Elements of Comparitive Morphology of Bacteria

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Preface

Günther Enderlein (1872–1968) was born into a family of teachers in Leipzig. After earning his high school diploma, he studied in the natural sciences at the university, specializing in zoology. He was graduated summa cum laude.

He became curator of the Berlin Zoological Museum. He wrote over 500 scientific papers as a zoologist.

Enderlein founded his own microbiological institute in Berlin, where he developed new types of preparations from molds. He later became production manager at the Sanum firm (Berlin/Hamburg). After the facilities were moved to Aumühle in the vicinity of Hamburg, he devoted himself totally to setting up his own enterprise, "Ibica".

Enderlein died in 1968, and the firm was able to continue on only a few years under the leadership of his widow, Sigrid Enderlein. When the production facilities were taken over by Sanum-Kehlbeck in Hoya, the preparations program was expanded, based on the latest scientific findings.

The most important areas of activity at the Ibica Institute had to do with Pleomorphism and symbiosis, building on the research of Antoine Bechamp. The fate of this researcher closely resembles that of Enderlein: he too had to struggle against prejudice and error.

In his best-known work, on the "microzymes", Bechamp declared that all animal and plant cells contained minuscule granules (Granulations moléculaires) that did not die when the organism died, but rather lived on. He said they were the source of fermentation, and that microorganisms could arise from them as well (cited from Dunbar).

This brief statement formed the basis for Pleomorphism the direction in which future research should have moved. However, Pasteur's influence was able to establish the view that microbes could be classified into fixed and unchangeable species and genera. Each species was said to cause a specific disease.

The following article is excerpted from Prof. Dr. Enderlein's "Bacteria Cyclogeny".

Elements of Comparative Morphology of Bacteria

Natura non facit saltus.
Linné, philosophia botanica.

It is impossible to obtain a clear understanding of the nature of organisms without determining clear and definitely defined morphological units and without precise Morphological nomenclature.

Also, for a bacteriologic research on a comparative Morphological basis, the first requirement is for a strict Morphological nomenclature. When that is entirely

missing, the development of a comparative bacterial morphology beyond the most primitive beginnings will be blocked.

We have seen the reason for the endless controversy that developed between pleomorphists and monomorphists on the basis of the correct Morphological and systematic ideas of Cohn, even though they were yet far removed from a cyclogenetic comprehension. That reason was the total lack of a comparative Morphological schooling of the contenders. But with few exceptions, the classifying genus name of Cohn *(Micrococcus, Bacterium, Bacillus, Vibrio)* were used as Morphological names. This usage which, unfortunately, has become common to this day, has caused immense confusion within the whole of the morphology and systemization of bacteria. Surely, these names were adopted for Morphological purposes just because there were no Morphological names to be found within bacteriology.

Oddly enough, this need for Morphological names that became evident soon after Cohn's perspective —particularly because the purely conceptual forms of Lankester and Buchner could not be applied in comparative morphology —has not been recognized by anyone in half a century after Cohn. While systemization has in recent times undergone essential developments through the influence of outstanding botanists —Fischer, Migula, Meyer, to name a few —morphology remained nearly entirely static on the level of Cohn. The main reason lies in that the excellent later developments, which were chiefly in the area of biological morphology and were connected with significant Morphological researchers — such as Zopf, Metschnikoff, Wasserzug among the monomorphists whose contingency is chiefly on the side of practitioners and physiologists —has been crushed. Even to this day, it is entirely suppressed. Monomorphism rules to this day in bacteriology to the extreme of assigning everything pertaining to Morphological varieties as a degeneration, withering, or Teratology *(involution, crippling)* and mutation.

Therefore, it is not surprising that even later, outstanding individual results—I remind you of the diphtheria results by Hewlett and Knight, etc. —remained without any consideration just because they contradicted the phantom of "Monomorphism."

A. The Morphological Unit (Mychit)

The Mychit is the Morphological unit and the building stone of which all bacteria are composed, with the exception of the Monomychota, which present but one single Mych.

1. The Mychit

Fig. 1. *Micrococcus aureus (Rosenb. 1884). Two Mychit, a Pliotrophit on the left, an Atrophit on the right, on which the marginal Mych is visible. Enl. 10,000:1.*

A cell with a single Mych is the Mychit *(comp. Fig. 1)*. As has been explained at another point, the Mychit is the primal cell. The form of the Mychit is usually that of a ball with a marginal, or nearly marginal, Mych *(comp. Fig. 1)*).

Examples of Mychit are all individuals of the Monomychota, excepting their splitting conditions, such as *Micrococcus.* Additionally, the Basit and the Gonidie of Dimychota belong here.

The Mych can be entirely without trophoconic covering *(in Atrophosis)*, or it has a weak trophoconic covering in Miotrophosis, then having a Trophosomelle; or a Trophosom in case of a thicker trophoconic covering; or the entire Mychit is filled with Tropoconies in Pliotrophosis *(Fig. 1)*.

The Atrophit can be stained very weakly and with gram-staining it is usually gram-negative. The Pliotrophit is gram-positive and usually strongly stainable. Thus, the same species can have gram-positive and gram-negative Mychit. All so-called gram-positive micrococci have in cultures always more or fewer Atrophit beside the Pliotrophit. The Atrophit are then gram-negative. The number of Atrophit increases especially in older cultures *(for instance, Micrococcus aureus)*.

The Mych of the Monomychota (such as Micrococcus) is very small, usually ca. 0.1 μ in diameter, that of the Mychit of higher forms *(Dimychota)* is usually much larger, ca. 0.2-0.25 μ. In this way, the assumption seems justified that the presence of a larger amount of nucleic substance *(Mychin)* in a Mych enables the organism to attain a higher phylogenetic development.

Because the largest number of Mychit in microscopic preparations naturally do not allow the Mych to be seen as marginal, the proof of the Mych in the Mychit actually always being marginally located, can be established only through long, comparative observation. The Mych of an Atrophit usually appears optically in all possible locations relative to the margin, which is the basis for the transparency and the ball-shape of the Mychit. This can be easily confirmed by scattering some glass balls, with each having a black spot painted on it. In the revision at hand, nearly always the Mych has been drawn in on the edge to keep the marginal location of it clearly in mind, even though the microscopic pictures frequently show other views.

