

ON THE NATURE OF BACTERIA

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BRIEF REVIEW OF CURRENT CONCEPTIONS OF THE LOWER ORGANISMS

The question in regard to the position of bacteria in the organic system has received but little attention in medical bacteriology. This is explainable partly because the solution of the question may seem to be of minor practical significance, partly because its discussion demands so extensive a special study that the physician must not be blamed if he hesitates to pass so far beyond the limits of his field. The reason that I, nevertheless, dare to take up this question is that apparently important observations for its solution have been made by medical bacteriologists, observations that have not received due consideration either in botanical or medical circles. Furthermore, in distinction to many others, I am firmly of the opinion that a better knowledge of the nature of bacteria in the long run cannot but be of importance even in practical medicine.

As this article is intended for physicians it seems well to begin with a presentation of the views of a botanist in regard to the development of the lower organisms and then later take up the different theories about the position of the bacteria. I shall follow Lotsy¹ especially. He points out that there is no sharp line dividing the lower animals and plants, because there are organisms that under certain conditions possess chlorophyll and prepare their own food, and that under other conditions are colorless and take up prepared food in fluid or solid state. In the same individual nutrition may be distinctly "animal" and "vegetable." The discovery of such organisms puts an end for good to the search for a definite difference between the animal and the vegetable kingdom. In looking for lower and lower organisms the flagellates are reached, which possess both animal and vegetable characteristics. The primordial organisms may have been like flagellates; they surely lived in water and were able to prepare their own food. Whether the food was assimilated by photosynthesis or not, that is to say, whether these organisms possessed coloring matter or not, is difficult to decide because there are

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¹ Vorträge über botanische Stammesgeschichte, 1907.

plants without coloring matter that are able to produce organic substances from inorganic.

As the nearest relatives to these hypothetical primordial organisms, Lotsy mentions the so-called *Protomastigma*, which are colorless organisms without cell wall that swim about by means of cilia. Descendants of these organisms have acquired the power of photosynthesis and of forming coloring matter. In this way arose green, yellowish-brown, red and bluish-green flagellates; from these in turn developed the lower algae and from these the rest of the vegetable kingdom.

How do these flagellates look? Lotsy describes a low form, called *Pyramidomonas*, and also a somewhat further developed form, *Chlamydomonas*. *Pyramidomonas* consists of a mass of protoplasm without any cellulose membrane provided with a nucleus and a so-called chromatophor which is a green organ for photosynthesis. Then there are four cilia, situated on a specially formed head-end. Multiplication takes place by simple longitudinal division while the organism is in motion.

Chlamydomonas is more developed in that it has a cellulose membrane and before division changes into a resting form, from which later arise daughter cells with two or four cilia; these cells reach the same size as the mother cell. Multiplication also takes place in a sexual way, the mother cells give rise to 8-32 small daughter cells, which are not capable of independent development, but which unite with similar cells from another individual and together form new organisms—zygotes developed from the union of two gametes.

The next steps in development go in three directions: (1) the cells, which are formed by sexual reproduction, do not separate but form a motile colony; (2) the daughter cells form a colony, which is stationary; (3) the *chlamydomonas* cell becomes immotile and grows out to form a many nucleated tube, which later by branching may assume most variable forms. In the higher forms the cell is divided by transverse membranes. These three groups are included under the name "Isokontae" and constitute a part of the green algae. The forms belonging to group 3 are called "Siphonales" by Lotsy. In these the sexual reproduction reaches its highest development as seen, for example, in *Vaucheria*. This form is made up of a long tubular structure and multiplies sexually; in the latter case there is formed ciliated swarming spores, which rapidly reach maturity. In sexual reproduction the same individual forms two branches, one the male organ (antheridium), the other the female (oogonium). From the antheridium arise spermatozoa, one of

which enters the oogonium and unites therein with the nucleus. The zygote thus formed later surrounds itself with a membrane. In addition to this reproduction through special organs *Vaucheria* may multiply also in another manner: A loosened fragment from any part of the thallus may grow into a new organism, indeed a protoplasmic mass cut off from the wall of the thread may do the same.

From Isokontae arise the higher plants.

Where the border between Isokontae and Protozoa runs, that is, where the animal kingdom begins, is a matter of difference of opinion. Lotsy places *Chlamydomonas* in Isokontae, while Döflein² places not only *Chlamydomonas* but also a number of higher Isokontae among the protozoa. This does not mean that Döflein regards them as animals; it simply indicates that zoologists in their efforts to trace the development of these organisms come down to the same group as the botanists.

The course from Isokontae to the higher plants does not interest us at present, and the next step will be to trace the lower fungi from the algae just mentioned.

Lotsy includes the lower sponges under Siphonomycetes and divides them into three groups, Monoblepharideae, Zygomycetes and Oomycetes.

From what forms of Siphonales Siphonomycetes are to be derived cannot be determined accurately. With respect to sexual reproduction, Monoblepharides stand closest to *Vaucheria*. These fungi are aqueous, and form antheridia with spermatozoa and oogonia with eggs. In both the other groups the sexual mode of reproduction has been changed so that the gametes do not escape and seek the oogonia but the gametangia copulate. This is dependent on the fact that the fungi have become land plants, hence the spermatazoa no longer have any medium in which to move, and this is true also of the zoosporangia and the swarming spores. Such zoosporangia and motile spores have been found in Monoblepharida, but in the others sporangia with immotile spores have developed. A further development of the sporangium is the conidium, which is formed as the sporangium produces only one spore at the same time as the wall and the membrane of the spore no longer are differentiated.

Siphonomycetes correspond fairly well to the old name Phycomycetes as they were called on account of their similarity to the algae.

As example of fungi belonging to this group may be mentioned Mucoraceae, which have a branching unicellular thallus, which forms

² Lehrbuch der Protozoenkunde, 1909.

partly many-spored sporangia, partly gametangia which copulate. Furthermore, Mucoraceae may reproduce themselves by the formation of oidia, gemmae and chlamydospores. The first arise by way of transverse partitions in the originally unicellular mycelium, which thus is divided into many cells. When the thread falls to pieces each cell may multiply by budding like yeast cells, and form mycelium. If the oidia differ from the rest of the mycelium in having either a thicker membrane or a darker color they are called gemmae. Chlamydospores arise in the protoplasm of the mycelium, which becomes clumped, and the clump surrounds itself with a solid membrane.

The older mycologists with Brefeld at the head derived the higher fungi from Phycomycetes.

The higher fungi, which in distinction to the lower are multicellular, are included usually under the name Eumycetes. The two most important groups are Ascomycetes, characterized by an ascus, the principal organ of reproduction consisting of a hypha changed to a sporangium-like structure containing a fixed number of spores, usually eight; and Basidiomycetes, in which the spores consist of conidia fastened to a special conidiophorous structure, the so-called basidium, by means of fine shafts (sterigma). According to Brefeld's system, the ascus is the homologue of the sporangium of Phycomycetes and the basidium with their conidiophores. The evolution is regarded as having come through the so-called Hemiasci and Hemibasidii. One can understand how Lindau could say that the fungi is that group of plants which in course of evolution gradually has lost sexual characteristics. Others are of a different opinion, e.g., Lotsy. They do not believe that the asci are developed from the sporangia. On the basis of cytologic observations they believe that the ascus is comparable with the sporangium in the bracken, which is something entirely different. Lotsy calls the structure diplosporangium. In order to understand the condition better, it may be said that in bracken the gametes are differentiated into eggs and spermatozoa. The bracken develops from the fertilized egg or zygote. Its cells contain $2x$ chromozomes if one assumes x chromozomes in one gamete. Lotsy consequently calls bracken the $2x$ generation. Sporangia now form that contain mother cells, which through reduction give rise to four spores, which subsequently develop into a prothallium, the x generation, which in turn gives rise to gametes. The mother cells of the spores are called "gonotokontes."

