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on the morphology of the microorganism of leprosy

Adolpho Lutz
On the Morphology of the Microorganism of Leprosy

Introductory Note *

In 1886, A. Lutz presented his studies on the structure and biology of the acid-fast microorganisms of leprosy and tuberculosis. Published only four years after the tubercle bacillus had been discovered, his work was in many ways far in advance of his time. In the seventy years which have elapsed, his different observations have been advanced again and by others as new discoveries.

In studying the structure of leprosy and tubercle bacilli, Lutz described very fully their granular appearance, with the granules strung along the rods right up to their rounded ends and with others lying free. Irregular staining and granule formation had been seen before; Lutz demonstrated his technique for bringing them out consistently in all the microorganisms of a preparation. Koch himself noticed granules as bright corpuscles in unstained preparations and also obtained some discontinuously stained bacteria.

He took the unstained parts of the latter to correspond to the granules and for a time believed them to be spores. Neisser had drawn quite similar conclusions in leprosy. A. Lutz made it clear that the granules in stained preparations corresponded to those of the unstained, that the interstices must not be taken for spores, and were not spore-shaped, as then depicted. The granules strung along the rods were also not spores.

Lutz further described a second type of granule. These granules were found in much fewer numbers, were thick-walled like a resistance-form, and larger; they were localized at one of the two extremities of a rod or else lay free; at times they took the contrast color in their central portion. These also have been re-described by others as new (cf. the literature up to 1918 in F. Löhnis, Studies upon the life cycles of the bacteria, part I, published by the National Academy of Sciences, 1922, p.81-4, 85, 105, 107, 124, 133, 137, 159, 160, 162, 163, 173-5, 194 and Plates J and R).

* Introductory note written in English probably by Gualter Adolpho Lutz, in June 1956, when Bertha Lutz provided the translation of their father’s article from German to Portuguese. There are many manuscript and typed versions of these texts at BR. MN. Fundo Adolpho Lutz, caixa 22, pasta 256. Both endeavours happened soon after the celebration of Adolpho Lutz birth centenary.
Lutz also studied the clumps of bacteria of the zoogloeas or globiformations, which he did not consider to be intracellular inclusions; he explained the substance embedding the rods as derived from the microorganisms themselves.

Since Lutz was able to demonstrate the granular forms consistently, he did not regard them as degenerate bacilli. The latter interpretation has often been voiced by those who, using other stains, would see the granules only occasionally and by chance. Lutz viewed the granules as live elements capable of development. This early work of his is seldom mentioned in studies on the life-cycle of the acid-fast bacteria, such as are still being carried out. In the earlier part of this century, a great deal of attention was drawn to Much’s views on the granular forms of tubercle-bacilli and the possibility of granules to form new rods. This is largely what Lutz had already indicated, except that in addition, Much claimed that granules could be found even where no acid-fast rods were to be seen.

The method of staining proposed by Much, however, is by and large practically the same as the modification of the Gram method used by Lutz, and Unna pointed out that the granular form of Much was the Coccothrix structure described by Lutz.

The observations made by Lutz on the morphology and biology of the organisms of leprosy and tuberculosis led him to separate them from the genus Bacillus and to create a new genus for them. He proposed the genus Coccothrix, family Coccothricaceae, and gave a diagnosis and succinct description of the generic characters. The placing of the germs of tuberculosis and leprosy in a different genus and family is now accepted in determinative bacteriology. The fact that Lutz’s early publications came out in a periodical devoted to dermatology and not to microbiology may be partly responsible for the adoption of another name proposed ten years later. Dating from 1886, the generic name Coccothrix, covered by a description, has undoubted priority over Mycobacterium Lehmann and Neumann, 1896, and ought to be used in accordance with the accepted rules of botanical and bacteriological nomenclature.
On the Morphology of the Microorganism of Leprosy*

Dr. Adolpho Lutz

The microorganisms generally named leprosy bacilli are found in the fluids of the tissues, in pus and in sections of diseased organs, partly isolated, part in larger aggregations. The latter are always imbedded in a voluminous, gelatinous mass, which holds them together firmly, whereas the former are often devoid of such a sheath. These two conditions are connected by a series of intermediary stages, which allow the life history of the organism to be reconstructed, in part, starting from the isolated bacilli, apparently devoid of involucres as the undoubtedly earlier stage.

