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NEW OTOLOGICAL VIEWS

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IN this paper it is proposed to present some new views on the following subjects :

(1) The division of the middle-ear cavity and the Eustachian tube.

(2) The origin of the pneumatic spaces of the middle ear and their covering epithelium.

(3) The origin, morphology, extension and the function of the jelly-like embryonic tissue of the middle-ear spaces.

(4) The pneumatization and the eburnation of the temporal bone.

(5) The pathogenesis and some clinical aspects of middle-ear disease.

These observations are based on many years of my clinical experience combined with histological and histopathological studies of serial sections of one hundred temporal bones and Eustachian tubes. The work was carried out during the years 1934-1939 in the Jagellonian University, Cracow, Poland, and later on in the Medical School of the Hadassah Hospital in Jerusalem, Palestine.

1. The division of the middle-ear cavity and the Eustachian tube

A new conception of the mucous membrane of the Eustachian tube and middle ear is presented.

The mucous membrane of the tube with its muco-serous glands and the lymphoid tissue is in sharp contrast with the lining of the rest of the middle-ear spaces. These spaces are devoid of a true mucous membrane. In view of their origin, their morphology and the lining they may be defined as a serous covering membrane, not secreting but rather transudative in nature.

Before discussing this in more detail it is necessary to refer briefly to some historical points.

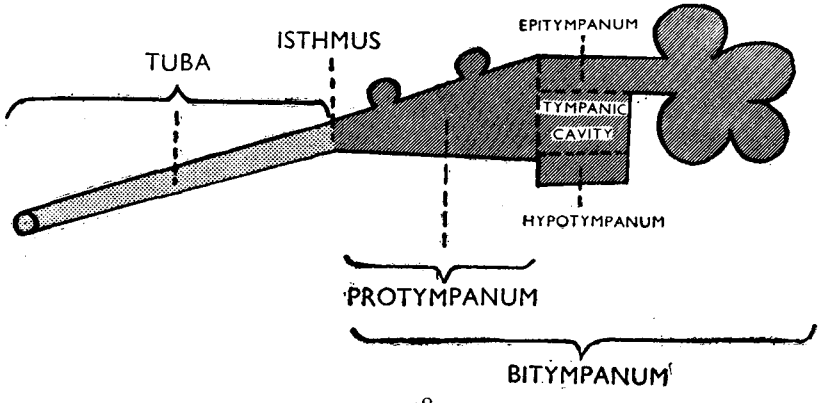
In the year 1563 Fallopius founded the conception of the tympanic cavity which is valid to-day, in that he compared its general shape to that

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of a military drum. Two years later Eustachio described the cartilaginous-membranous tube. In 1717, i.e. 150 years later Valsalva established the conception of the bony part of the tube. In 1862 Ruedinger described the definite division of the tube into the bony and cartilaginous-membranous parts. This holds good to-day.

Now, what exactly is the bony tube? From the historical point of view it is an anatomical section which was missed both by Fallopius and Eustachio in their descriptions. Fallopius did not fit it into his military drum form and Eustachio was interested only in the cartilaginous-membranous muscular canal connecting the middle ear with the pharynx. Actually the bony tube is a section lying between the tube of Eustachio and the tympanic cavity of Fallopius. Valsalva said about it: It is " a continuation of the bone in which is contained the tympanic cavity " (*Continuatio ossis, in quo tympani cavitas continetur*). In spite of this correct observation it appeared to Valsalva, still more to Ruedinger, that this section was not part of the tympanic cavity, but rather of the tube. In their day, when clinical otology had not yet developed, these conclusions were of no special significance, and it was the authority of the writers that preserved the idea to this day. Valsalva's and Ruedinger's division is incorrect and cannot stand investigation from an embryological and anatomical or clinical standpoint.

Before proceeding to the proof of this statement, it is necessary to discuss the hereby proposed division. The complex conception of the cartilaginous + bony tube has to be split into its correct parts. The bony tube has to be separated from the " so-called tube ", and from now on by tube will be meant a structure which corresponds in a general way to the original Eustachian tube, i.e. cartilaginous-membranous tube. The separate bony tube, an anterior evagination of the tympanic cavity, simply becomes incorporated into the tympanic cavity, and in analogy to epitympanum and hypotympanum will be known as " Protympanum ". This extended tympanic cavity (tympanic cavity + protympanum + pneumatic spaces) will be called " bitympanum ".