Several investigators have found similar conditions among Ascomycetes. Thus Harper found that in "Sphaerothea" the vegetative mycelial

threads by bulging give rise to oogonia and antheridia, both with one nucleus, the nuclei uniting to form a zygote which in turn gives rise to an ascus. The zygote constitutes $2x$ generation and the ascospores are "gonies," which form the x generation. The ascus is consequently not a phycomycete-sporangium, because this belongs to the x generation, nor is it a gameteangium, but it is what Lotsy calls a diplosporangium because it belongs to the $2x$ generation. In principle the conditions are similar in other Ascomycetes and Basidiomycetes except that in the majority the uniting nuclei are not separated into male and female, but are of the same kind (apogamy). These views, advocated even as early as by de Bary,³ do not correspond with Brefeld's system. A part of Ascomycetes are regarded as coming from Phycomycetes, among which are found some with alternation in generation similar to that just described, but the so-called hemiasci play no part herein. Hemiasci are, according to Lotsy, of the nature of a simple sporangium. Other Ascomycetes, Uredineae and Basidiomycetes, are regarded as arising from Floridinae or the red algae, but the course of this development is not of interest at this time.

There are two other groups, which it seems necessary to understand, namely, Ustilagineae and Saccharomycetes. The latter are regarded as closely related to Ascomycetes. Some form spores with, and some without, copulation. Lotsy has suggested that Saccharomycetes are reduced Ascomycetes; those which form spores without copulation would correspond to the x generation and the formation of spores would be assumed to take place parthenogenetically. By copulation there would form as in Ascomycetes a $2x$ generation, a diplosporangium. In the noncopulating it might be possible that a single spore might be formed of each yeast cell. In reality *Saccharomyces* without copulation forms four spores, *Schizosaccharomyces octosporus* and *Pombe* without copulation form, respectively, 8 and 4 spores. Anything definite in regard to the origin of Saccharomycetes is not known.

As example of Ustilago may be mentioned, *U. carbo* which is a parasite and causes smut on oats. This fungus lives in the ground as chlamydospores which form a promycelium with few cells out of which bud forth yeast-like conidia. Later these conidia may form a mycelium like the yeast, but they may also in case they enter an oat plant develop into a tubular branching mycelium growing in the fruit. Chlamydospores are formed in the mycelium by a change of the cell walls into mucus while the spore acquires a new membrane. In Brefeld's system

³ *Morphologie der Pilze*, 1884.

Ustilagineae and Hemibasidii occupy a place between Phycomycetes and Basidiomycetes. Since the newer investigations just mentioned have deprived them of this place at the same time as the nature of the basidium has been made clear, it has not been possible to classify them satisfactorily. Ustilagineae appear to have some interest in connection with the question under discussion and I shall return to them later. It remains to discuss briefly two other groups of fungi, namely, Fungi imperfecti and Myxomycetes.

The so-called Fungi imperfecti form a large group which could not be assigned any definite place, and consequently was included in an artificial group. The mycelium of these fungi may be both hyphal and budding. The same kind may appear in both these forms under different conditions. Fructification, both sporangial and sexual, is absent completely. Multiplication takes place only through spores, which in many kinds arise anywhere in the mycelium and are not gathered together in clearly differentiated conidiophores. Any difference between the spores and vegetative cells that have budded out from the mycelium often cannot be distinguished. A form of spore-formation takes place also as hyphae separated into oidia. The formation of resting cells with thick walls occurs also.

Since of old it has been known that many Fungi imperfecti are simply conidial forms of higher fungi (Basidiomycetes, Ascomycetes, Ustilagineae, and even Phycomycetes), it has been pointed out that *Ustilago* and *Mucor* during long periods appeared in the form of budding mycelium, and *Mucor* with hyphae that could form Chlamydospores or separate into oidia. The same is true in the case of many Ascomycetes and Basidiomycetes. Through exact investigations it has been found that many Fungi imperfecti may be made to form organs of fructification, particularly asci.

In other cases, in which such organs have not been found, this may depend on faulty observation, but it has also been thought that certain Fungi imperfecti do not possess such higher organs, which have been lost in the course of evolution. This conception that at least a part of Fungi imperfecti are reduced higher fungi is expressed by Zopf.

As to Myxomycetes, it may be pointed out that Lotsy classes them with animals rather than with plants. At a certain stage they consist of an ameba-like organism which creeps about by ameboid movement and takes up solid food. This ameba may be able to form spores covered with cellulose from which subsequently new amebas may develop by the

protoplasm creeping out through the membrane and forming a new individual.

A few words in regard to Cyanophyceae may be in order at this point. This is a group of algae which also has been looked on as related to the bacteria. Cyanophyceae, or the bluish-green algae, are called also Schizophyceae because they multiply by fission. They possess a bluish-green coloring matter, as indicated by the name, and nourish themselves by photosynthesis. The cell has no cilia; a nucleus has not been demonstrated definitely; in other respects, however, the cell is highly organized and contains a so-called central body, which is regarded by some as a nucleus, by others as a vacuole containing food in reserve.

VIEWS AS TO THE PLACE OF BACTERIA IN THE SYSTEM

First, it is necessary to understand clearly what is meant by bacteria. It may well happen that organisms, far removed from one another, are designated with this name, and that the bacterial world consequently may be of polyphylogenetic origin. As it would take too much space to enter into the details of this question at this time, I shall content myself by accepting the definition of Meyer,⁴ and regard as bacteria the organisms which he calls Eubacteria. Meyer includes here also the group that Lehmann and Neumann designate Actinomycetes.

That bacteria are plants and most closely related to Cyanophyceae was claimed as early as in 1853 by Cohn, who regarded them as the first and simplest division in the organic world and accepted Naegli's designation Schizomycetes, consolidating these with Schizophyceae without, however, regarding bacteria as real fungi. He divided the schizophytes without regard as to whether they contained any coloring matter or not, and in that way created a rather peculiar system. Cohn has had many followers. In opposition to Cohn, Meyer claims that there are many similarities, but many more differences between Cyanophyceae and bacteria, and emphasizes especially that the former develop chlamydospores and the latter endospores, the former lacking cilia. He also points out the absence of a central body. On account of these conditions Meyer does not believe that the bacteria are Cyanophyceae that have been reduced through saprophytism and parasitism. I have reached the same conclusion as Meyer but on other grounds. In regard to the spore question, I cannot assign it such great importance for reasons to which I shall return, and in regard to motility, Meyer himself has

⁴ *Die Zelle der Bakterien*, 1912.

acknowledged, in the discussion of his theory that bacteria belong to Ascomycetes, that cilia have little systematic significance. On the other hand, there is no multiplication by budding in Cyanophyceae nor formation of branching threads which can separate into oidia. This, however, is the case with bacteria and, as we shall see, in large degree. To discuss further the eventual relationship of Cyanophyceae to bacteria does not seem necessary because any such theory would appear false at the moment that it became clear that bacteria are more closely related to Fungi, as I shall show.