To obtain the findings described below, it is advisable not to limit oneself to the usual differential staining, but to apply a series of different methods of observation, successively. Once the differential diagnosis of leprosy has been established by the usual methods, every preparation made from nodes may be regarded as a pure culture, provided the nodes are not ulcerated and that the preparations are free from fungi. (Accidentally introduced organisms would be recognizable by their small number and mostly also by their form.) I examine the preparations in various media (air, water, Canada balsam etc.) and use different stains, following their penetration carefully under the microscope and also investigate the effects of decolorization on overstained preparations. By this procedure, I have been led to results which diverge from the accepted views on several points.

By cutting across a node fixed in alcohol or osmic acid immediately after extirpation and scraping the surface of the section with a scalpel, or by using a smear of the fluid from a fresh non-ulcerated node, a sufficient quantity of rods can always be obtained, especially if the portion of the incised node lying just under the surface is used.

Examination, in water, and after drying in air, shows, besides smooth and bare rods, others with a regular thickening located either at one end or in the middle, and which is drop-like in wet preparations; when this thickening is more fully developed it surrounds the whole rod or leaves only one end free; when several of these rods lie close together they form a confluent common sheath, which often seems very voluminous for the small number of microorganisms enclosed; however, when the sheath reaches a certain, moderate size, the contours of the individual rods disappear entirely and it is only by modifying the methods of observation that the true nature of these conglomerations can be ascertained (figs. 1, 2).

The substance imbedding the rods plays an important part in the leprous neo-formations, as it constitutes the major part of the colonies of rods; and since the latter make up a very large or even the major part of the volume of the nodes, as can be seen...
Explanation of the figures

1. Rods with wet gelatinous sheath.

2. Rods with dried gelatinous sheath.

3, 4, 5. The same clump of rods in wet, half-dried and in completely dried states.

6. A clump of rods broken up into a conglomeration of coccoid spheres by Gram-stain and decolorization with nitric acid alcohol. (The individual granules are more uniform than here represented and completely round.)

7. Rods broken up into dot-form, colon-form, i-form and Coccothrix-form. (Intense overstaining with fuchsin, long immersion in 25% watery solution of nitric acid, decolorization in 60-70% alcohol.)

8. Unstained, thick-walled cells, isolated and linked up.

9. 10. 11 Large cells, taking contrast-colour, seen isolated and at the end of either homogenous or broken up rods.

In preparing the drawings, Hartnack O c.5, Leitz O il-imm. O bj. 1/12 were used.
in good sections, it becomes evident that this vegetative product plays an important role in the thickening of the skin. For the time being, I shall call this substance the gelatinous or mucous sheath, as I presume that it is very similar to other involucres so designated, which are very common in the class of fungi and algae, in some species of which they are so massive as to influence the whole physical appearance of the colony, which even macroscopically takes the form of gelatinous or mucilaginous membranes and clumps (as in Mycoderma aceti, Nostoc etc.).

While wet, the mucous sheath appears homogenous and is rather refringent; smaller fragments are glassy, and larger ones have a silky sheen. As long as it is turgid, the contours are rounded and regular with a drusy aspect in the larger ramified conglomerates (fig. 3). If the involucre has shrunk through desiccation, the contours become broken and the surface angular or rugose. Light is refracted in different ways by the edges and this may produce a false image simulating bacilli although the imbedded organisms are by no means visible. The rods with a partial gelatinous sheath look as if they had been broken off from a crumbling mass and can easily be mistaken for shapeless fragments of tissue (fig. 2). If weak solutions of the usual aniline dies are added to preparations in this condition, the mucoid sheath quickly absorbs them and takes on a deep stain. However, it relinquishes the colors with the same ease they are absorbed and it is only due to this circumstance that the sheath generally appears colorless, when the usual methods of staining are used. However, with a strong gentian staining, followed by iodine-iodide solution and bleaching in alcohol with 3% nitric acid (Gram's method), not infrequently preparations are obtained in which the sheath appears distinctly bluish-red, standing out from the colorless or contrastingly stained tissues. This would suggest that the sheath of the leprosy bacilli is similar in composition to the capsules of the pneumonia cocci of Friedlaender, which can also be stained with anilin-gentian. By simple treatment of the gentian preparations with an aqueous solution of nitric acid (1:4) and diluted alcohol, a staining of the substance of the sheath is often obtained. On the other hand, I have seen some preparations of fresh juices of tissues which had been treated with fuchsin according to Ehrlich’s method, in which the gelatinous substance sometimes acquired a contrasting coloration with methylen blue.