2. The Mychomitosis and the Diplomychit

The splitting process of a Mychit is initiated by the splitting process of the Mych itself, called Mychomitosis or Mychokinesis. Due to the exclusively certain opportunity for observing the Mych in stained condition within Mychit without trophoconic accumulation, assurance about the Mychomitosis can also be gained only from such individuals that permit a penetrating view due to Atrophosis.

For proving Mychomitosis, it would be helpful to have a form that naturally tends to a strong Miotrophosis. Such is offered in the form of, e.g., *Diplococcus intracellularis (Weichselb. 1887)*. Due to its extraordinarily small capacity for

depositing reserve substances of Tropoconies, it shows a special sensitivity for less favorable conditions, thus dying easily, because it is a distinct parasite.

One can find the growth form of the Mychit more frequently in cultures of about two days. The last remnants of Tropoconies can be dissolved by heating the covering glass smear and using a 5% soda solution, or by treatment with alcohol and ether.

The splitting of the Mych now proceeds in the following way, as is first to be shown with the *Diplococcus intracellularis (Weichs. 1887)*, the pathogen of cerebrospinal meningitis.

Fig. 12-19. *Diplococcus intracellularis (Weichselb. 1887). Enl. 10,000:1.*

Fig. 12. *Mychit with single Mych.* — ***Fig. 13****. Mychit with broadened Mych.* — ***Fig. 14.*** *Mychit with a Mychozyg, consisting of two daughter Mych and a connective Mychomit.* — ***Fig. 15.*** *The two daughter Mych become separated by the reduction of the Mychomit.* — ***Fig.16.*** *The two daughter Mych distance themselves.* — ***Fig. 17.*** *The two daughter Mych distance themselves further.* — ***Fig. 18.*** *The two daughter Mych approach the poles under simultaneous stretching of the cell,* — ***Fig. 19.*** *After reaching the poles, cell division commences. The two daughter Mychit are still flattened toward each other (Diplomychit).*

Fig. 12 represents a normal Mychit. Fig. 13 shows an ellipsoid broadening of the Mych. Fig. 14 shows a further stage: two button-shaped swellings, the daughter Mych, have developed at the ends of the rod-like, somewhat bent cell wall. The rod connecting the daughter Mych is the Mychomit. The Mychomit, inclusive of the button-shaped daughter Mych, is called Mychozyg *(= primal nucleic bow)*. Fig. 15 shows how the Mychomit becomes reduced at a rather close distance in this species.

With this illustration, we must meet a Mychit containing not just one Mych, but two of them, which are identically large, as always happens in splitting. Seeing this strictly morphologically, a single cell has, herewith, become a double formation, the Dimychit, a progressive development. There will be greater elucidation of the Dimychit as an additional unit later on. At the present, the Dimychit represents but a transitory stage, not needing closer attention.

In the further course of events, the distance between the two daughter Mych broadens progressively, the Mychostasis. This can be seen from Fig. 16 and 17. Here, frequent diviations from the ball-shape occur, which may happen in very different ways in diverse species. Often, they manifest a broadened cross diameter *(vertical to the Mychostasis)*. Only then a stretching of the cell develops along the axis with a simultaneous narrowing during the progressive lengthening of the Mychostasis *(Fig. 18)*. The beginning of the tightening and cutting off of the two cells from one another can take place before, during, and after the moving of the daughter Mych into the cellular poles. In the case at hand, it occurs only after this

process. The consequence is that, with this species and also many others, clear Dimychit —even with short Mychostasis *(stenostatic)* —can be found in numbers.

These newly developed daughter Mychit become a Diplomychit *(Fig. 19)* as long as they are still flattened toward each other. The *Diplococcus gonorrhoeae (Flügg)* is an example of a Diplomychit.

This condition can either become ball shaped through the further development of both, or it can persist as it is. Both may be the case in the species at hand.

Such a development in the Mychit can be proven for all bacteria through all the stages of forms. They are found in the *Micrococcus* and also in the *Bacillus, Corynobacterium, Microspira,* etc. For example, the cholera pathogen makes for very beautiful pictures, and also the typhus pathogen, *Syncrotis buccalis (Rob.)* and many bacterial species. In some varieties one needs to scan larger amounts of material to find suitable Atrophit of the Mychit, or one has to undertake a dissolution of the disruptive Tropoconies through 5%-soda and alcohol and ether.

Interesting pictures can be found with such individuals or species that show little trophoconial accumulations, without completed atrophy, especially when a stronger lengthening of the Mychostasis *(eurystat)* occurs.

Fig.20-26. *Microspira comma Schröt. 1886. Mychomitosis of Gonidie. Enlargement 10,000:1.*

Fig. 20. *Mychit with simple Mych.* — ***Fig. 21.*** *Pseudozyg (two daughter Mych) with trophoconic covering and one Trophode which connects them.* — ***Fig. 22.*** *Likewise, the daughter Mych, further removed.* — ***Fig. 23.*** *Likewise, daughter Mych reaching the pole.* — ***Fig. 24.*** *Likewise, the Trophode paling in the center.* — ***Fig. 25.*** *Likewise, the Trophode disappearing at the center.* — ***Fig. 26.*** *Dimychit without Trophode.*

Such a case is pictured in Fig. 20-26 involving the cholera pathogen. These pictures, which can easily be found, e.g. in the germination of Gonidien among Miotrophit and Pliotrophit, show essential deviations from the processes just discussed. Fig. 20 shows the Mychit with typical Mych.

Here, we find a subtle trophoconic covering around the Mych. In Fig. 21, the daughter Mych has already moved far apart, although there is still a connective thread. According to coloring and structure, however, this thread is no Mychomit but a subtle trace of trophoconic accumulations, the Trophode. The development of the Trophode is to be understood this way:

When the Mychomit has a trophoconic covering, the latter remains for a time after the reduction of the Mychomit. The Trophode, likewise, is always positioned on the wall, although optically it often appears in other locations, as some of the

above illustrations show. The dumbbell shaped bow of two daughter Mych and their connecting Trophode resulting, is accordingly no Mychozyg but is to be called a Pseudozyg. The Mych distancing itself from the original Mych appears in the illustration to be smaller than the first. This phenomenon is caused by the different strengths of their trophoconic coverings. In reality, both daughter Mych are entirely identical after a Mychomitosis. Possibly, the difference in the coverings is also connected with the larger absorption of nutrients by the Mych moving away.