While Cohn placed the bacteria lowest in the vegetable kingdom, there are others who regard them as closely related to Flagellatae but lower than these, that is to say, they constitute the organisms that come nearest to the hypothetic primordial organisms. Thus Bütschi⁵ points out that the bacteria present great similarity to the lowest flagellates. He places special stress on the power of bacteria to move. This characteristic does not in the bacteria as in the algae concern reproductive cells, but the vegetative phase. As in the flagellates, the cells may divide themselves while in motion. He explains the simpler organization as a reduction on the basis of saprophytism. He regards the endospores of bacteria as the homologs of the "Dauercysten" of the flagellates. This opinion is shared in general by de Bary, and Fischer⁶ emphasizes that bacteria constitute the lowest group of protozoa, being the common source of Flagellatae and Cyanophyceae.

On the other hand, A. Meyer seems to be right in thinking that bacteria have little in common with flagellates. He repeats the definition that Klebs gave the flagellates, part of which may be emphasized especially, namely, that they are provided with a definitely differentiated anterior end and a number of pulsating vacuoles and at the same time they divide themselves longitudinally. Meyer mentions a flagellate (*Spumella vulgaris*) which he thinks most closely resembles bacteria and then shows that the similarity after all is quite minimal. It may be mentioned that this flagellate takes up solid food and possesses pulsating vacuoles.

There remains the question of the relation of bacteria to fungi. It may be pointed out at once that the bacteria naturally are fungi if one means simply thallophytes without chromatophores, but this does not tell us anything concerning their relation to the fungi in reality. Cohn observed a fact that suggested a relation between the bacteria and the

⁵ Weitere Ausführungen über den Bau der Cyanophyceen u. Bakterien, 1896.

⁶ Vorlesungen über Bakterien, 1897.

fungi, when he discovered that *Micrococcus* as it multiplies may form a rosary-like structure, which led him to doubt whether it in reality concerned a cellular division and not a kind of budding as seen in *Saccharomycetes*. In the meantime, he did not consider the matter further but regarded the similarity as external only. Brefeld, on the other hand, believes that the division, which the larger forms of bacteria undergo, is much like the formation of oidia and he regards spore-formation by bacteria and the formation of chlamydo-spores by *Basidiomycetes* and *Ascomycetes* as homologous processes, reaching the conclusion that in the future bacteria may be found to be developmental forms of higher fungi. He points out that there is lacking branching threads, which grow at the points. Migula finds an analogy between the spore formation of bacteria and *Saccharomyces*. Others are of similar opinion. Meyer himself believes that the bacteria stand close to *Ascomycetes* and *Hemiascomycetes*, by the side of which he places the bacteria in his system. He points out that the vegetative body in *Ascomycetes* and bacteria is a thread, which can divide itself irregularly and show branching with growth at the point. The cell membrane and protoplasm are similar, and the vacuoles are also similar and occupy the same place in the cell which in both cases may contain glycogen, fat, and 'volutin.' In both there may be formation of oidia and a relatively highly developed sporangium. It appears that Meyer regards bacterial spore-formation and the formation of asci and hemiasci as homologous, the asci being of the nature of sporangia.

As early as 1893 Johan-Olsen⁷ observed that streptococci and sarcina divided themselves in a manner that could not be regarded as different from the budding of yeasts, and he holds that Almquist, Gasparini, Metschnikoff and Nocard demonstrated that mycelial fungi may be smaller than small bacteria and in certain stages appear as bacteria. He claimed to have seen motile bacteria with endogenous spore-formation give rise to a branching mycelium and he concludes that morphologically bacteria cannot be separated from the fungi.

Almquist⁸ made important investigations with respect to the questions now discussed of the organisms of cholera, typhoid fever, and diphtheria, and he found that under certain conditions they would form round bodies by way of budding, bodies which later by continued budding would give rise to similar forms or grow out into rods and threads. He found further that these organisms might assume the form of plas-

⁷ Om Sop paa levende Jordbund, 1893.

⁸ Zeitschr. f. Hyg. u. Infektionskr., 1917, 83, p. 1.

modia such as had been described earlier by de Bary, Hueppe and others. Almquist regards this as indicating that there are points of connection on the part of these organisms with *Saccharomycetes*, *Myxomycetes* and thread fungi. More recently Almquist and Koraen report that they have observed budding in micrococci, thus confirming Cohn and Johan-Olsen.

Gamaleia, in 1900, expressed the same views as Almquist and emphasized especially that the higher fungi under certain conditions may form oidia that multiply by division, and he regards it as likely that the bacteria are simply oidial forms of fungi belonging to the family *Streptothricheae*. He has observed also bacterial plasmodia and he regards the mucoid layer, which is found more or less well marked around all bacteria, as the protoplasm, the bacteria themselves being the nuclei. The plasmodium arises from the coalescence of the protoplasm of several bacteria. The formation may be called also zooglea, and in certain cases it is capable of independent motion.

The plasmodium of Gamaleia and Almquist is placed in the foreground by Löhnis and Smith,⁹ according to whom each bacterium passes through a developmental cycle which may be divided into two alternating phases. In one phase the bacterium appears as an organized, in the other as an amorphous, structure. They state that "the amorphous stage has been called the 'symplastic' stage because at this time the living matter previously inclosed in the separate cells undergoes a thorough mixing either by a 'melting together' of the content of many cells which leave the empty cell walls behind them. In the first case a readily stainable, in the latter case an unstainable 'sympiasm' is produced." Here it may be pointed out that Hueppe regarded zooglea as a resting stage. Löhnis and Smith describe a number of different types that bacteria may assume when they have organized form, among others a coalescence of two individuals, "conjunction," and gonidia-formation within the cells. Their scheme is very complicated as shown by fig. 1. This scheme was developed on the basis of studies of *B. azotobacter*. It was found that forty different kinds of bacteria developed in the same way, generally speaking.

Independently,¹⁰ I have found in diphtheria bacilli and diphtheroids the same structures as described by Löhnis and Smith, but I give them what I think is a simpler explanation in that I tried to explain all forms on the basis that the bacteria in their nature are *Fungi imperfecti*. This

⁹ Jour. Agric. Research, 1916, 6, p. 675.

¹⁰ Acta Oto-Laryngologica, 1918, 1, p. 131; Acta Medica Scandinavica, 1920, 53, p. 1.

explanation does not appeal to Löhnis and Smith; they state that de Negri¹¹ who studied a corynebacteria isolated from cases of malignant granuloma, concludes that it concerns blastomycetes, and then they go on to say: "Therefore he was carried away to the entirely incorrect conclusion that those large budding forms were some kind of 'blastomycetes' and the organism studied by him should be separated from the bacteria and placed among Fungi imperfecti. A comparative study of any of the common bacteria—for example *B. subtilis*—would easily have prevented this serious error." Both Almquist, as well as Löhnis and Smith, thus appear to be unwilling to draw any botanical consequences of their discoveries.