The refraction of light by the mucous sheath is not only much greater than that of air but also than that of water; consequently, it is visible in both media, though more distinct in the former. If it is placed in a medium with a refraction comparable to that of glass, and which can be obtained by mixing alcohol and carbon sulphide, the sharp contours disappear. When the mucous sheath is dehydrated and embedded in Canada balsam, the sheath is only visible if it is stained.

Unna has already pointed out explicitly that those gelatinous masses are neither cells, nor contained in cells. Their reaction to gentian is an added proof to those he already adduced. As the latest textbook on pathology, by Ziegler, still states that the bacilli of leprosy can be found inside cells, I should like to state my conviction that the original statement to this effect is due to a misinterpretation of the figures observed under the microscope in which the contours of the zoogloea were taken for cell membranes and the gelatinous substance for cellular protoplasm. Following up this mistaken interpretation,

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1 According to de Bary and to what has been observed until now, these gelatinous clumps are made up of a substance analogous to cellulose.
the nucleus was looked for but could not be found. Meanwhile, Touton, in his latest paper (Fortschritte der Medizin, 1886, n.2) takes up this view once more, but modifying it so as to consider the zoogloea as contained in a cell, with the nucleus preserved but pressed against the cell-membrane and even flattened out by the mass of bacilli. In presenting this view, he is not entitled to call upon the authority of former observers to support it, since their interpretation was quite different from his; on the contrary, the burden of proof must rest upon his own efforts. Whether he has furnished evidence to support his new indication, I shall leave to future observers to say; personally, I find the reasons given by him for accepting his view that inclusion in cells is the rule entirely unconvincing. On the contrary, I believe that an intra-cellular location can, in most cases, be completely excluded. Considering the nature of the object it is evident that some slides will always seem ambiguous, thus leaving room for individual interpretation by the observer. Touton, in placing his nuclei in a peripheral layer of protoplasm, limited by a second cellular contour, has evidently based his views on slides which can readily be interpreted in an entirely different manner by other observers equally conversant with microscopic technique. Spindle-shaped cells with nuclei elongated in one direction and flattened in another are common enough in leprous nodes (and elsewhere) and may easily lie adjacent to a mass of bacteria. The fact that the methods in general do not clearly show cell contours will surely be agreed upon; moreover, the mere shape of an adjacent nucleus cannot, in my opinion, justify the assumption that it has been compressed between a mass of bacilli and a cell membrane.

A deeper discussion of Touton’s views (published after conclusion of the investigations which I now present) does not belong in here. I should, however, like to mention, that in my opinion the theory of intracellular location only became popular because of a similar behavior observed in the microorganism of tuberculosis, which is morphologically akin to that of leprosy. Reasoning by analogy is not permissible in this case, the more so as the cell is not the actual and exclusive nutritive medium for the tuberculosis organism, which also multiplies in a life-less culture medium (blood serum) and most likely also in lymph, blood and in the secretion found in the bronchi and caverns. Besides, no one has shown that giant cells exist in leprous nodes, and this in itself is an indication that the two organisms react differently in the tissues.

Leaving the gelatinous sheath aside and turning to its contents, i. e. the bacilli, it is seen that they take the form of straight slightly curved rods, extraordinarily variable in length, which may attain that of the diameter of a red blood corpuscle. They are, however, by no means homogenous, being on the contrary composed of two different substances, which differ in their reactions to different stains. By present-day methods, it is much easier to observe this than to obtain tolerably uniformly stained rods. This fact is interpreted by Neisser and others as being due to clear spaces, which interrupt the continuity of the rod and which have been looked upon as due to the formation of interstitial spores. I cannot agree with this view in any way. If so, the light parts ought to present convex contours against the edges of the darker ones, since spores are taken to be round or at least oval. It is easy to prove that the converse is the case, i.e. that the light parts are cylindrical with concave extremities, whereas the deeply stained portions are rounded. Voltolini, who observed this condition in tubercle bacilli (after short treatment with concentrated nitric acid) seems to consider it simply as an effect of coagulation. He was unable to obtain a similar condition in old specimens of leprosy bacilli. Now, I propose to show that it is just
in the latter that it can be made very clear. It is no more an artifact than any other histological differentiation which is only brought out by reagents or stains.