In the splitting process of the Mych, the Tropoconies may be evenly or unevenly distributed so that one side of the Dimychit may have Trophosom provided, while the other side is atrophic.

By the way, the Pseudozyg gets more attention in newer literature, and it is usually described as a dumbbell or as a dumbbell shaped formation.

As the cell stretches further, the daughter Mych approaches the pole progressively, as seen in Fig. 22 and reaches it in Fig. 23. The Trophode continues to remain into this stage, but in diverse strengths in various individuals and species. Fig. 24 pictures a subsequent stage, in which the Trophode begins to fade away, especially at the center. The reduction of the Trophode through additional consumption of Tropoconies has progressed even further in Fig. 25, so that only two subtle remnants remain inserted in the two Mych, while the center has a broad break. Finally, Fig. 26 pictures the Dimychit entirely free of the Trophode. This example shows a longer Mychostasis. Subsequent to this stage, there occurs a tightening, which precedes the separation into two Mychit.

In individuals that are strongly filled with Tropoconies, all these processes cannot be determined. Also, in some species, no individuals can be found that contain but few Tropoconies. In these, all such processes are entirely covered by Tropoconies. Through creating unfavorable conditions, individuals deficient in Tropoconies can then be frequently maintained. Likewise, hunger-forms, which can be produced in a hanging drop of physiological saline solution after a variable number of days, but these usually show no longer any splitting processes.

Especially in forms that have their highest development between Mychit and Dimychit —that is, in the organisms that consist of but one Mych, such as the genus *Micrococcus, Streptococcus (here Mychit are in chain formation)*, etc. — most species excel in their strong capacity for accumulating Tropoconies. However, here too, one always finds Atrophit in older colonies.

Now and then, there occur also species that make an exception to this, such as the already quoted *Diplococcus intracellularis*. But also among representatives of the genus *Streptococcus* one sometimes finds species whose single individuals take on stains with usual coloring agents very differently. A portion is dark and full of Tropoconies, another portion remains quite unstained. With close attention, all transits can be easily proven. These individuals being mixed in manifold ways and showing strong and weak coloring within chains, usually partly take on the color, and partly not, so that gram-staining results in a varicolored picture.

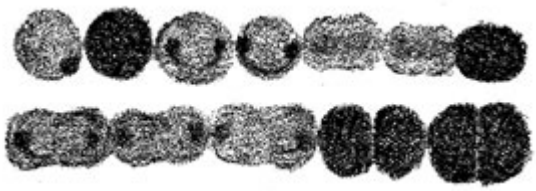

Fig. 27. *Streptococcus spec.from tonsilar smear. Two connected portions. Enlargment 10,000:1. Mychit (Pliotrophie and Miotrophie), Mychit with pseudozygen Dimychit.*

Such a species has been cultivated several times, e.g. from a tonsillar smear, a *Streptococcus spec.,* of which two chain sections are pictured in Fig. 27. In this species, the same pictures could be recognized as they have been described for the *Microspira.* All stages are mixed in colorful rows. Both Trophode, simple Mychit without splitting processes, miotrophic and also pliotrophic, Dimychit, etc. can be recognized on the two pictured chain sections.

3. The Mychomer and the Mychomerit

During the formation of sexual cells, the Mych becomes reduced in size down to half, the Mychomer. The cell with a Mychomer is a Mychomerit.

Among these must be counted the Gonit, the Spermit and the Oit, which will be dealt with in V B 1, V B 2 and V B 3.

4. The Triplomychit

The Triplomychit is a growth form in which 3 Mychit are radially arranged, close together and flattened toward each other. They do not form a Morphological unit.

Fig. 28: *Sarcina spec. Triplomychit. (magnification 1:10,000)* — ***Fig. 29:*** *Diplococcus intracellularis (Weichselb. 1887). Dimychit, Mych arranged as a triangle through nuclear division of one Mych diagonally to Mychostasis. (magnification 1:10,000)*

The 3 Mychit may be of identical size, but usually one of them is a little larger, as shown in Fig. 28. Its occurrence seems usually to arise from a Diplomychit, by one of the two Mychit splitting vertically to the axis between the two Mych before the isolation or rounding into ball-shape has happened in the other Mychit.

The Triplomychit has no special significance. Generally, it is rare. It occurs temporarily, sometimes also in some other micrococci species and also happens in morphologically lower developmental forms of higher bacilli.

Occasional reports seem to indicate that the Triplomychit can also at times come about from a Dimychit, in which one Mych has doubled through splitting vertically to the Mychostasis, that is, from a single cell with three Mych, such as the case pictured in Fig. 29 of the cerebrospinal meningitis pathogen.

B. The Pliomychit

Each individual bacterium that contains more than one Mychit —that is to say, deviates from the common ball shape of the Mychit —is a Pliomychit.

As we have seen in the previous section: the first step into multiplicity is the union of two Mychit into one unit, the Dimychit. But, while this Dimychit is of a labile size and a very transitory form of the Mychit through its splitting into two Mychit, within the phylogenetic rise, the Dimychit comes into manifestation as the first step of the communization of two Mychit, as being a compact organic unit. This unit is the building block on which all higher bacterial shapes are structured and of which they are composed.

The union of two Dimychits into an individual is the Didimychit, of more than two such building blocks the Syndimychit. Examples are all those bacteria which in their development over the ball form can develop beyond their main growth form.

Two or more Mychit united into a singular individual bacterium have no kind of demarcation between each other, but only a common covering. The fact should become very clear that, here, in this unity of Mychit in their tiny dimension entirely different mechanical conditions prevail than in higher, or much higher, organized cells, such as Protozoa and Metazoa, etc.

1. The Dimychit

The Dimychit is the union of two Mychit into a single cell. The two Mych stand near the poles of the lengthy cell. The Dimychit is also a morphological unit of a building block for all higher steps in the organization of bacteria. In association with Dimychit, every building block must, appropriately, be termed by a special name: Dimychosis. Likewise, a Mychit in association within a Dimychit or a Dimychose is to be termed a Mychose.