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New Otological Views

Since Rathke described the "buccal cavity" of mammalian embryos in the years 1825-1827, many divergent views have been expressed on the embryological origins of the tube and the pneumatic middle-ear complex. The most frequently presented view was, that the tube and the middle-ear complex arose from the germinal tissue of the first branchial cleft. Reichert suggested that it was incorrect, and Frazer showed distinctly that the origin was of both types: the tube is formed from the germinal tissue of the first branchial cleft, but the integral parts of the middle ear, surrounded by the temporal bone, are formed independently from the germinal tissue of the second branchial cleft. From these integral parts of the middle ear there develops later the tympanic cavity with its pneumatic spaces and the bony tube, while the cartilaginous tube develops from the first branchial cleft. Thus, in accordance with our terminology, *the tube originates from the first branchial cleft and the bitympanum from the second cleft.*

From the point of view of *anatomy* the name "bony tube" is superfluous.

Among the methods used to demonstrate the shape and form of the middle-ear spaces is the taking of casts. Casts of the bony spaces and soft tissues show that the medial, lateral and superior walls of the human tympanic cavity pass without interruption of smoothness of line or surface to the corresponding walls of the bony tube (or protympanum). Only in the transition of the inferior wall of the hypotympanum to the inferior wall of the protypmanum there is some interruption of line, and even here there is as a rule an obtuse angle.

The same picture is obtained from slides of longitudinal sections through the lumen of the tubo-tympanic space of man. These sections show that the bone reaches to the narrowest part of the tube, i.e. to the isthmus. Like the tympanic cavity, the bony tube is always a definite space, inalterable in size and shape while in contrast the cartilaginous tube in its state of inactivity is merely a potential space which opens but slightly, and only then as a result of active muscular contraction.

Also from the point of view of *comparative anatomy* the name "bony tube" is superfluous. When comparative anatomists speak of the tube they always mean a structure which corresponds in size and shape to the cartilaginous-membranous tube of human beings. The factors which bring about the narrowing of that part of the tympanic cavity known as the bony tube (protympanum) are (1) the tensor tympani muscle and (2) the bulge formed by the carotid canal. In those mammals in which the carotid artery follows a different course, there is no such structure as the bony tube. In spite of this narrowing the so-called and generally recognized "ostium tympanicium tubae osseae" represents a construction absolutely artificial in nature, and except for the angle in the inferior wall is devoid of morphological or physiological foundation.

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Further, in relation to the pneumatic system there is no difference between the tympanic cavity and the bony tube : the peritubal cells are essentially like the other pneumatic cells of the temporal bone, such as the periantral, peritympanic, mastoid cells, etc.

From the *histological* standpoint the border between the tube and the bitympanum is not so sharp. The typical mucous membrane of the tube with its ciliated epithelium may be followed beyond the border line of the tube into the protympanum, the tympanic cavity and even into the mastoid antrum. The lymphoid tissue, however, is always limited to the tube as a constant and characteristic constituent part of its submucosa. It does not encroach on the mucosa of the protympanum except in pronounced pathological conditions. The encroachment of the ciliated epithelium is explained as follows : Histological structures should not be regarded as absolutely static, for they are an expression of changing physiological processes which are going on in the organism. Supporting tissues such as bone and cartilage follow different biological rules from superficial tissues such as mucous membranes with their covering epithelium. The latter, in contrast to the former, are constantly affected by the function of defence against exogenous agents. In the fœtus, where exogenous agents play as yet a small part, the ciliated epithelium is found limited to the tube. After birth, this relationship undergoes a gradual change. Thus the shift of the epithelium towards the protympanum sketched above should be regarded as an ever changing phenomenon, and in the adult as an expression of a continuously actual physiological defence process in the middle ear. The mucous membrane and its covering epithelium represent not a separating element, but one connecting and equalizing the two basically different regions, i.e. the tube and the bitympanum. This epithelial shift does not alter the fact that the bitympanum is a separate entity.

