the female insect is examined, it would be noticed that there are four projections, the longest of them is the anal process, opposite to it are the two stigmatic processes and between them lies the spinoid process. If carefully examined under a dissecting microscope, on either side of the spinoid process would be found a pair of depressions more towards the stigmatic processes. If some kind of material is to fill all the space between these four projections, the substance must arise from a special seat of origin. The dermal glands are already so thickly distributed all over the skin that they could not be imagined to congregate more at the caudal end. Therefore, the substance occupying this space must arise from some other source. The two pairs of depressions spoken of above give rise to the ether-soluble portion, which is possibly produced by the malphigian tubes. The ether-soluble portion, therefore, acts like a space-filling material. On either side of the anal process there is a concave plate of hard wax which functions as armature plates and affords a free movement to the anal process when the insect is alive. Similarly two flat splints of wax plates, on either side of the spinoid process, keep it in an erect position and give it some kind of rigidity and support. The filling material between them all is the ether-soluble constituent. Professor Tschirch supposes this substance
to be fatty acid and not a resin in the sense the word is applied to the ether-insoluble portion. This explains how this material is so diffusible, and by virtue of its chemical nature acts as a penetrating and a filling material.

The spinoid process is thus fixed into the ceiling of the cell between two plates of wax and embedded along with them into the ether-soluble portion of lac, which mainly fills the central portion of the roof of the vault. If the insect should now exude more and more of lac, and thus raise the roof of its resinous home, the insect would be pulled longitudinally by means of the spinoid process and thereby, its body would be prevented from lagging behind. In the latter case the insect would have had to produce a thicker chitinous skin and use much more resistance to keep its product of exudation from pressing its body surface. The spinoid process, it would be seen, is actually embedded in the ether-soluble portion of lac and the plates of wax on either side of it function only secondarily in keeping it erect. If it is to support the entire weight of the insect, it is clear that a smooth nail-like form is not so desirable as a rough one.

Previous workers mention of a dorsal or anal spine. It seems to me safest to speak of it rather as a spinoid process or even as processes, for in some cases there are more than one projection attaching the insect to its ceiling. The spinoid process has a basal portion which is not chitinised, the more prominent portion in outline looks like a helmet or a dome, or like a steeple, or like a finger-like projection. This applies to the commercial lac insects. The top-most extremity of an oriental dome is a needle pointing towards the sky. The same is also true of a helmet. In the spinoid process there is a straight dagger-shaped or poniard-shaped needle pointing into the ceiling. Sometime it looks like a forked dagger. In one case, from the material sent to me from Indo-China, I have found two distinct spines on the top of the spinoid process. At the junction of the spine and the dome there are usually several chitinous projections which are miniature spines. These are sometimes arranged within a definite area and look like a ring at the base of the dagger-shaped
main spine. Oftener these lesser spines are distributed irregularly and this gives the spinoid process a rough appearance.

The rough nature of the spinoid process, the strange occurrence of two needles in one instance and in other cases supplementary projections like immature spinoid processes, all support the view forwarded here that this process functions in fixing the insect to its ceiling.

As already mentioned, lac insects grow with their caudal ends towards the ground, i.e., on the lower surface of a horizontal twig. The spine lies at the caudal end and therefore does not support the weight of the insect against the force of gravity. As has been already explained, it functions in regulating the growth of the body in relation to its product of secretion and is intended to overcome the force exerted by the enlarging resinous cell. This pressure from the sides is much greater than the force of gravity. At the time when the larvæ swarm the anal process is drawn in and makes a right angle with the longitudinal axis of the insect. Such a case is illustrated by Mr. Green in his figures for *T. ficii* described by him in *Indian Museum Records* for 1903. The anal process is pulled by muscles, but is kept in position to facilitate the birth of young ones by means of the spine, which is fixed into the ceiling. This further supports the view that the spinoid process plays a mechanical role and acts like a nail.