While the Mych is marginal within the Mychit, it appears in the Dimychit as not always marginal, but is frequently more or less removed from the pole. Fig. 39 seems to show such a case. However, such pictures are no absolute proof because the Mych needs not stand precisely polar —and, actually, is often not polar —so that this situation may present an optical illusion. However, such pictures sometimes occur with regularity and exclusively, so that in those cases a marginal position is impossible. Because already in the Dimychit the pure Mych without trophoconic covering is microscopically invisible even in an Atrophit, a fine trophoconic covering is here already required and most expedient for the determination of its position. In this way, the Trophosomelle indicate rather

precisely the position of the Mych. However, the Trophosom also localize at least the area of the Mych so that, empirically, the place for the Mych can be at least approximately determined. In the case of a pure Atrophit *(Fig. 40)*, one depends entirely on a comparative morphological perspective.

The distance between the centers of the Mych within a Dimychit, or in a Dimychosis, is the Mychostasis. For comparative morphological examinations, this Mychostasis is of greatest importance and must be repeatedly compared in order to reach clear images about the structure and the morphological relationships particular to the unit *(the Dimychit and the Dimychose)*. Even in Dimychit with faint Trophosomelle one can determine the Mychostasis with certainty.

Finally, the remaining lipoids can be dissolved with ether. Only then should one stain. Preparations, for which only half of the coverglass has been treated with soda, result in excellent contrast pictures.

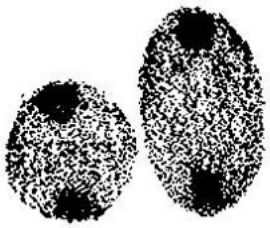

Fig. 30 and 31. *Microspira comma Schröt. Two Dimychit with Trophosomelle. Enl. 1:10,000.*

Fig. 30. *Stenostatic Dimychit (in the splitting of Gonidie and Basit).* — ***Fig. 31.*** *Eurystatic Dimychit (in the germination of Gonidie and in the Phytit).*

The Mychostase can be short *(stenostat)* as shown in Fig. 30 for a Miotrophit of a Dimychit of the cholera pathogen and as they occur in the splitting of Gonidie and Basit, or it is long *(eurostat)*. This type is pictured in Fig.31, likewise of a cholera pathogen, as Dimychit, which is common with the Phytit and which also occurs in the germination of Gonidie. In general one can say, the shorter the Mychostase is, the more the Mych are marginal, and vice versa.

The axis length of a bacterial rod is the average length of the whole rod with no consideration of the position and number of the Mych.

Right at this point, let me call attention to phenomena that can easily mislead, although they involve higher communities which are treated upon in a later section. Let it be noted right here to avoid such hurdles. I refer to longer rods which, due to their end-positioned Trophosom *(comp. Fig. 33)* appear at first sight to be Dimychit, although being noticeable for their greater length. Because it is at times possible for Dimychit and Dimychose to be very strongly stenostatic, a reliable Morphological interpretation is possible only through a careful comparison with other individuals of the same culture, combined with

comparative measurements. For instance, Fig. 32 shows a normal Dimychit with two Trophosom of the typhoid pathogen, while Fig. 33 —although simulating a Dimychit —belongs to a longer communization *(Didimychit)*, in which the two central Mych do not reveal its presence due to the lacking trophoconic coating, thereby remaining entirely invisible even in this stronger and richer Cytoplasma.

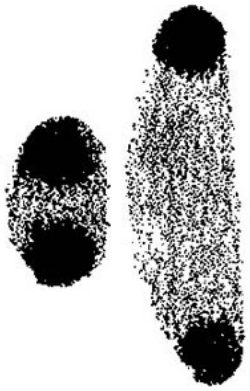

Fig. 32 and 33. *Acystia typhi (Eberth 1880). Enl. 1:10,000.*

Fig. 32. *Dimychit with 2 Trophosom from a younger culture. —* ***Fig. 33.*** *Dimychit with 2 Telotrophosom from a 4-day old culture of agar with 6-1/2% common salt.*

The Mychostase of the Dimychit is but a little shorter than its axis length.

In every Dimychit, the Mych can be uncovered, that is invisible, or it can be covered by Trophosomelle or by a Trophosom, which make its presence perceptible. In between, there are all sorts of transits. The extreme of the strongly stainable variety is the short rod *(Dimychit)* that is entirely filled with Trophoconies, in which no more Trophosom can be noted, because everything that is equally dark, strongly takes on the stain; and the other extreme toward the weakly stainable side, is the entirely atrophic Dimychit.

Concerning the distribution of the Trophosom and Trophosomelle, there are only the following possibilities:

1. 2 Trophosom *(Fig. 37)*;
2. 1 Trophosom + 0 Trophosomelle *(Fig. 38)*;
3. 1 Trophosom + 1 Trophosomelle ;
4. 0 Trophosom + 1 Trophosomelle *(Fig. 39)*;
5. 2 Trophosomelle;
6. without Trophosom and without Trophosomelle *(Fig. 40)*.

The following is a pictorial representation of some of these forms distributed in the reserve apparatus, based on developmental forms of *Corynobacterium pseudodiphtheriticum (Lehm. et Neum. 1899)* in Fig. 34 to 40.

We see that, already within a Dimychit, there can take place functional assignments relating to the storing of reserve substances. True, these diversities also partly depend on the life functions within the Dimychit, with the consequence that reserve substances get faster use in one area than in another.

Fig. 34-40. *Corynobacterium pseudodiphtheriticum (Lehm. et Neum. 1899). Enl. 1:10,000.* ***Fig. 34.*** *Mychit pliotrophic. —* ***Fig. 35.*** *Mychit miotrophic. —* ***Fig. 36.*** *Formation of Dimychit from the Gonidie. —* ***Fig. 37.*** *Dimychit with 2 Trophosom. —* ***Fig. 38.*** *Dimychit with 1 Trophosom. —* ***Fig. 39.*** *Dimychit with 1 Trophosomelle. —* ***Fig. 40.*** *Dimychit, atrophic, without Trophosom and without Trophosomelle.*

That the distribution of labor can take on a much greater significance in higher communizations, will be seen later in the Syndimychit and, especially, in the formation of Gonidie, Cystit, Sporit, and Oidie. There, certain Dimychose take over the feeding of these reproductive and permanent forms, etc. These Dimychose are the Trophodimychose. It has not been possible to ascertain, pro or con, whether an individual nutrition simultaneously runs parallel to this feeding of the reproductive and permanent forms through Trophodimychose.