Consideration of the *physiology* of this region further supports the proposed division. The two essential functions of the bitympanum and the tube are the transmission of sound and the equalizing of air pressure. The equalization of air pressure is the function of the cartilaginous-membranous tube exclusively. It is carried out by the active muscular opening mechanism of the tube. The rigid walled bony tube has nothing to do with this function. On the other hand the protympanum, i.e. the bony tube participates in the sound transmission function of the bitympanum as a whole, i.e. also of the tympanic cavity and the pneumatic spaces of the middle ear.

2. The origin of the pneumatic spaces of the middle ear and their covering epithelium

According to a variety of opinions[1] the middle-ear region (i.e. the tube, the tympanic cavity and the pneumatic spaces) develops from the

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" tubotympanic epithelial duct ", a derivative of the first branchial cleft. Accordingly, the epithelial covering of this whole region is regarded as of an entodermal origin. In Keibel's[2] textbook of embryology this is expressed briefly : " The epithelial covering of the middle ear originates from entoderm." From a part of the tubo-tympanic duct there is formed a cleft, the " preformed tympanic cavity space ". The tympanic cavity develops from it. Its epithelium rests on a thin basal membrane. In the interior there is found the fœtal temporal bone with its periosteum ; the bone is involved in a permanent process of metamorphosis. Between the epithelium and the bone there is found a thick layer of embryonic tissue, to which most variable names were attached. However, it is most frequently described as jelly-like tissue. In the fifth fœtal month this jelly-like tissue begins to penetrate the bone, it erodes the bone and opens its marrow spaces. At the same time, however, it is subjected to a shrinking process. Thus there is formed a circular enlargement of the above mentioned preformed tympanic cavity space. This marks the onset of the pneumatization process which subsequently, following an essentially similar mechanism, continues after birth till the fourth or fifth year of life. Then the pneumatization of the middle ear is brought to completion in its main features. During all these phases the mucous membrane, especially the epithelium of the just formed pneumatic spaces, grows continuously into the newly formed ones.

Wendt (1873) has given us the histological definition of the jelly-like tissue of the middle-ear spaces. The jelly-like tissue contains few star-like and spindle-shaped cells provided with long processes. These processes are connected with each other in a net-like fashion. At the nodal points of the cell-processes we may find separate round cells. The described cellular framework is distributed in a seemingly amorphous, intercellular substance very rich in water. Till to-day nobody has revised this definition. Thus it must be considered as valid in our time, too, although it is seventy years old.

As far as the distribution of the jelly-like tissue is concerned Troeltsch finds it only and exclusively in the medial wall of the tympanic cavity of fœtuses, while Wendt also in the superior and inferior walls, though scanty.

And now some analysis of my own :

As is well known, the epithelium of the tube differs basically from that of the pneumatic spaces. The former is a double-layered stratified cylindrical ciliated epithelium with numerous goblet cells, the latter represents an endothelial-like layer of flat epithelium. According to the above mentioned unitarian entodermal theory of the development of the middle ear the flat epithelium obviously is a derivative of the cylindrical epithelium. However, we cannot find in the literature even the slightest indication for an answer to the question when and through what intermediary cytological structures this transformation of the

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cylindrical epithelium into a flat one is accomplished. The two histological structures are simply put together. There has been described only a demarcation line between them. However, individual workers, as for instance Koelliker, Kessel, Troeltsch, Brunner, Siebenmann, differ greatly in their opinion on this demarcation line. Brunner, for example, finds the cylindrical epithelium normally present in the whole tympanic cavity ; according to Troeltsch, it generally ends at the ostium tympanicum tubae. A similar opinion is expressed by Wittmaack.

I have followed up this question by thorough study of numerous continuous serial sections of slides from fœtal and post-fœtal periods. I came to the conclusion that from now on the question of this demarcation line has to be considered in a quite different way. This line is not constant but is subject to marked individual fluctuations. Strictly speaking it does not exist at all, as I shall show later on by proving the opinion on the unitary entodermal origin of both epithelial types. I found that the post-fœtal period cannot be of any help in answering this question as well as all the basic problems of the development of the middle ear, because the middle ear is already completed in all its main features at the time of birth. Moreover, also in the fœtal period one has to look back to quite early times. While studying fœtal periods early enough, I obtained results which in their principal points differ from those of such former authors as Hammar, Wittmaack, Siebenmann and others. My results agree fully with Frazer's embryological conclusions about the origin of the tube from the first gill cleft and of the middle ear from the second one :