To furnish this proof let us start from dry preparations fixed in alcohol or osmic acid, i.e., preparations which have been subjected to no greater alterations other than ordinary fixing and first examine the short and straight rods, which are generally quite plentiful. When the objective is lowered slowly, two clear, round, brilliant spots will come into view, lying at the poles and refracting light in the manner of convex surfaces. I call this form and the corresponding one seen in stained preparations the colon form, because of its similarity to the double points of the colon used in punctuation. Sometimes the dot at one pole is substituted by an elongate dash and this I shall designate as the i-form: an elongate form at both poles is much rarer. Finally, a whole row of such light, prominent, deeper staining points are found regularly spaced (streptococcus-form); often, the axis changes its direction slightly at these dots and it is this fact which causes the curvature and slight angularity of the rods.

With a different stain and moderate magnification, some preparations show apparently homogenous, uniformly stained rods. It is such figures that must have led to the organism being termed a bacillus. In so far as I have observed until now, they mostly appear when moderate staining has not been followed by decolorization or when the stain has been subsequently extracted by alcohol, chloroform or essential oils. (The process first indicated by Koch for the demonstration of tubercle bacilli seems especially appropriate for producing these figures; moreover different stains behave in different ways and the same stains may differ in results, according to the methods used.)

When gentian-violet or fuchsin is used and the preparations are first considerably overstained and then decolorized by prolonged and successive use of nitric acid and alcohol, quite different figures ensue. In each rod, a sharp demarcation between a deeply stained and a colorless or faintly stained substance can be seen. Sometimes a sort of double staining is obtained; with fuchsin it comprises dark and light red; with gentian between pale cherry red and deep blue-violet. The more intensely stained substance shows the above mentioned color, streptococcus and i forms; not infrequently, quite unconnected, rounded, coccus-like bodies, or microspheres, also become visible. If the interstitial substance has become totally decolorized, which generally happens in part of the rods, its existence is demonstrated by the coherent passive movement of the coccus-like groups (fig. 7). With incomplete decolorization, the impression of interrupted rods, like those seen in Unna’s plates is obtained. Continuous rods, rods with isolated interruptions, and rods broken up into streptococcus pattern often occur together in the same preparation; the impression then conveyed is that they represent different stages of development. This supposition is only partially justified, since there are no really homogenous rods.

By far the best preparations are obtained through the use of the following modification of Gram’s method:

Staining is allowed to proceed for a relatively long period with the aid of a higher temperature, in a diluted solution of anilin-gentian-violet. (If the stain is used in a more highly concentrated form very disturbing granular precipitations of the dye are liable to occur). When even the thin sections show a saturated deep blue-violet, they are put successively into iodine-iodide solution, absolute alcohol containing 10 to 50, concentrated nitric acid and then into acid-free alcohol. They are allowed to remain for some time in each of these solutions and the process is repeated several times, but in the
latter repetitions the iodine-iodide solution may be omitted. When the sections show only a bluish slate-gray color they are ready to be examined. I prefer to use as an examining solution, the excellent pure Thymen prepared by Schimmel and Co. of Leipzig. It does not attack the stain at all, it clears very well and it can be made volatile by heating without leaving any residue. If the sections are still deeply stained, clove oil is used and produces a slow and appropriate decolorization.

On examination, either a striking differential staining of dark, almost blue-black microspheres, lying in a pale-red rod are seen, or, if decolorization has proceeded further only the microspheres are left albeit, with a very intense coloration. Such preparations present a very beautiful picture, especially if a contrasting nuclear stain is also used. The clumps of bacilli appear as if made up of transparent masses interspersed with drops like stippling not unlike mist breaking up into its component droplets.

If focussing on the mass is correct the individual grains are all of the same size (with one exception which will be discussed below) and the distance between them is also uniform, provided that the curvature of the strands is taken into account. They are perfectly round, as I found upon examination with Zeiss Imm, 1/18, Oc. 5, and to the impartial observer they appear like masses of streptococci or micrococci, the component individuals of which have moved apart. According to the intensity of the stain slight differences of size are observed; they appear slightly larger when they have the right blue-black tone, then when they have the violet color found in insufficiently stained or subsequently decolorized preparations. They are, however, always considerably smaller than the average staphylococcus.