2. The Mychomitosis of the Dimychit and the Dimychosis

Because the Mych is not recognizable in the Dimychit as a Morphological unit *(not as a splitting phenomenon of the Mychit)* even in Atrophit due to the denser Cytoplasma and its thicker layer, the Mychomitosis cannot be directly recognized in its intrinsic processes in the Dimychit through the former means, the staining difference being too insignificant as compared to the size of the mass.

Contrastingly, the subsequent phenomena, especially the formation of Pseudozyg *(dumb-bells)* and the trophosomic formations are excellent occasions for the morphological knowledge of the processes involving growing and splitting. Very small Trophosomelle that are formed by a very thin layer of Trophoconies are especially suitable for evaluating this question because, first, they fix the presence and location of the Mych sufficiently by their delicateness, frequently presenting a circumference that is but little larger than the Mych itself. Second, because they present a fortunate mediation to the eye concerning the Morphological conditions through their exceptionally strong stainability. Because according to experience, the formation of Trophode and Pseudozyg follows subsequent to the Mychomitosis, and it occurs always only in splitting phenomena, this development offers a fine measuring rod for the Morphological analysis of growth and Arthrogony. Only in higher Dimychose associations it is needful to watch out for a phenomenon, namely, the formation of Pseudotrophode. These are trophoconic accumulations between two Trophode or Trophosomelle that are similar to Trophode, but they belong to diversified Dimychose. Such a Pseudotrophode is shown, for instance, in Fig. 179 *(Section VI a A 5 a)* in the Synascit of *Spirillum undula (Müll. 1786)*, between Trophosom 9 and 10. In more primitive Dimychose associations, the danger of confusing

it with the Trophode is no concern, because the neighboring Mych of diverse Dimychose usually lie in much closer proximity than the Mych belonging to one Dimychose. When a stronger accumulation of Trophoconies occurs at such a location, there never develops a thread-like connection, instead, Mych belonging to heterogenic Dimychose get covered over by an oval or round trophoconic accumulation. In the latter case especially, this could rather be confused with a Trophosom, while actually picturing two merged Trophosom.

For the recognition of all Morphological stages lying between a Dimychit and the development of two Dimychit from the one, those by nature tending toward Atrophose or Miotrophose are the species that are especially suitable, without resorting to chemical interventions. Because many varieties contain —beside the rich, trophosomic substance, which often fills the cell entirely, so that the Trophosom cannot be recognized —in addition, evenly distributed lipoid substances in the Cytoplasma that also strongly take on stain, all such bacterial species that are well supplied with reserve materials and are usually very vital, even outside the host organism, are generally not suitable for this purpose.

Fig. 41-48. *Bacterium spec., from sputum. From an agar culture. Enl. 10,000:1.*

Fig. 41. *Dimychit, pliotrophic. Densely filled with reserve materials, so that the Trophosom are not recognizable.* ***— Fig. 42.*** *Dimychit. The 2 Trophosom becoming distinct.* ***— Fig. 43.*** *Dimychit. The 2 Trophosom reduce their circumference and are becoming less dense, so that Trophosomelle are becoming distinct.* ***— Fig. 44.*** *Dimychit, miotrophic. The 2 Trophosomelle are clearly noticeable; the upper forms a Pseudozyg.* ***— Fig. 45.*** *Individual cell, miotrophic. The upper Pseudozyg has become fully developed, the lower just developing.* ***— Fig. 46.*** *Dimychit, miotrophic. Both Pseudozyg fully developed.* ***— Fig.47.*** *Dimychit, miotrophic, already with increased nutrients. The upper Pseudozyg in the center of the Trophode is paling; separation of both Dimychit from one another beginning.* ***— Fig. 48.*** *The 2 developed Dimychit commencing their Pliotrophosis, both still hanging together but shortly before separation. Each has 2 Trophosomelle.*

Species that tend to Atrophose or Miotrophose, are not plentiful. Sometimes, however, such species can be found in sputum and in tonsillar swabs. The reports pictured in Fig. 41-48 stem from such species that have been cultivated from sputum. The pliotrophic Dimychit presented in Fig. 41 is, thus, an individual cell that is so richly filled with reserve substances *(Trophoconies, Lipoid, etc.)* that it has an equally stained color that does not permit any recognition of either Trophosom or Trophosomelle. In the Mychomitosis that seems to begin in this condition, any food intake seems entirely excluded precisely because individuals involved in splitting consume their reserve substances. This brings about the Miotrophose and, finally, the Atrophose subsequent to the splitting processes and due to the energy exhaustion that is its consequence. In Fig. 42, one can already see the beginning exhaustion of the reserve substances, and in Fig. 43, even more so. In the paling Trophosom, the denser and chemically often differently

constituted innermost layers of the trophoconic coating distinguish themselves clearly here, so that one can already speak of Trophosomelle at this point.

After the strong paling of the entire Cytoplasma, due to the extensive consumption of reserve substances, Fig. 44 shows the beginning formation of a Pseudozyg, namely from the upper Mych downward. In Fig. 45, the upper Pseudozyg is complete, the lower does not seem complete as yet. In this species, the Trophode are strongly bent, allowing the path of the daughter-Mych to be visible. Fig. 46 shows the two Pseudozyg completed. Now begins a gradual stretching of the entire individual cell. The paling of the Trophode through the consumption or distribution of the Trophoconies is visible in Fig. 47 in the upper Pseudozyg. The paling begins at its strongest in the middle. Simultaneously, the gradual tying off of the developed two daughter-Dimychit is beginning, along with a renewed accumulation of reserve substances. This has progressed even further in Fig. 48. The two daughter Dimychit are still hanging together, although strongly tied off from each other. They have lost their Trophode entirely, and the four existing Mych are indicated by four Trophosomelle. Then, more reserve materials are gathered through the repeated onset of full food intake. The Pliotrophit falls apart entirely, and the described process repeats over again.

Such processes are easily observable in other species in quite similar ways through the recording of all these stages and their transits.