Now is the time to present the reasons in favor of the view that the bacteria really are Fungi imperfecti. In the first place, many bacteria in structure and form correspond fully with certain Fungi imperfecti. Take for an example of a hyphomycete a monilia; this may grow partly with hyphae, which form conidia by budding or separate into oidia, partly as a budding mycelium composed of long or short buds, a number of factors largely unknown being responsible for the particular forms that may predominate in a culture. Evidence that many bacteria grow in a similar manner can be obtained from many investigators. Personally I have studied, as stated, the diphtheria bacillus and found that it may appear in all the forms of the monilia, that it multiplies by budding, that it may give rise to long or short budding mycelium, that it grows in branching hyphae, which secondarily fall apart into oida, and that it may produce conidia. These studies were made on cultures of a single cell and the budding was observed in hanging preparations under the microscope. These cells in microscopic structure show a minute similarity, as Meyer particularly has demonstrated. Equally convincing appearances have been found in the case of other bacteria, for example, fig. 3 from Johan-Olsen illustrating *B. mucoides* and *B. erythrosporus*; fig. 4, from Bouel, DuJardin-Beaumetz, Jasnnet and Jouan demonstrating the microbe of peripneumonia, and finally figs. 2, 9, and 10 from Meirowsky¹² representing, respectively, the tubercle bacillus, *Sp. pallida* and *B. paratyphosus* *B.* In regard to *Sp. pallida*, Meirowsky states that the spirochetes, like tubercle and lepra bacilli, presumably are fragments of higher plants belonging possibly to the thread fungi. In a study of the corynebacteria, without being familiar with Meirowsky's investigations, I took the opposite view in that I tried to show that these bacteria could appear also in vibrio and spirochete form and concluded that the

¹¹ Untersuchungen zur Kenntniss der Corynebacterien etc.; Folia Micro-biol., 1916, 4, p. 119. Quoted by Löhnis and Smith.⁹

¹² Studien über die Fortpflanzung von Bakterien, Spirillen u. Spirochäten.

spirochete or spirilla and the fusiform bacilli in the so-called fusospirillary infections are simply developmental forms of the same organism. In this article I have brought together the views of recent investigators in regard to bacteria of different kinds in order to show that what is true in regard to the kinds just mentioned is generally true also.

In view of what has been said it would seem to be unnecessary to discuss the question of the relationship of bacteria with Flagellatae and Cyanophyceae. But the question of nuclei and spores, as well as motility of bacteria, deserves some consideration.

If the bacteria are *Fungi imperfecti* they should like these have a differentiated nucleus, and such it may be said has not yet been demonstrated. This is true, but as Lotsy states, it may not mean so much. Thus to demonstrate nuclei in objects as large as the yeast fungi has been associated with great technical difficulties and it may therefore be that the nucleus of the bacteria so far has escaped us. Besides, there are investigators who believe that they have demonstrated nuclei in bacteria, for example Nakanishi, A. Meyer and others. Of course if one regards bacteria as *Fungi imperfecti* one cannot accept the theory that the chromatin is spread diffusely in the cell body, because this assumes it would seem a much lower developmental stage.

As to the spore question, the endospores of the bacteria are lasting cells. Such are very frequent in the lower plants and animals, but according to many observers the spore-formation by bacteria is peculiar in that the protoplasm concentrates itself in one part of the cell and there surrounds itself with a membrane. According to Bütschli anything like this occurs only in a species of Flagellatae, a fact he cites in favor of his view that there is a close relation between the flagellates and the bacteria. The opposite of the formation of such endospores would be a cyst formation from swelling of the cell membrane and thickening. Van Tighen divides Schizophytes in those with cysts and those with endospores. Others compare the endospores with the chlamydo-spores of fungi, notably Brefeld, and so far as I can see this is warranted. Thus Lotsy describes the formation of chlamydo-spores in *Mucor* as follows: Here and there in the mycelium the protoplasm clumps itself and becomes surrounded with a membrane. The same thing occurs in *Ustilago*. As mentioned, Meyer does not approve of this view and regards the endospores as the homologue of asci of hemiasci. Meyer's theory will probably not be accepted by many. If the ascus is regarded, as it is by Lotsy, as a diplosporangium that arises through copulation, then this theory seems still more unwarranted. However,

PLATE I

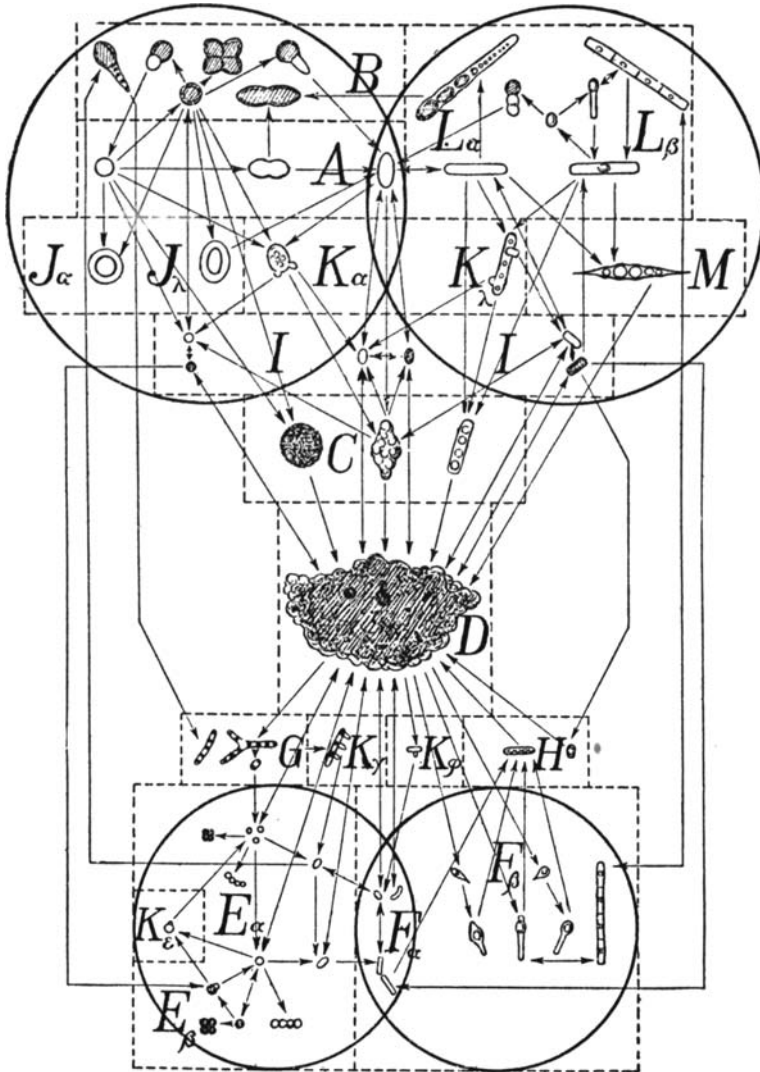
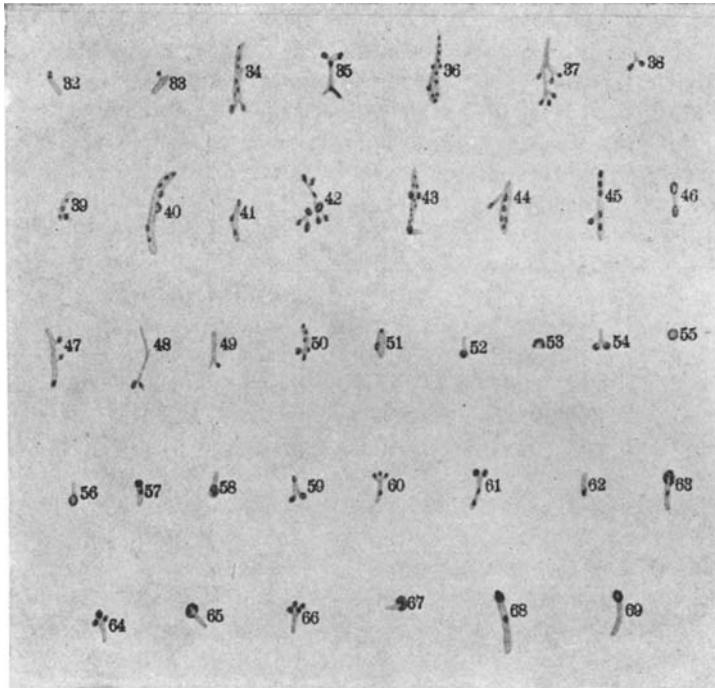