In the fourth fœtal month we find numerous small marrow spaces inside the just developing temporal bone. These spaces are placed at a certain distance from that embryonic tissue of tubal origin, which is known as tubo-tympanic duct. Among these small marrow spaces we find one which is remarkably larger than the other ones. Its red marrow tissue does not seem to differ at the beginning from the marrow of the small marrow spaces and actually they are communicating with each other. Gradually, however, there occurs a transformation in the structure of that larger marrow space. Its cytologic polymorphism, so characteristic for marrow tissue, disappears. It becomes poorer in cells. Finally, it assumes the poor-in-cell structure of the typical jelly-like tissue as described by Wendt. In this tissue there is formed further on a cleft-like space. To its walls endothelial-like cells, originating from the mesenchym of its marrow become apposed gradually. These mesenchymal cells come to be the covering epithelium of the cleft-space.

At the same time the above mentioned tubal canal, i.e. the so-called tubo-tympanic duct grows in the posterior and lateral direction, still separated from the described cleft space by a layer of germinal tissue. In consequence of growth processes of both the tubal canal and the cleft space

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structures the two become approximated to each other. Finally, after the tissue separating them has disappeared, they unite to form a roomy continuing entity with a common lumen. This is the true origin of the tubo-tympanic space in which the above described cleft-space—a derivative of the marrow—is to be looked upon as the original tympanic cavity.

Teleologically speaking we should describe the process in such a way as to take into account a biological tendency which puts on a definite section of the marrow tissue inside the temporal bone a special function, namely that of sound transmission, while the tubal canal fulfils the function of equalization of air pressure, both functions being intimately associated with each other. Knowing the development we have to consider the described processes, i.e. :

(*a*) the transformation of the rich-in-cells marrow into the poor-in-cells jelly-like tissue,

(*b*) the formation of the cleft, and

(*c*) the self-epithelization (*pneumatization*) of the cleft,

as an adaptation process to the acoustic functions. We may observe also elsewhere in human and animal organisms similar structural developments : for example during the formation of blood vessels from cleft-like structures of the mesenchyme.

It is clear that simultaneously with the fusion of the two mentioned structures also two different epithelia come into mutual contact : the cylindrical entodermal epithelium of the tubal duct and the endotheliform mesenchymal flat epithelium of the pre-tympanic cavity.

No question of any transformation of the cylindrical epithelium into the flat one or *vice versa* exists at all. That is the reason why no cytological structures of such transformation could have been described. From the first moment of their union the two kinds of epithelium are designed for continual contact, but they are *a priori* different and remain so. Their difference is not only a morphological but also a functional one :

The cylindrical epithelium of the tube resembles functionally and morphologically as well as in its origin the epithelium of the nasopharynx and that of the upper respiratory passages. Similarly as the latter it develops morphologically so as to form a typical mucous membrane, a loose submucosa and acinar sero-mucous glands. Also the adenoid tissue, stopping in the fœtal tube at the ostium pharyngeum, grows gradually into the tubal mucous membrane. The tube forms a secretory organ as well as one of defence. On the other side the submucosa of the tube contain, especially laterally and inferiorly, rich loose tissue which is responsible for its ability to form folds. This is related to the motorial function of the tube (opening and closing).

Quite different from that of the tubal epithelium is the origin, the morphology and the function of the one-layered flat epithelium of the

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bitympanum : in contrast to the highly developed tubal mucosa, the lining of the bitympanum is formed by a thin membrane. It forms only a delicate separating layer between the acoustic air-space and the periosteum of the temporal bone, respectively the jelly-like tissue. Spread smoothly over its basis it preserves the integrity of the pneumatic space and acts—together with ossicles, tympanic membrane, labyrinthine windows, ligaments and tympanic cavity muscles—as a sound-transmitting and sound-transforming medium.

On the other hand, it is relatively powerless when facing chemical, toxic and infectious factors. Never does it respond to stimuli by a secretion as it is devoid of glands. Depending on circumstances its reaction consists of transudation or exudation of a serous respectively inflammatory, at times also bloody or purulent fluid, possibly also with production of fibrin. It recalls both morphologically and functionally the features of a serous membrane. Thus, I might propose to consider the description of the lining of the bitympanum as a mucous membrane as unfounded and define it, in some analogy with the endocardium, as "*endotympanum*".