Also, in the treated species, the described processes are usually simultaneous in both Mych. Such a simultaneously occurring Mychomitosis and the subsequent processes in both Mych of a Dimychit or a Dimychosis is to be called Isozygie. The above-described non-simultaneous course —which is, at least in the Dimychit, not as frequent —is a very common occurrence in higher communizations, and is called Protozygie.

If the separation of two Dimychit, that have come about from a single Dimychit through the Mychomitosis of the two Mych, does not occur and, instead, they remain firmly united with each other, it is called a Didimychit. The two Morphological building blocks corresponding to the Dimychit, from which the Didimychit has developed as a phylogenetically higher standing community, are to be termed Dimychose, as suggested earlier. If one intends to make these visible in such species that hide all these Morphological details under a rich coating of reserve substances due to their pliotrophic tendency, there are two ways to remove these.

The one path is the artificial creation of hunger forms, which allow the observation of many Morphologically important details. For this purpose, one brings bacterial material into a hanging drop of physiological saline solution and places it under a good seal on a hollow slide, keeping it dark for quite a long number of days. When stained, such material shows that, usually, a large portion of the reserve materials has been consumed, thus removing the obstruction for a penetrating look. Very beautiful pictures result from such preparations of, for instance, the cholera pathogen.

The other path is based on undertaking chemical steps. The Lipoid are best released through a mixture of alcohol and ether, into which one submerges the air-dried or else alcohol-hardened glass smear. Here also, the cholera pathogen is

quoted as an example. It offers a beautiful picture of the Trophosom, which would otherwise be covered over by the richly abounding Lipoid.

A large portion of the constituents of the Trophosom, namely the nucleic acid compounds, can be released through a 5% soda solution. For this purpose, one heaps the soda solution on the air-dried and hardened cover smear, then heating it more or less strongly several times above a small or large gas flame. Several longer pauses in between are expedient. In each case, only the experiment, and the comparison of the stained preparations resulting, alone yield the correct measure. For instance, this method is very favorable for Morphological diphtheria examinations, because many Morphological details can become recognized only in this way, particularly because the diphtheria Trophosom are often developed very large and the Gonidie and Cystit would otherwise cover everything.

For some purposes, especially also for the diphtheria pathogen, a combined process is recommended. In that case it is expedient to apply soda first and then dissolve the Lipoid, while vice versa, the bacterial layer easily peels away from the cover glass.

3. The Didimychit

The Didimychit is the union of two Dimychose into a higher association and into one individual. As elaborated in a later occurring passage, the term cell can be used throughout for the Mychose of all lower and higher associated units, as also for the latter. This term cannot at all be scientifically viewed as a standardized Morphological concept, and this name also is used for protozoic cells and metazoic cells as a collective term.

Right from the beginning,the joining of the two Dimychose points to the possibility of building higher arrangements through direct lengthening. Fig. 46 *(IV B 2)* displays how the two middle Mych are not arranged one behind the other along the longitudinal axis of the cell; rather an important deviation is observed. With the separation of the Didimychit, this deviant orientation of the Mychostose along the cell axis quickly becomes well balanced, and as seen in Fig. 47, right in front of the eyes, both middle Mych saddle the axis in both Dimychit. From this the arrangement of the Dimychose in the Didimychit can be considered: 1. catatact, 2. syntact.

The catatact positioning in a Didimychit or in a higher association *(Syndimychit)* is the arrangment in a row whereby the Mych and the Mychostase lie along the longitudinal axis of the cell.

The syntact positioning of the Dimychose in a Didimychit or in a higher association *(Syndimychit)* is that arrangement in which the Mych and the Mychostase are not arranged in the length axis, one behind the other, so that they lie irregularly, oblique or across to the length axis, namely, either several of the Dimychose or all, or else, 2 or more Mychostase are side by side in the length direction, either parallel to the length axis or, usually, disarranged. For this, compare Section VI a A 5, and also Fig. 182.

While the arrangement of the Trophosom and Trophosomelle in the Dimychit has rather limited possibilities, it reaches a considerable number in the catatact Didimychit, even apart from considering all the transitory and in between forms.

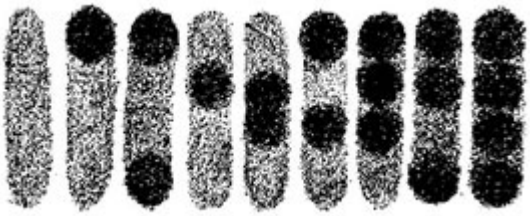

Fig. 49-57. *Corynobacterium pseudodiphtheriticum (Lehm. et Neum. 1899). Diverse possibilities of arrangement of Trophosom in the Didimychit. Enl. 1:10,000.*

Fig. 49. *Atrophit. No Trophosom.* ***— Fig. 50.*** *1 Telotrophosom.* ***— Fig. 51.*** *2 Telotrophosom. — Fig. 52. Ascotrophosom. — Fig. 53. 2 Ascotrophosom.*

— Fig. 54. *1 Telotrophosom and 1 Ascotrophosom.* ***— Fig. 55.*** *1 Telotrophosom and 2 Ascotrophosom.* ***— Fig. 56.*** *2 Telotrophosom and 1 Ascotrophosom.* ***— Fig. 57.*** *4 Trophosom (2 Telotrophosom and 2 Ascotrophosom).*

First, let us compile the possibilities that can occur in the arrangement of Trophosom, based on some *Corynobacterium pseudodiphtheriticum (Lehm. et Neum. 1899)*, isolated from a tonsillar swab. In Fig. 49-57 these are pictorially represented, having been generally observed in medical evidences; only one possibility is not pictured here. There is a total of ten possibilities. The Atrophit shown in Fig. 49 lacks any Trophosom. An end-positioned Trophosom *(Telotrophosom)* is shown in Fig. 50, two Telotrophosom can be seen in Fig. 51. In the central portion, there can be one *(Fig. 52)* or two *(Fig. 53)* Trophosom *(Ascotrophosom)*. One Telotrophosom each and one Ascotrophosom can be separated, as shown in Fig. 54, or both lie close together *(not pictured)*. Three Trophosom can be arranged in only the two possibilities pictured, namely Fig. 55 *(1 Telotrophosom and 2 Ascotrophosom)* and Fig. 56 *(2 Telotrophosom and 1 Ascotrophosom)*. Fig. 57 shows the presence of all four Trophosom.