When the innermost layers of the rod substance are still somewhat stained, one is easily convinced that all the so-called bacilli can be broken up and that one is dealing with a general rule and not with a single stage of development. The value of the method used lies in the evidence it affords for this fact, which in turn justifies the emphasis laid on the structural peculiarities. The images described have presumably all been seen before but I do not know of any author who insists on their universal character. Since these conditions can only be judged in successful preparations (which are often quite difficult to obtain) I wish to forestall any criticisms based on unsuccessful preparations. If they are good, the figures seen are clear and unequivocal. Considering the importance of this method I shall now describe my experiences with it, briefly.

Upon using Gram’s method and decolorizing with acidulated alcohol (which should have contained 3% nitric acid but which had become probably more concentrated, owing to unequal evaporation), I first obtained figures like cocci disposed in regular rows but still connected by a fine thread (cf. the last four individual drawings in fig. 7 and a photograph from Koch’s in Mittheilungen des deutschen Reichsgesundheitsamtes, vol. 1, fig. 39). Since I was also able to obtain such preparations with tubercle bacilli, at times with all the rods showing this structure, I realized that it did not correspond to an artifact but to a presentation of normal conditions. A leprosy section of this kind had stood for several days in clove oil and was then brought into absolute alcohol again. On examination I suddenly found the figure described above of loose rows and heads of cocci. Since there had been no posterior treatment, it could only be due to an easier decolorization of the interstitial filamentous substance.

I naturally tried to make more of such sections and after a few unsuccessful attempts, several successful preparations were obtained in which decolorization had been made
with alcohol acidulated with hydrochloric acid, some with and some without the additional use of clove oil. These followed another whole series of useless efforts, in which sometimes the whole zoogloea became differentially stained and at others a homogeneous staining of the rods or else intense precipitation occurred. Gradually the sources of error seemed to emerge, pointing to an initially too weak staining, too short a permanence in the iodine-iodide solution and an insufficient percentage of acid in the alcohol. The differentiation is essentially due to the action of hydrochloric or nitric acid, not diluted in water, but used in alcoholic solution of as high a concentration as possible without damaging the sections (the latter should be neither too large nor too thin). Care must be taken in preparing this mixture. Absolute alcohol had best be used only for final rinsing. Clove oil has the advantage of extracting the stain least from the coccus-like cells and of thus furthering and correcting the differential staining; but if it is carried into the balsam it will end by deteriorating the sections. Therefore it has to be extracted with ether. A good guarantee for the preservation of sections is desiccating the sections previously rinsed out in water and then enclosing them in melted and previously exsiccated Canada balsam (U nna's method).

The interstitial substance of the rods has the following properties: it accepts anilin dyes fairly easily but gives them up again with the same ease. Once it has been treated with acids, it loses the property of fixing anilin dyes completely. For this reason the colorless parts of the rods do not accept any differential staining when the sections are prepared by the usual methods. All the properties just mentioned are held in common with the gelatinous sheath. The disappearance of the contours of the interstitial substance in the gelatinous outer case shows that both have approximately the same index of refraction. It is for the same reason that a piece of ice free of bubbles and dust disappears when immersed in water and that some crustaceans like Leptodora hyalina, although macroscopically quite visible, become imperceptible in their natural environment.

The small differences which sometimes occur as to refraction and staining are explainable by differences in the degree of turgescence. The fact that the swollen substance holding a good deal of water has a different refraction from the dehydrated one is best shown by its visibility in Canada balsam (see figs. of foci having imbibed water in U nna's paper published in this number and the ordinary appearance seen with the oil method used for simulating cells in Neisser, Ziemssen, Specielle Pathologie und Therapie, v. XIV, I). The youngest innermost layers are the least turgescent, the most recently formed, perhaps barely colloid, therefore fix the stain best. Their reaction to stains comes nearest to that of the granulations so that even if concentrated nitric acid is used, they often form a stained bridge from one granulation to another, showing the site of the last division. Only through the successive action of iodine and strong mineral acids can a correct picture of all the bacilli in a section be obtained.