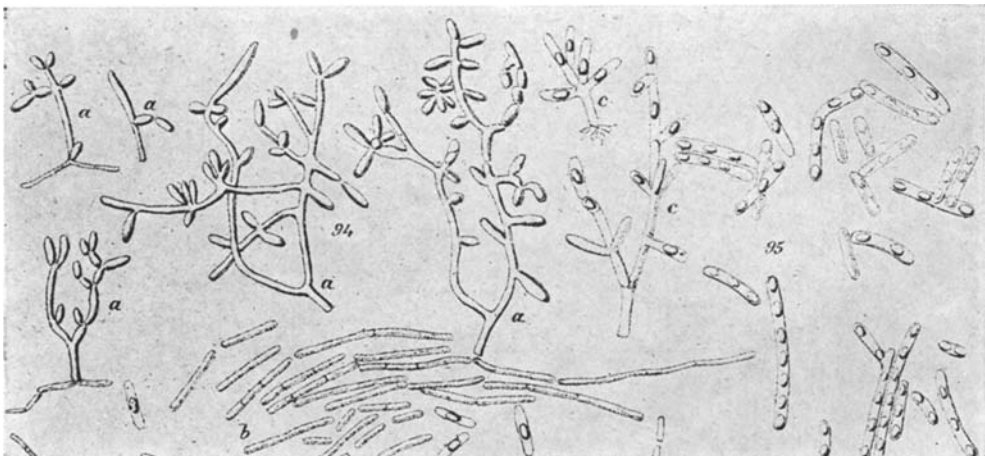
Fig. 1.—Life cycles of *B. azotobacter* after Löhnis and Smith. According to these authors, other bacteria, generally speaking, pass through similar cycles. It is of special interest to note the great similarity between the forms in the upper left circle and the diphtheria bacilli in plate 4, figure 6:28-36; figure 6:14 and plate 5, figure 8:7.

PLATE II



2

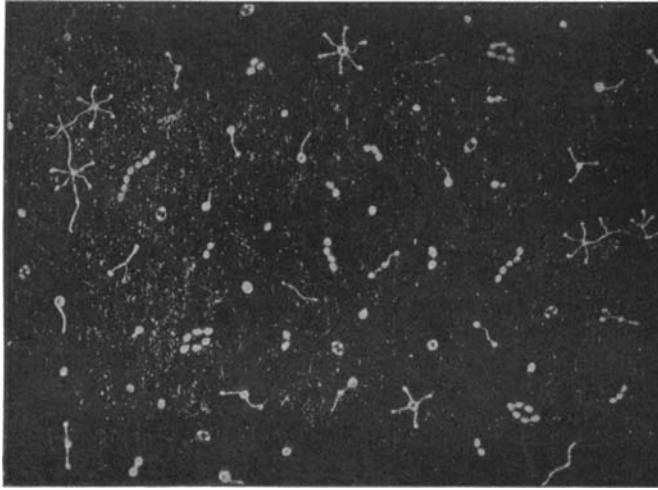
Fig. 2.—*B. tuberculosis*, bovine type, according to Meirowsky.



3

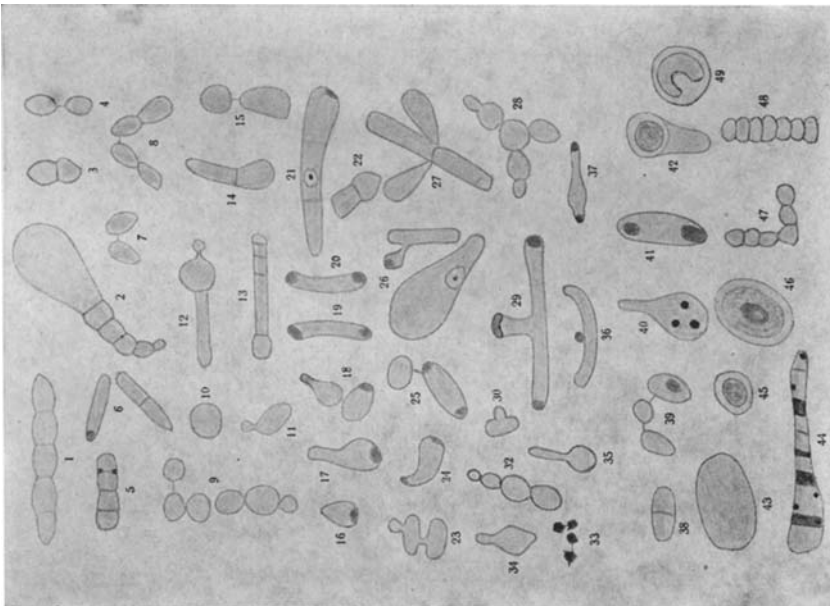
Fig. 3.—*B. mucoides* (94) and *B. erythrosporus* (95) according to —Johan-Olsen.

PLATE III



4

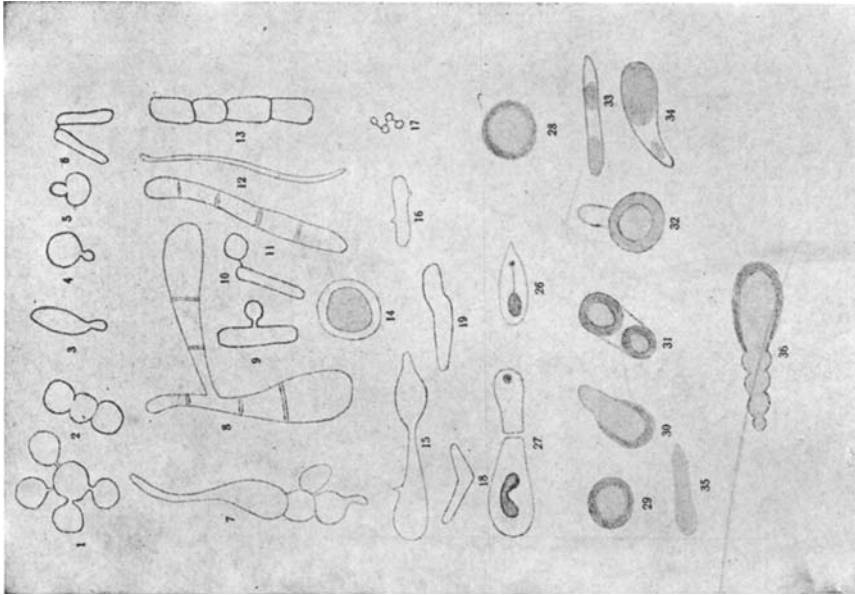
Fig. 4.—The microbe of peripneumonia according to Bouel, Dujardin-Beaumetz, Jaennet and Jouan.