It must be clear by now that, as the insect secretes greater and greater quantity of lac, or as its dome enlarges more and more, it exerts an ever-increasing force on the spinoid process, especially when we consider that the walls of a cell are being pushed longitudinally by similar secretion product of its neighbours. If two pieces of hard wood are to be nailed together, a smooth or needle-like nail would be sufficient; on the contrary, to give the same amount of firmness to two pieces of soft wood rough nails would be required. To regulate the length of the main spine and of the number of the lesser spines, which contribute to the rough appearance of the spinoid process, it is supplied with glands. These together with their ducts usually look like a string with beads. Such a figure is given by Mr. Green in his standard work for *T. albizziae*. In the case of *S. trijuga*, the tissue adjoining
the spinoid process is thick like a cord rather than thin like a thread. In this instance the chitinous layer of the spinoid process is also very thick.

The spinoid process is not chitinised throughout its entire length. From this it may be inferred that only the portion actually embedded in the layer of lac is chitinised. If the spine is vertically inserted into the resin, then to some extent it may also show the thickness of the bed, but often the insertion is not in a line parallel to the longitudinal axis of the insect, but somewhat to an angle and therefore shows a diagonal and not a vertical penetration into the strata of lac. It does so in order to acquire more firmness by having a greater length inserted into the ceiling. But this fact is indicative of the greater degree of pressure exerted in some cases and of the nature of the bed. We may imagine a nail fixed into a plank, which does not reach the other side of the wood, and this would give the idea of how the spinoid process is "boxed in". The nail might be driven straight, or at an angle and only the portion of the nail in contact with the wood represents in our case the chitinous portion, or the length actually embedded in lac. As a rough nail might indicate a soft wood and a plain nail a hard wood, similarly, a short and rough spinoid process would mean a soft bed with a greater quantity of ether-soluble portion, while, when there is a harder material forming the strata, it offers less room for the development of a rough spinoid process, but the force exerted on the spine necessitates the insertion of a greater length of the process. It is saying, as it were, that, when a nail is driven into a piece of hard wood, it requires great force to drive it straight and there is a tendency for the nail to enter it in a diagonal direction. Thus a short and rough spine means more ether-soluble portion, while a long and smooth spinoid process is due to more of ether-insoluble resin. The long spinoid process invariably means one diagonally placed as contrasted with a vertical one.

The stigmatic processes, as different from the spinoid process, are embedded into the mass of resin throughout their entire length. At the base of each structure is a spiracular opening and this is
connected with the atmosphere outside by a long hair-like passage along the entire length of the stigmatic process. This passage is kept lubricated, as it were, by a soft wax. The spinoid process may be inclined, the stigmatic processes are always vertically placed on the caudal surface. The stigmatic process is not one long tube like the figure of the letter I, but has a projection at the base and looks in outline like the letter L, only the lower arm is more obtusely placed. When the insect grows along with others in a colony, the shape of the body is like a pear, in which case the caudal area is small. The stigmatic processes in this instance are longer, for the exudation of the insect now collects in a smaller area and forms a thicker bed, which is of course a better protective form for the insect. When it grows isolated, the caudal end is broad and the secretion is more uniformly distributed and the length of the stigmatic process is correspondingly less in harmony with a thinner coat of lac.

The caudal surface being increased by the apple-shape of the insect growing isolated, the same quantity of secreted material now spreads over a larger area in a thinner layer. The stigmatic processes in this case are not longer, but, what they lose in length they seem to acquire in breadth, and we find well developed basal portions on either side of the spiracular openings. Usually in the case of insects growing in a colony the two stigmatic processes are not only long, but they grow together, as it were, and form one piece without any space between them. When the insect grows isolated, the caudal surface is larger and there is space between the two stigmatic processes. The portion of the skin between them and the spinoid process has a web-like appearance due to its partial chitinisation. This net seems to act as a sort of roof supporting the pressure from the caudal surface. The basal development of the stigmatic processes evidently also helps as supports against pressure from the sides. I have instances where the insects represent, so to speak, length without breadth, and look like broken pieces of lead pencils of 5 mm. in length. To overcome such danger due to pressure from the sides the stigmatic processes have developed chitinous structures on either side of the spiracular openings.
If with the spinoid process the insect grows lengthwise, the stigmatic processes help its breadth-wise development. In the fullgrown insect the stigmatic process extends below the spiracle but the chitinised portion of the skin does not proceed far beyond. In cases, specially, in material received from Indo-China and Assam, there are long extensions of such chitinous structures. These look like longitudinal ribs on either side of the insect, supporting the individual from being pressed by the exudation product of its neighbours. In these insects we also meet with the longest examples of the spinoid process. In some cases it looks almost finger-like and smooth and may be as long as the anal process itself. The stigmatic processes, however, are quite sessile, showing the layer of lac is not particularly thick.