Trophosomelle can be distributed in the same way, and finally, Trophosom and Trophosomelle can occur mixed up in the most diverse fashion. In the Didimychit, the latter have 46 possibilities of combining. With patience, one can easily observe all these possibilities, if there is suitable material. Moreover, one can find numerous transitory conditions that may appear very different in the diverse species, while corresponding in their Morphological foundation.

Fig. 58-62. *Bacterium spec. from a tonsillar smear. Didimychit. Enl. 1:10,000.*

Fig. 58. *1 Telotrophosom, 1 Trophosomelle.* **— *Fig. 59.*** *2 Trophosomelle.* **— *Fig. 60.*** *4 Trophosomelle.* **— *Fig. 61.*** *4 Trophosom.* **— *Fig. 62.*** *Pliotrophit, which barely allows recognition of the 4 Trophosom.*

A few additional examples of the genus *Bacterium* and isolated from a tonsillar swab of isolated species have been selected randomly from among numerous other combinations. They are pictured in Fig. 58 to 62, precisely corresponding to their originals. In Fig. 58, one can see 1 Telotrophosom and an end-positioned Trophosomelle, in Fig. 59, 2 end-positioned Trophosomelle. In Fig. 60, the presence of all four marginal Mych is made visible to the eye through Trophosomelle, in Fig. 61 through Trophosom, which finally in Fig. 62 are rather strongly covered by a rich accumulation of reserve substances. Naturally, in this species also all possible combinations are found, along with, Pliotrophit with stronger accumulations of reserve substances, etc. Pliotrophit are usually predominantly present.

Already on the basis of medical evidence up to this point, the knowledge is becoming firm that the extremely manifold

appearances of rods within a single species —as they are occurring extremely frequently within morphologically identical structures, here that of the Didimychit —show no comparative morphological differences throughout, but that they are only appearances of the different accumulations of reserve materials within the diverse morphological units of a higher association.

As with the Dimychit, so also with the Didimychit, one can —after some practice and with comparative measuring of the usually present Trophosom and Trophosomelle, which function as aids —easily determine that the Didimychit is composed of four Mychit and, therefore, must contain four Mych.

4. The Syndimychit

The Syndimychit is the unification of more than two Dimychose into a higher association and into a single individual.

As already with the Didimychit, the difference in the arrangement of Dimychose comes even more strongly into view here. The catatact and syntact arrangement is here much more conspicuous and of greater importance.

The catatact Syndimychit occurs from the Didimychit through the additional splitting of the Mych of one or both Dimychosis and the simultaneous arrangement of the developed new Mych into the longitudinal axis of the rod. Additional singular splitting can always increasingly lengthen the rod, which can extend into extraordinarily long threads.

Fig. 63. *Bacillus solmsi Klein. Piece of a Syndimychit with 4 Dimychose. Enl. 1:10,000.*

As we have already learned from the simple association of two Dimychose, the two allied Mych of a Dimychose are frequently further distant from each other than two Mych of neighboring Dimychose; this is also the case in the Syndimychit. To make such a construction visible, forms with numerous Trophosomelle again offer a suitable preparation. Because, for Trophoconies Methylene blue is a favorable stain, it is recommended to use this stain for it. Fig. 63 shows a selected piece of a Syndimychit from *Bacillus Solmsi* Klein 1889, which forms rather long threads. The whole thread consisted of 10 Dimychose.

In many forms, however, the Dimychose are arranged in such a way that the Mych stand at approximately identical distances. Finally in some cases the two Mych of the Dimychose seem to have less distance from each other than from the neighboring Dimychose. Species with catatact Dimychit threads that have unequal thicknesses also display certain differences in the arrangement of the Dimychose in a Syndimychit. One can frequently find such formations, for instance, in the diphtheria pathogen *(Fig. 64 and 65)*. True, one must always pay attention to the fact that there may be atrophic Mychose within each Dimychose.

64. (top) 65. (bottom)

Fig. 64. *Corynobacterium diphtheriae (Löffl.). Syndimychit. Enl. 1:10,000.* **— *Fig. 65.*** *Likewise, Syndimychit of 12 Mychose, also 6 Dimychit. Enl. 1:10,000.*

The Mychose can —as already in lower associations, so also in Syndimychit — present very diversified appearances, according to the amount of stored reserve materials, and they may be arranged in most diversified ways. Consequently, atrophic Mychose, Mychose with Trophosomelle and with Trophosom, etc. may follow each other in arbitrary order. Fig. 64 and 65 show such arrangements. In 4 and 10 in Fig. 65, we are dealing with atrophic Mychose, so that this diphtherial

rod is composed of 12 Mychose. The first and eleventh, stronger thickened Mychose are structures that are to be described as Cystit in the following Section.

Another example from the area of catatact Syndimychit has been taken from among the spirally serpentine bacteria. Fig. 66 shows an example of a *Treponema Vincenti (Blanch. 1906)*, which stems from a tonsillar swab in a case of Vincent's Angina. This disease is produced by the quoted Spirochaetide, in community with the *Fusiformis hastilis (Seitz)*. This rod also is morphologically a catatact Syndimychit. In favorably stained, strongly trophic examples, one can see here also Trophosom and Trophosomelle.

Fig. 66. *Treponema Vincenti (Blanch. 1906). Syndimychit with Trophosom and Trophosomelle. Enl. 1:10,000.*

The end-positioned Trophosom in a catatact Syndimychit also are to be referred to as Telotrophosom and the others as Ascotrophosom.

The biomorphological concept Ascit contains chiefly catatact Syndimychit. Therefore, there is additional information about the catatact Syndimychit in Section VI a A 4.

The syntact Syndimychit comprises associations of more than two Dimychose into one bacterial individual. In these, the Mychostase are either all or in part arranged obliquely or across to the length axis of the rod. Such forms come to be developed by the Mychomitosis of the single Mych arranging themselves, not along the length axis, but obliquely or vertically to it.