5

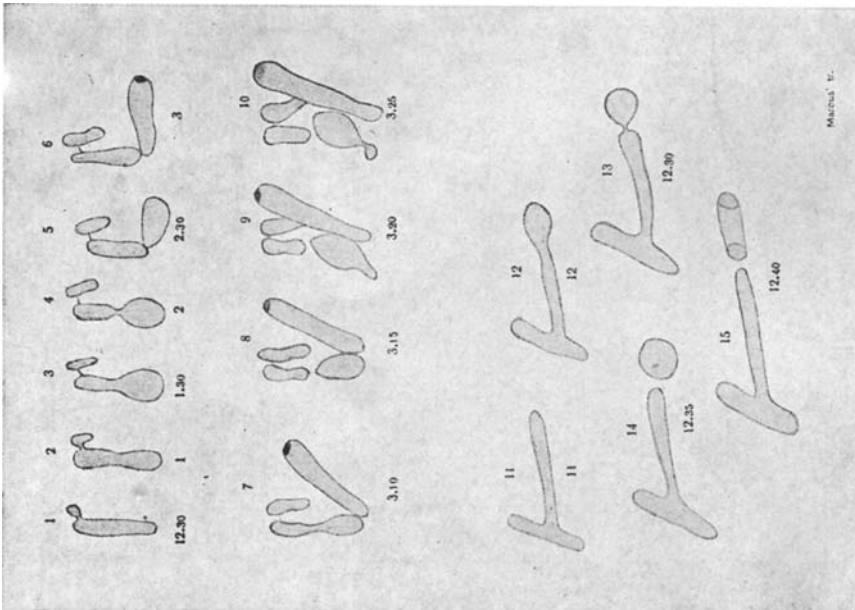
Fig. 5.—*B. diphtheriae* according to Bergstrand.

PLATE IV



6

Fig. 6.—*B. diphtheriae* according to Bergstrand.



7

Fig. 7.—*B. diphtheriae* according to Bergstrand. This illustration shows the development of this bacillus as followed under the microscope in hanging blocks.

PLATE V

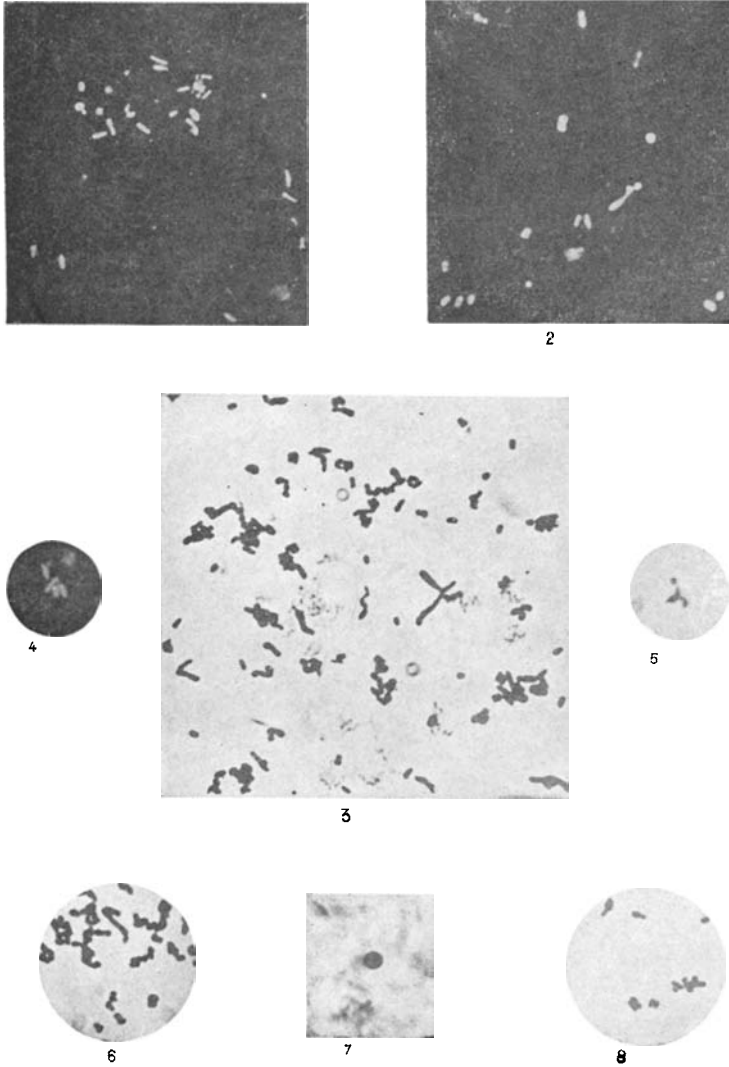
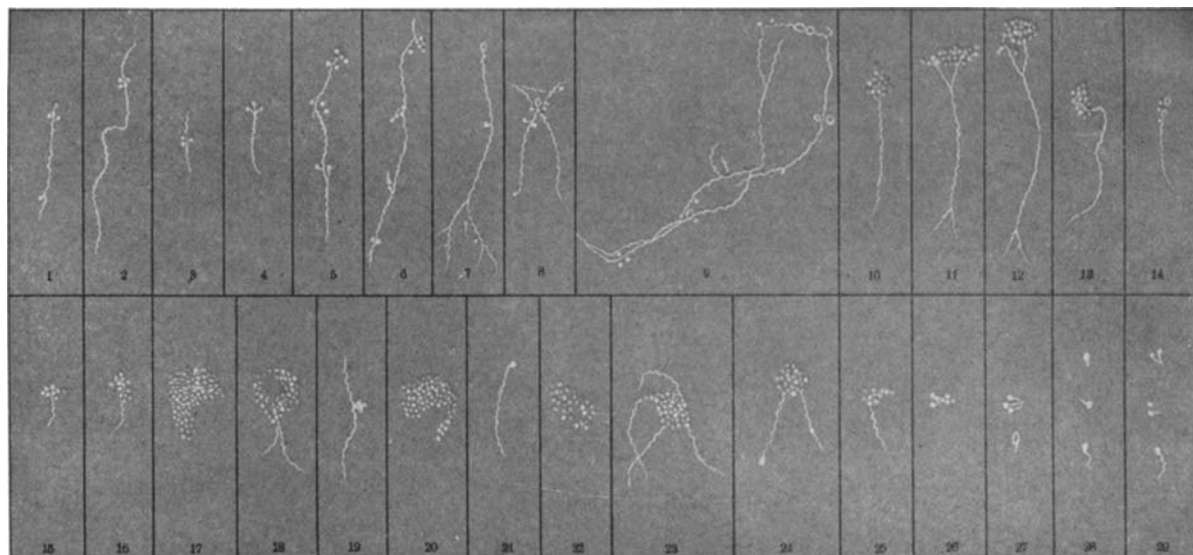
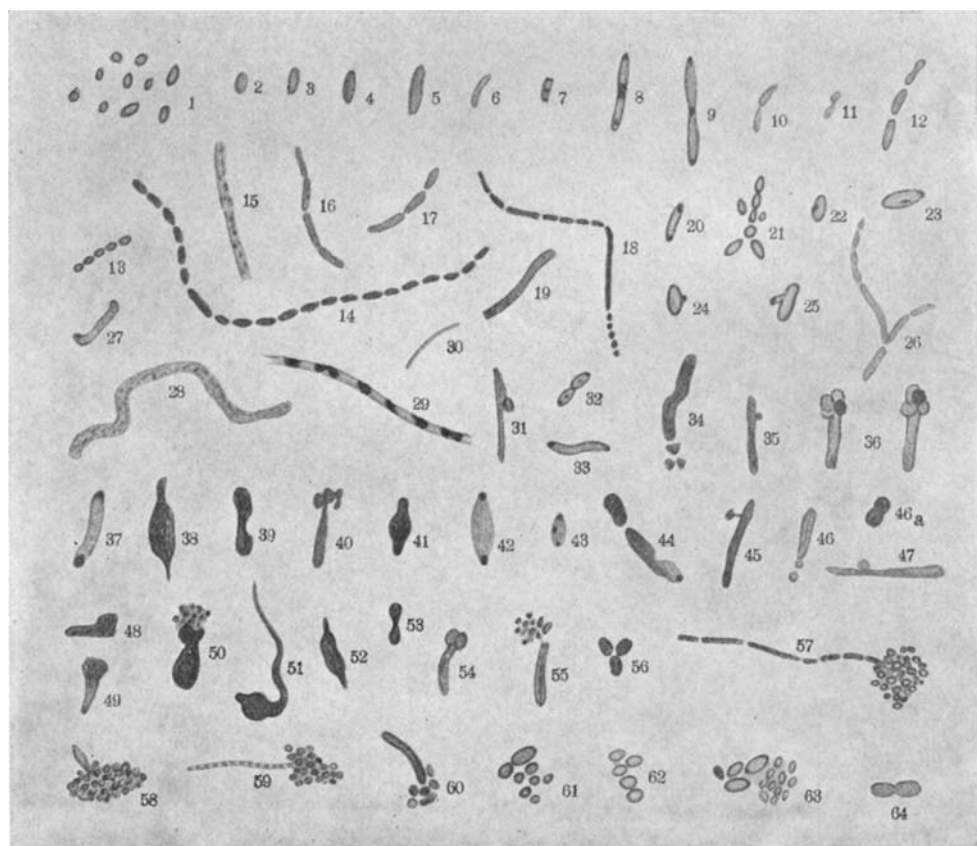