If we grant this insect to secrete a lesser ratio of ether-soluble constituent, it naturally follows that the material forming the cell is harder, being made of a greater proportion of the ether-insoluble resin. This material, being less plastic by nature, offers greater resistance to the development of the insect body. The chitinous ribs may be assumed to help the insect in growing breadth-wise. The material pushed, as it were, from the sides, accumulates at the caudal end, not by force of gravity, but by virtue of the pressure from the sides of the insects growing together. It then arches over the caudal end, where it forms a roof and pulls the insect in a longitudinal direction. The spinoid process is now called upon to do its duty. If the material were more plastic, a ring of lesser spines would hook the insect firmly into the ceiling but the ether-insoluble portion, being harder, offers greater resistance to the development of these minor spines. Hence, what could have been done by a short and rough spinoid process is now performed by a long and smooth one. In this case the insertion is longitudinal. The occurrence in one instance of two needles on the spinoid process shows how a smooth finger-like projection had to be fixed into the ceiling to avoid its being slipped off. It may be also said here that the diameter of the spinoid process is least, when its length is the greatest and its surface the smoothest.

It is the ether-insoluble portion of lac which is very liable to changes of temperature. When shellac becomes dehydrated and
refuses to melt it is due mainly to a change in this constitution. Mr. 
Hautefeuille, in his masterly monograph on the *Lac Industry of Indo-
China*, gives his readers the impression that lac purified locally is more 
liable to become insoluble in alcohol than that manufactured from 
Indian stick lac. This further supports the view that the root of the 
trouble might be with the insect, which exudes an insufficient ratio of 
ether-soluble portion and from such a deficiency troubles arise on stor-
ing. The Indo-Chinese stick lac is much darker than the material 
collected from *B. frondosa* and *S. trijuga*. The dark coloured varie-
ties in India are never purified by themselves. It is possible, like the 
Indo-Chinese raw-material, these might also contain poorer proportion 
of ether-soluble constituent. In India the dark varieties of resin are 
mixed with the stuff derived from *B. frondosa* before the whole mass 
is finally melted and converted into shellac. Raison d'être for such 
a time-honoured recipe might be the poverty of all dark varieties of 
lac in the ether-soluble constituent. It would be interesting to analyse 
the different sorts of stick lac and see if the ether-soluble portion stands 
in inverse ratio to the intensity of the colour of lac resin. The longest 
stigmatic processes are found in the insects on *S. trijuga*. They are 
nearly as long as the anal process. From this we infer that the bed 
of lac into which these are embedded is fairly thick. This can be in-
dependently verified as mentioned already. The spinoid process has 
a broad diameter and the helmet portion is very thickly chitinised. 
Long projections at the caudal end mean more material to fill the space 
between them. I presume therefore that the ether-soluble constituent 
would be highest in the case of Nagoli lac, as *S. trijuga* lac is commer-
cially called.