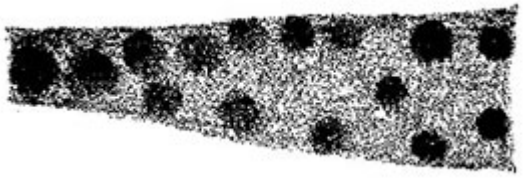

Fig. 67. *Migulanum anthracis (Koch 1876). Piece from the center of a syntact Syndimychit (Synascit) from a three-day old culture of agar, with 61/2 NaCl. From the borderline between catatact and syntact Syndimychit. Enl. 1:10,000.*

For an example, a piece from a thread of the anthrax *(Tanners' disease)* pathogen is presented *(Fig. 67)*. It stems from a 3-day old agar culture with the addition of a 61/2% saline solution. On the left, there remains a piece of a catatact arrangement

of Mychose, while a syntact arrangement of Dimychose adjoins it. The position of the Mych is indicated by the Trophosomelle. By the way, examples pictured by Löffler *(1887 Table II, Fig. 4a)* of the anthrax pathogen show a similar organization; however, Löffler interpreted the Trophosomelle as "a deposition of staining substance in the form of fine granules." Also, Löffler believed that insufficient stain was responsible for these examples which were considered to be abnormally stained. He says: "The coarser and finer granulation stems from insufficiently long staining of the bacilli and their long washing in alcohol."

By the way, the fact that catatact and syntact Syndimychit are found simultaneously in one example of a phenomenon that occurs more or less frequently, or rarely in all Synascota. The transit is either gradual or sudden. Therefore, in the splitting, the one half can occasionally be catatact, the other syntact. Prowazek pictured such an example in 1906, stemming from a *Treponema gallinarum* Bl. 1905, which is reproduced here as Fig. 68.

Fig. 68. *Treponema gallinarum R.Bl. 1905. Left syntact, right catatact Syndimychit briefly before splitting. (According to: Prowazek, Arb. Kais. Public Health Office 23. 1906, Tab. II, Fig. 10b.)*

The syntact Syndimychit can also accumulate a great number of Dimychose in its breadth so that gigantic bacterial individuals can come about, as presented, e.g. *Syncrotis* Enderl., *Phragmidiothrix*, Engl. and the most extreme *Schaudinnum*, Enderl. A series of pictures of syntact Syndimychit are found in the Section about the Synascit *(VI a A 5 a)*.

Among such gigantic, syntact Syndimychit, individuals with very numerous Trophosomelle are often found. Such examples have a granulated appearance. They caused Schaudinn *(1902)* and others to ascribe to the bacterial cell a "diffused" nucleus, due to the distribution of chromatin substance being spread throughout the cell, which —according to prevailing views of that time — represented the nucleic substance.

That in higher Dimychose associations, such as the catatact and syntact Syndimychit, there may also be individual Mychose mixed in here and there, beside the typical Dimychose, is understandable when one takes into account that Isozygie does not always occur in both Mych of a Dimychose, but that individual Mychose may remain over through Protozygie; sometimes they have a longer existence as Mychose. For instance, the Syndimychit of *Spirillum undula (Müll. 1786)* in Fig. 181, which seemingly consists of 3 Dimychose, actually has two single Mychose right in the center of the rod. They have apparently been left over when the two end Mychose of the Dimychit pictured in Fig. 180 had developed themselves through Protozygie into Dimychose, while the two in

the center seem to represent Mychose, even though they might give the appearance of Dimychose.

C. The Symmychon and the Symmychit

The Symmychon is a polydynamic Mych. Its content corresponds to not merely one, but several, Mych united into one homogenous body. Its diameter is larger than that of a Mych.

The Symmychit is a Mychit with a Symmychon.

In all types of bacterial cells discussed until now, whether composed of one or more Mychose, we were always dealing with a univalent Mych. A splitting of the Mych occurred only then when it was able to expand either through nutrition from outside or through the reserve substances from the Cytoplasma. To observe under a microscope a simple splitting of e.g. a Dimychit into two, is always a task requiring patience, even under favorable nutritional conditions. However, if one brings living material without food, for example, into a hanging drop of Physiological saline solution, all growth is quickly interrupted. Even all those phenomena that occur quickly under unfavorable conditions, including the formation of Gonidie, stop completely in this way, so that one can see even after days that there has been no more growth, rather, that each bacterial individual has partly or entirely consumed its reserve substance. Such hunger forms frequently offer themselves as favorable objects for comparative Morphological examinations.

The first form in which I noticed a strikingly different attitude, was the Zoit of the cholera pathogen. A more detailed description of the Zoit and the Pseudascit follows in Section VI a A 7 and 8.

In another passage, it is pointed out in greater detail that the Zoit can be found only in cultures stemming from cholera stools, or such that have not been cultivated much further. When one brings such material with Zoit into a hanging drop of saline solution, which excludes any nutrition in the material, and then observes the unicellular Zoit, one sees that they grow in less than 2 hours into long threads *(Pseudascit)*, while the Dimychit and Didimychit, which still contain 2 or 4 Mych, do not elongate themselves. If the one nucleus of the Zoit were equivalenced with the 2 or 4 nuclei of the cholera rod, there would have to be a much larger likelihood for the rod to elongate itself than for the Zoit. But, as mentioned, that is definitely not the case.

If, however, one continues to observe the Pseudascit, then it is found to split itself into 10-15 or even more Didimychit, which remain hanging together like in chains. This process again is concluded after ca. 2 hours.

How, then, is it possible that under entirely identical conditions there can develop within 3-4 hours 40-60, and more, nuclei from the nucleus of the Zoit and the chain of Didimychit that grew from it, when simultaneously the 2-4 nuclei *(Mych)* of the normal cholera rod experience no increase?

The singular possible interpretation for such evidence is the assumption of a multivalenced Mych, an assumption that gains additional ground, in that in

Protozoa quite similar phenomena are provable, as has been doubtlessly discovered in the excellent examinations of Hartmann *(1909, 1911)*. Hartmann calls such nuclei polyenergic nuclei.

On grounds of a comparative Morphological nature, that will be further explained in Section IX C, it is not advisable to transfer the term polyenergic nucleus onto the bacteria; therefore, the concept of polydynamic Mych or Symmychon should be used for the multivalenced Mych.

When it was possible later on to determine in another Symmychon, namely in the Cystit of the diphtheria pathogen, that its volume was considerably larger than that of the Mych, no more doubts could be seriously raised.

A Mychit with a Symmychon as its nucleus is a Symmychit. To be counted among the Symmychit is the Cystit and the Zoit, which will be thoroughly elucidated in Sections V A 3 a, b and VI * A 7.