Fig. 8.—*B. diptheriae* according to Bergstrand. Good budding forms are seen especially in 1 and 8; 3 shows a branching bacillus in different stages of separation into oidia; 7 illustrates a double contoured cyst-like lasting form.



9

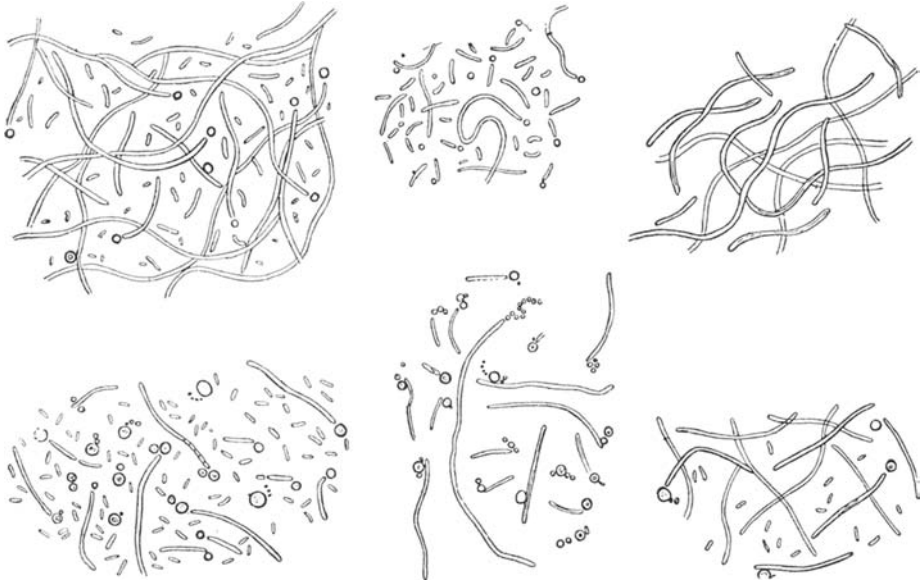
Fig. 9.—*Spirochaeta pallida* according to Meirowsky. Some forms show a definite budding, and round coccuslike forms are also seen.



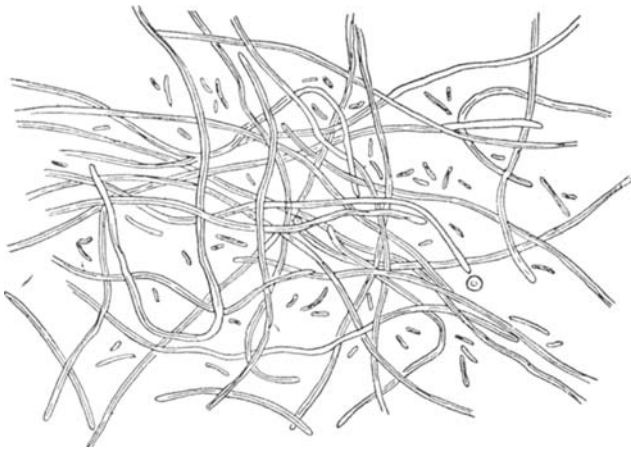
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Fig. 10.—*B. paratyphosus B* according to Meirowsky. Note especially 29, which shows a long thread in which the protoplasm has formed clumps, which are more deeply stained, but the spaces between the clumps do not seem to have been empty. The significance of these forms, which are found in a variety of bacteria, has been discussed by Bergstrand in an article on *Corynebacteria* (Nord. med. Archiv, Acta Med., 1919). Probably these clumps are homologous with the fragmentation spores described by Boström in *Actinomyces* and reproduced their kind after the disintegration of the hypha.

PLATE VII

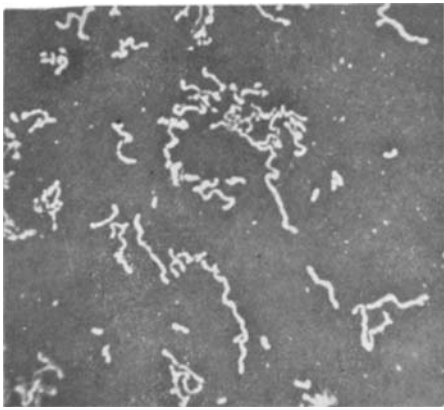


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12

Figs. 11 and 12.—*B. typhosus* according to Almquist. Note the round forms, some of which are reproduced with thicker walls. Possibly it may concern structures similar to the double contoured bodies described by Löhnis and Smith and by Bergstrand. Note also the threadlike forms of the typhoid bacillus in figure 12, 9 (myceloid, Almquist).