The actual chitinised portion of the spine in *T. minuta* has the 
shape of a rose thorn and is not like a long needle or a dagger. The 
stigmatic processes are very poorly developed also. In front of the 
anal process there is a pair of accessory attachment projections inten-
ded no doubt to fix the pseudo-lac insect in a flatter roof at more points 
than is the case with lac insects proper. Similar structures are also 
found in *T. larrae* or the Arizona lac insect. Professor Stillman 
has shown in *Berichte der Chem. Ges.* for 1880 that its stick lac gives
60% alcohol-soluble constituent. I feel sure that the ether-soluble portion would be very poor, and, if from this point of view a fresh analysis be made, there would be found a great difference between the Indian and American specimens of stick lac.

I particularly like to mention this for the following reasons. It might be said that, as the insect body is flat, its dorsal surface should be attached to the ceiling of the cell in more than one place to give the same amount of rigidity, which a pear-shaped insect would acquire by being fixed at one main spot. This is quite true, but it is not the direct conclusion to be drawn from it. The flat shape of the insect is a consequence of its not being able to secrete sufficient ether-soluble portion and this in its turn leads to the insect being attached to its cell at five places by two stigmatic processes, by one main spinoid process and by two accessory attachment processes in front of the anal process. The American insect is not flat and yet it has these auxiliary attachment processes. Similar rudimentary projections in addition to the actual spinoid process have also been found to a much less extent and in individual cases in the material received from Indo-China. In the early stages the commercial lac insects do not produce ether-soluble portion as distinct from ether-insoluble one. At that time they show poor development of wax filaments and their excreta are insignificant in quantity. On dissolving the insects, just when they have completed the third moult, we find practically no sign of hard wax embedded within the mass of lac. The body is much flatter and the outline is lobed. The spinoid processes are not much developed and the glandular plate on the roof of the stigmatic process does not form a continuous piece of chitinised structure including the spiracular opening. The anal spine is long and triangular like a short thorn of *Acacia arabica*. It is not a helmet-shaped or dome-shaped chitinous structure. There are naturally no lesser spines also. Both morphologically and in their products of secretion the young stages of lac insects proper compare to some degree with the full grown pseudo-lac insects.

Attention was drawn to the fact that the encrustation of *T. minuta* leaves a large insoluble residue in alcohol. It means that this
substance has no analogous constituent in lac proper, or that it represents the ether-insoluble portion, which has been altered in its physical properties by some dehydrating agencies. Such a change, apparently, invariably occurs in the ether-insoluble constituent of pseudo-lac, granting that it is not an entirely different substance. If it is the same constituent, which always goes wrong, then it at least signifies the absence of its associated product, the ether-soluble portion. These two constituents have been compared to a concrete. We might say there is a distinct chemical affinity between them; their co-existence might be called a case of physico-chemical symbiosis, for the absence of the ether-soluble portion means a dehydrated condition of ether-insoluble portion, which thus also makes it insoluble in alcohol.

*Wingless males and their phylogenetic significance.*

In the case of lac insects on *F. mysorensis* it was noticed that there is a tendency to produce many more males and, when there is such an unhealthy excess of male population, these are always winged. Dr. Nagai in his paper on the influence of nutrition on the sexes of the fern, *Prothalia*, (J. College of Agriculture, Tokyo, 1915) says, "it may be that the male is phylogenetically a more primitive form than the female." It is saying, as it were, that Adam was born before Eve. Apparently the winged male is more ancient than the wingless one. From this we conclude the insect on *F. mysorensis*, which produces more winged forms than others, is the most primitive of all commercial lac insects in India. Inasmuch as the insect on *Shorea talura* produces the least proportion of winged males, it must be looked upon as the youngest of them. The *Ficus* insect seems to be the most probable stock from which the Mysore lac insect has been derived.

What is true of species may also be applied to ascertain the historical difference between two genera. When we compare the insect on *Pongamia glabra* with that on *F. mysorensis*, the former appears older; for it never produces any other forms of males but the winged ones. Pseudo-lac insect, as a class, therefore, produces no wingless males. Only winged males have been found in the Travancore insect
and in *T. silvestri*. This must also be true of all the Australian and African species of *Tachardia* and also of the Indian insect *T. decorella* varthæ, described by Mr. Green from Darjiling. *T. albizziae* in Ceylon produces lac proper. Mr. Green mentions that this insect produces winged and wingless forms. *T. conchiferata* similarly supports a local lac industry. Mr. Green does not mention if wingless forms of this species have been discovered. I am certain that they do exist. *T. larrae*, in Arizona, produces lac very much allied to the Indian material. I am inclined to believe that in wingless males would also be this case found.