Now that the facts have been presented, I should like to discuss briefly the explanations, which in my opinion interpret these facts and also bring them into agreement with other known phenomena. The elemental part of the leprosy organism (schizomycete) is the granulation, which originally has a firm and thin membrane, gradually thickening and becoming colloid through turgescence. The cell included divides, without participation of the cellular membrane, into two new granulations, which gradually move apart and become invested with new membranes, while remaining within the older one. The division always occurs in one direction alone and leads each time to the increase of the gelatinous
envolucrè by one more layer; this process can be clearly observed in certain algae, Gloeocapsa for instance, though in that genus the division is not limited to one axis only. The innermost sheath in which the small spheres are lodged, somewhat like the seeds in a pod (e.g. those of Cassia fistula) can be represented as a bacillus; the outer turgescence layers constitute the gelationous outer sheath, which may become confluent with these of a neighbouring row of granulations, thus forming a zoogloea.

The various schyzomycetes differ as to the form of the distended membrane and as to its early or late gelatinous metamorphosis; and these differences are brought out by staining and may lead to very divergent interpretations. The gelatinous sheath may be drawn in between the individual cells, invest them in a straight line, or bulge out; if it takes up the stain it will make out of a diplococcus an oval coccus; out of a row of cocci (Streptococcus) a rod with varying size and rounded extremities. In fact I have several times succeeded in dissociating such a structure into two or more round cells and I think it possible that the rounded ends may furnish a good criterion for recognising a structure made up of round elements. It also seems probable that this form applies to the microorganisms of the granulomata.

I have already indicated above that the differences in coloration of the different layers of the gelatinous sheath are only relative; this explains why a rod or coccus may appear narrower when stained by one method, then when another is used, which stains one more layer.

My observations also explain why a microorganism may be sometimes described as a rod and at others as a coccus. When Disse and Taguchi claimed to have found rods and spores, stainable with gentian, in the blood of syphilitics, it seems very likely that what they had were the granular cell-elements (certainly not spores) which form the elemental components of the rods, possibly the bacillus of Lutsgarten. This may also explain the finding of micrococci in other diseases which are generally attributed to bacilli.

The objection may be made that the round cells are spores. This interpretation is, however, opposed by a number of facts, such as the constancy of their presence, their reaction to anilin dyes, the probability that they can divide, which has not been demonstrated for the spores of bacilli, and lastly by the occurrence of other cells, which as will be shown below are closer to spores.

Until now only two of the elements which take part in the formation of the zoogloea masses have been considered; there is, however, a third element, which although quantitatively negligible is likely to be all the more important functionally. This is composed of peculiar, cell-like elements, which would seem to be connected with the reproduction of the species, to judge by analogy.

Even in unstained preparations, isolated cells can be observed at the extremity of the rods, which differ from the others in size, form and refringency. Similar structures, which are resistant to alkalis and acids, are to be found here and there, in part within the zoogloea masses, in part within the tissues and even, although seldom, inside the epithelial layers.

The study of these corpuscles and of their location is best made with stained sections. In preparations carried out by the usual methods, one finds:

1. At the end of the bacillus-shaped filaments, one can see relatively infrequent cells stained in the same color as the others, but thicker, more intensely stained
and more elongate in shape. Their longest diameter is often somewhat oblique, so that a shape ensues similar to that of the notes used in music for a semibreve or a crotchet with the head placed obliquely to the stem of the note. At times, similar structures may be found free (cf. fig. 10, 11).

2. A number of similar, apparently round or oval bodies, which can only be distinguished by the fact that they do not stain, have a double contour and refract light to a much higher degree. They are consequently easy to recognise in air, water, glycerin, different oils, Canada balsam and in carbon sulphide itself, even when they lie in the zoogloea masses or interstitially in the tissues. The majority are free and consequently may be taken for impurities; their reaction to acids and alcalis, their insolubility in carbon sulphide, and especially the circumstance that they can be found connected with the so-called bacilli speak against this interpretation. If dyes are allowed to act for longer periods, their contents, but not their membrane, become slightly stained somehow (fig. 8).

3. In sections decolorized by strong mineral acids and given a second stain, rounded bodies are not infrequently found colored by the contrasting stain and showing a diameter greatly surpassing that of the coccus-like cells. One would hardly suppose a connection between these two structures were it not for the fact that a small differently stained formation undoubtedly form the end of the rod. They differ from the bodies previously described, not only in color, but also by their large size, less regular shape and lack of the intensely brilliant surface of the others. They often show one, less often two prolongations like a very thin thread, which are mostly not placed radially but rather at a tangent, so that a shape akin to that of a note of music can again be produced (fig. 9).

As to the interpretation of the bodies described above, the following conclusions might not seem too far-fetched.