1



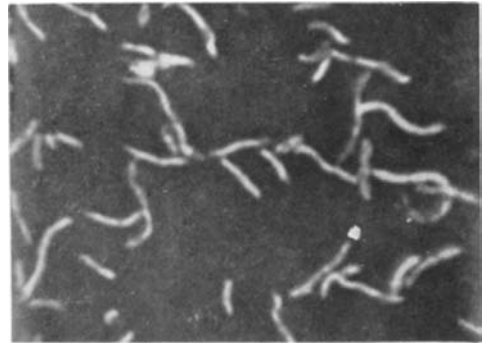
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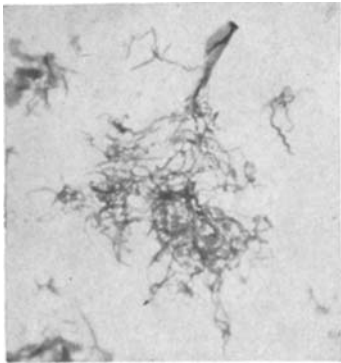
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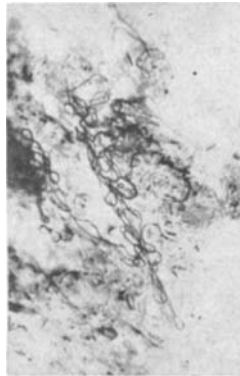
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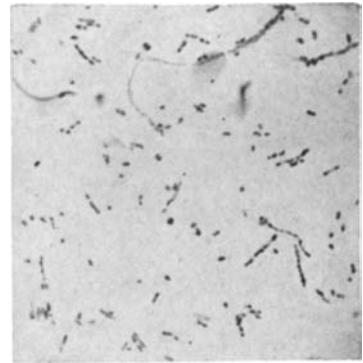
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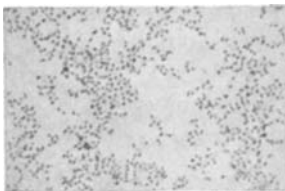
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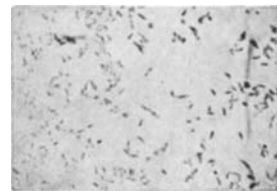
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Fig. 13.—*Corynebacteria* according to Bergstrand. Variable magnification. Note the marked polymorphism; even spirochete forms were seen, which are not reproduced here. A comparison between these forms and Meirrowsky's illustrations of *B. paratyphosus* shows striking similarities. Figure 13, 2, shows in the end of a hypha a structure that clearly is homologous with Löhnis and Smith "symplastic stage." Figure 13, 3, shows beautiful "en navette" forms and budding.

this may be only apparent, and Lotsy regards it as possible that Saccharomycetes are reduced Ascomycetes that in part form diplosporangia by copulation but also haplosporangia parthogenetically. This opens the road for the bacteria. It seems to me that for the present it would be better to regard bacterial spores as vegetative; further reasons for this view will be given.

According to de Bary and Hueppe, bacteria have also another kind of spore, namely, arthrospores. These are rounded or oval structures that originate by constriction of the protoplasm, the cell dividing itself, the daughter cells surrounding themselves with a thick membrane. These are, therefore, more like cysts. According to Hueppe, but scant attention has been given to arthrospores. In diphtheria bacilli I have found two peculiar lasting forms, consisting of large acid-fast cells with thick double contoured walls, formed in the original cells, frequently one in each end of a rod. They do not deviate in any way from the chlamydospores of Mucoraceae. Frequently one finds only a small remnant of the original bacillus hanging to the spores. If this disappears we have a body, which greatly resembles cysts of Saccharomycetes. Figs. 6, 28 to 32 show all these forms, which clearly resemble the arthrospores of de Bary and Hueppe more than the endospores of the bacteria. Subsequently, I have observed similar bodies in many other bacteria and also the outgrowth of a rod-shaped structure through the thick membrane. Similar bodies are also found in Almquist's illustration (figs. 11 and 12), although he does not mention them. He mentions only rounded bodies that may grow out into rods, and that he calls bacterial conidia. Hueppe also discusses conidia, but neither explains what is meant by this expression. I think all these observations may be summarized as follows: Bacteria may grow as long and short buds; one form may develop from the other; from a coccus may grow a rod and vice versa; in addition there occur lasting forms with thick walls which likewise may develop from a coccus—or a rod-form. This does not occur by budding, but in the same way as endospores grow. Endospores and the structures described are related and probably homologous with the chlamydospores of fungi.

Finally, bacteria may develop in still another way: In the threads of actinomycetes arise as we know rounded or oval clumps of condensed protoplasm, which become more and more prominent at the same time as the thread otherwise becomes empty. The thread may burst and the clumps may be set free. Boström called these clumps spores and believed that they gave rise to new individuals. These structures are

found in most bacteria, if they are cultivated in the proper way. The indications are that they may reproduce their kind, as Boström believed, and this is not remarkable when we consider what has been said about certain algae in which a drop of protoplasm pushed out through a hole in the cell may give rise to a new individual.

It remains to consider the motility of bacteria, about which there is not much to say. This property is of great importance and the theories of Bütschli in regard to the relationship of the bacteria to Flagellatae may not be dismissed off-hand. However, if it is found that the immotile bacteria are fungi, it would seem that the motile also are fungi because it is hardly likely that motile and immotile bacteria have different phylogenesis. Mobility may be regarded as a property that bacteria regained when they as reduced higher fungi returned to living in water. The higher fungi are land inhabitants developed from aqueous plants a certain stage of which was a motile stage.

In his well-known work Lotsy quotes from Zopf at the end of his chapter on the bacteria to this effect:

According to the theory of Cohn of the constancy of fission fungi it may be assumed that the forms discussed possess complete morphologic independence, that is to say, that under different nutritive conditions they reproduce always their own, consequently do not assume mutual genetic relations. For example, according to Cohn, a micrococcus form can produce only micrococci, not rods or spirals, and similarly spirals can give rise to spirals only and not to rods and cocci, etc.

This theory now has only historical value. It has been replaced by the theory of Billroth and Nägeli, in regard to the genetic connection of fungi. As strengthened by the author (Zopf) this theory holds that the fission fungi, probably with some exceptions, are able to pass through different developmental stages corresponding to the vegetative forms already described. After the studies of Cienkowski on certain fission fungi and the investigation of Neelsen of the fungus of blue milk had shown the genetic connection of coccal, rod, and leptothrix forms, definite evidence was brought forward by Zopf that the highest developed fission fungi (*Cladothrix*, *Begiatoa*) form not only these developmental forms but also curved forms of all kinds (spirilla, spirochetes, vibrios, ophidomonades).

Lotsy comments as follows: We now know on the contrary that Cohn's theory has been completely verified and that Zopf's views have been found to be erroneous.

But as shown in my presentation, the conception swings back into harmony with Zopf's view in that the bacteria may be regarded as Fungi imperfecti developed through reduction of higher forms and not as lowly primordial organism to be placed at the very beginning of the organic world.