*Symbiotic yeasts and lac insects proper.*

As has been said before, the lac insect is a bag containing living cultures of symbiotic organisms. Pseudo-lac insects may contain bacteria but the absence of yeasts in them shows their more primitive form, bacteria being more ancient than yeasts. In the case of lac insects proper we also meet with dot shape or cocc i bacteria, but I am not sure if these are not derived from the plant, and hence the point, which is under investigation, does not permit any safe conclusion being drawn at present. Dr. Hudson, Entomologist to the Government of Ceylon, some two years ago, was kind enough to send me some living specimens of *T. albizziae*. These contained yeast-like refractive bodies showing that their hosts were true lac insects. I am sure *T. conchiferata* would also show the presence of symbiotic yeasts. Similarly, *T. larrae* would give positive evidence. The Australian insect *T. decorella* of Maskell or the Indian variety *T. decorella* varthæ, would prove their absence. *T. angulata* of Froggatt from N. S. Wales in Australia and the several species of *Tachardia*, discovered by Messrs. Bodkin and Brain, would be allied to *T. minuta*, and instead of yeasts, might contain bacteria.

*Genuine and pseudo-lac insects.*

Summarising what has been said so far with regard to the insects, which produce lac proper and a pseudo-lac encrustation, we get to the following main differences between them:—

1. Lac insect proper gives rise to an exudation, which is translucent or glass like in appearance and which cracks naturally showing its
brittle nature. Lac proper is a fragile substance and breaks on pressure, the fracture being like that of a broken crystal. It melts with heat, dissolves without swelling in alcohol, contains two constituents, ether-soluble resin and ether-insoluble portion. In the mass of lac is embedded a hard kind of wax, which also dissolves in warm alcohol. The insect exudes soft wax in the form of cotton-like filament outside the cell.

The spinoid process is elongated into a blind tube. The actual spine is on the top of this process. There are other lesser spines, which contribute to a rough surface of the spinoid process. Each of the two stigmatic processes form one piece with the posterior spiracular openings.

The shape of the body is spheroidal, or apple-shaped, or egg shaped, or pear-shaped. Around the equatorial region there are six patches of wax pores.

The insect excretes a large quantity of honey-dew which contains glucose and fructose. The anal process has well developed anal hairs around the anal aperture.

There are winged and wingless forms of males. The male puparium is flat, like a slipper in shape.

Yeast-like symbiotic organisms are invariably present. Life cycle has definite periods for larval swarming and for the emergence of males; they do not interlap.

II. Pseudo-lac insects produce an encrustation which is leathery rather than resinous or glassy. No cracks are observed on these cells, instead, we often meet with folds on the encrustation. Pseudo-lac can be cut with a razor without breaking it into pieces and gives the appearance of a hardened piece of gelatine. The encrustation melts without liquefying, although it emits a smell like shellac. In alcohol it swells, like gum tragacanth in water, and leaves a large insoluble residue. There is not much of hard wax embedded in the mass of
exudation. Possibly there is no ether-soluble portion also. The insect exudes from the stigmatic areas filaments of fibrous silken threads as opposed to fragile and cotton-like ones. None is produced from the anal end.

The stigmatic process does not form one piece with the spiracular opening. The spinoid process is much simpler and smoother; the spine is like a rose thorn and not like a dagger, or like a needle.

The general shape of the insect is flatter, especially, on the ventral side. The body outline is lobed and not circular. The wax pores at the peripheral region are not arranged in six well defined patches as they are one with lac insects proper.

Pseudo-lac insects excrete very poor quantities of any liquid from the anal aperture. Qualitatively speaking it does not contain any sugary matter. The anal hairs are very delicate, more like other coccids than like true lac insects.