The cells lying at the ends of the thread must be considered as similar to the heterocysts of *Nostoc*. As long as they have no particularly thickened membrane, they react to stains like the other cells; subsequently they become invested with a thick, only very little slightly permeable membrane, such as is often found in the spores of fungi. Finally a gelatinous mass forms around them, which is stainable but which gives up the stain when decolorized with acids. Whether the gelatinous outer sheath is formed by the turgescence of the membrane or by the contents after the rupturing of the membrane, it is difficult to say; in any case, the small appendages may be fringes of a ruptured membrane.

For reasons of analogy, it would seem that these cells have a special function, i.e., that of reproduction; the thick membrane suggesting a form of resistance (the heterocysts of *Nostoc* are, however, not stated to have this property). I have not been able to make sure of germination but have seen figures which might allow such an interpretation.

Up to now, I have always found these bodies at the end of the rods (not along them) or else fissured off and lying free.

From Mittenzweig (Die Bakteriologie der Infektionskrankheiten), I deduce that Fluegge saw round bodies with a conical elongation, besides rods, in leprosy. They should be identical with the oval terminal cells described by me. Matterstock made similar findings in the syphilis bacillus.
If my presentation is correct, and this can be put to the test of control-observations, it becomes evident that the name Bacillus no longer applies to the leprosy organism, since the genus Bacillus is defined as rod-like cells, or complexes of cells, which are not further differentiated and which produce endogenous spores. I propose the new generic name of Coccothrix, as a genus of the family Coccothricaceae, for the organism of leprosy and other related species. The genus can be defined as follows:

Small, round, coccus-like cells, which divide without participation of the investing membrane and only in one direction, so that they are found either isolated or disposed in linear rows. They are invested by membranes which distend and swell to a gelatinous consistence by turgescence; the individual cells are separated by interstitial parts which exceed their diameter in size. Structures like strings of pearls or like rods, appear when the innermost layers of the membranous, gelatinous sheath are stained; larger cells, partly oval and with a double contour are found, either free or at the end of the cell-rows. This genus comprises initially both the organism of leprosy and that of tuberculosis. Some other organisms of putrefaction seen by me should also belong to it, as well as the schizomycete photographed by Koch already mentioned above and, to judge by its similarity, also the so-called Bacillus malariae of Klebs and Tommasi.

Without going into this further, I should like to say a few words about the so-called tubercle bacillus.

My interpretation of this is decidedly opposed to that of its discoverer. From the figure of the light interstice published by him (Mitth. des Reichsgesundheitamtes Bd. II, Pl. X, fig. 47) one might infer a completely different structure.

Owing to the minute size of the object and the differences in staining methods, such differences are possible. It gives me satisfaction to note, however, that the results obtained by me in regard to leprosy were obtained by others in regard to tuberculosis, though so far as I know, no one has proceeded on the decisive and energetic summing up that is required for a clear cut understanding of the principles involved. Already the first fuchsin preparation of inoculated tuberculosis made by Prof. Schröner in Naples and shown by him to me under the highest magnification showed the typical Streptococcus form. Retrospectively, I remember perfectly that the Professor called my attention to them. If I am not mistaken, Prof. Schröner had already then, prior to my study of the organism of leprosy, observed the formation of spores in the tubercle organism, by which of course are not meant the clear interstitial spaces. Though I am unacquainted with the details, I presume that he saw the same forms which I observed in leprosy and thus feel it my duty not to stand in the way of his priority.

Voltolini also saw the condition resembling a string of pearls in the tubercle bacilli, after treatment with concentrated nitric acid, before I did, but he took them for artifacts produced by coagulation. (Breslauer aertztl. Zeitschrift, 1885, n.15). Gram, whose method, somewhat modified, produces the most convincing figures, also speaks of a granular, streptococcus-like aspect of the tubercle bacilli. The first probably corresponds to the Coccothrix condition (filaments with enclosed granulations), of which I was also able to make good preparations with tubercle bacilli.

For the material used in this paper I am indebted to Professor Unna, to whom I was drawn by the wish to continue studying Leprosy, with which medical practice in Brazil had already made me familiar. I am very grateful to him for the opportunity to do so and for the friendly interest with which he accompanied and furthered this work. I also venture
to express the hope that his initiative and sustained efforts may succeed in changing the listlessness with which this disease is generally looked upon in this wide territorial range to an active interest in research on and treatment of Leprosy.