Only winged males are known in pseudo-lac insects, the male puparium is slightly arched upwards at the caudal end. Intercellular yeasts are absent, instead, there may be bacteria.

Life cycle seems to take ten months. There are no definite periods for the larval swarming; males and larva can often be observed at the same time on the same tree.

It is thus clear that the two classes of insects differ in vital respects. To overlook the above differences would mean attaching too much significance to a common spine which, again, is not identical in both of them. If still these insects should be classified as members of the same genus, it seems to me, the genus *Inglisia* should be included at least in the same sub-family. These insects also have an analogous spine and this should be sufficient reason for them to be called lac insects. Their product of secretion is purely waxy but this should not prejudice an honest taxonomist. It is a pity that members of the sub-family *Tachardinæ*, instead of a spinoid tower, do not own a hump, for then, we should have been in a position to trace their descent and look upon these insects as the nearest hexapodous ancestors of the camel.
Physiologically the Tachardinae, or the lac insects proper, and the pseudo-lac insects, differ from the cochineal insects in the latter not producing any lac or insect-resin; from the wax insects of the genus Ceroplastes, by the absence of dye in this case; and from the genus Inglisia, by the fact that the latter insects do not produce either a dye or an alcohol-soluble constituent. Inasmuch as there are more pseudo-lac insects, I propose retaining for them the old name of Tachardia and for lac insects proper I suggest the more connotative word, Lakshadia, derived from the Sanskrit word, Laksha. Tachardia lacca on Butea frondosa therefore becomes Lakshadia indica. It exudes a lemon-yellow resin and is likely to be mistaken only with the product of the insect on S. trijuga. This insect exudes a thick layer of resin and has very strongly developed stigmatic processes and a spinoid process. This insect I propose naming Lakshadia nagoliensis, inasmuch Nagoli lac is a regular trade name. Kusam lac insects may be made to grow on other trees and in this case it would be safer not to name it after any particular host-plant. Sind lac is much more yellow and its insect should be called Lakshadia sindica. Next darkest lac comes from Assam and Indo-China. I feel sure, it is the same insect as found in South China and also in Burma. I therefore propose naming it Lakshadia chinensis. The long spinoid process and the rib-like chitinous extensions of the stigmatic processes should be additional guides in its identification. The next darkest lac is the product of the Mysore lac insect. It is the smallest commercial lac insect in India. It is the only trivoltine insect of its kind. It is to be called Lakshadia mysorensis. The darkest lac almost garnet-coloured or ruby-coloured variety, comes from F. mysorensis. It is also found in Hyderabad on F. bengalensis and also to a lesser extent on F. religiosa. In Bombay I found the same species on Albizzia lebbek in December 1916. My friend Mr. Swaminathan, of the National University, Adyar, sent me specimens of lac, found on F. Benjamina in the Botanical Gardens, Madras, which again belongs to this insect. It might be the same species, which also occurs more or less rarely in Indo-China and in the Philippines. Considering its wide distribution with regard to host-plants and geography, I propose calling it:
Lakshadice communis. If T. ficiei of Green should prove to be different from L. Indica, or the insect found in Behar on Z. jujuba and on Butea frondosa, then it would be named L. ficiei. His Ceylonese insects would be called, Lakshadice albizziae and L. conchiferata. The American insect may be called L. larrae. The Ceylonese and the Arizona insects seem much more related together. They grow isolated rather than form large colonies. On the whole there does not seem to be such a difference between the Indian insects and these as to separate them by creating another genus.

Further work is in progress and it is hoped that a genetical study of these insects would decide several points not yet clear. The morphological stand-point is very inefficient in classifying these insects and unless the factor of adaptability has been first studied by cross-inoculation experiments, it is distinctly misleading. So far only two lace insects proper, Lakshadice mysorensis and L. communis in Mysore, have been studied by cultural experiments. Both have been found different from each other and new to Science.

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