A few words must be said about the line of demarcation between the two kinds of epithelium: the cylindrical and flat one. As I have said already their delimitation is by no means constant according to the fluctuating physiological or pathological processes which take place continuously in the tubo-bitympanic spaces. Those processes are influenced by tubogenous or hæmatogenous factors. Of these factors the tubogenous ones are especially frequent. The growing significance of the latter during the last section of fœtal life and still more so during post-fœtal life brings it about that the cylindrical ciliated epithelium of the tube and its whole mucous membrane is continuously advancing against the delicate and somehow defenceless endotympanum. Just towards the end of fœtal life it has proceeded as far as the border between the protympanum and tympanic cavity and even into the antrum. This may occur even when the physiological conditions be obviously undisturbed. The two epithelial types may grow through each other. In serial sections from the ninth and tenth fœtal months I found that in microscopically small parts the antral wall was covered alternately with one-layered flat epithelium and ciliated cylindrical tubal epithelium. No microscopical signs of any pathological processes in those cases were observed.

3. The origin, morphology, extension and function of the jelly-like tissue of the middle-ear spaces

The microscopic picture of the sparsely celled jelly-like tissue as described by Wendt is to be found only in a small number of my investigated cases. In the other cases I found all the possible transitional pictures starting with that of Wendt and ending with the typical pictures

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of the richly cellular bone marrow. Considering the polymorphism of this tissue I propose to base its nomenclature not on a morphological but rather on a functional background and to call it " pneumatic tissue " instead of the term " jelly-like tissue."

The cause of the variability of the morphological picture of the pneumatic tissue is its lively reaction to any chemical, toxic and infectious stimuli whether they come out from the pharynx through the lumen of the tubo-tympanic space or from the blood stream. The acoustic middle-ear space demands absolute exclusion of any stimuli excepting those which are sound specific. To this state of ideal rest Wendt's picture of pneumatic tissue is adequate. We will call it the " classical " jelly-like tissue. Any disturbance will bring about migration of cells from the bone marrow into the pneumatic tissue. The result is an increase in its cell-numbers.

Gradually intensified cellular migration due to continuously acting stimuli may lead even to an inflammatory infiltration. I have myself found such a picture in the fœtal middle ear and described them as " otitis media fœtalis "[3]

4. The pneumatization and eburnation of the temporal bone

I have described above the primary stages of pneumatization and the union of the pre-pneumatic space derived from the marrow tissue with the fœtal tube. The next stages of pneumatization are accomplished in a similar way. Thus, at the end of the fœtal period there is formed the mastoid antrum. Also in this case a pre-pneumatic space with its own mesenchymal epithelium is formed and later on it unites with the tympanic respectively epitympanic space. On the whole, as pneumatization continues, the subepithelial pneumatic tissue spreads more and more, still it never breaks its immediate connection with the deeper lying marrow tissue which is its mother-tissue. At the place where the pneumatization process has already come to an end, the pneumatic tissue becomes gradually thinned out and here and there it actually disappears. Later, in such places the endothelium of the bitympanum with its basement-membrane becomes directly apposed to the periosteum. In few places, however, the pneumatic tissue remains in the form of islands. Later I shall discuss in detail the significance of this fact.

It is very important to appreciate the fact that the scope of distribution of the pneumatic tissue corresponds closely to that of the bitympanum. It reaches on one side the far distant pneumatization region of the mastoid process and on the other side the narrow anterior end of the protympanum, i.e. the isthmus tubae. Here it ends sharply. The lateral wall of the tympanic cavity and of the protympanum, however, is not involved in the pneumatization process. That is due to the fact that the laterally situated os tympanicum of man is not subjected to any pneumatization.

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Thus, the pneumatic tissue forms a further histological support for my proposed division of the middle-ear spaces into bitympanum and tube.

The tubal cells described in otosurgery as petrous-bone-cells are nothing else but a part of the whole pneumatic system of the bitympanum, shifted into an advanced position of the protympanum.

Besides the origin, function and the scope of distribution of the pneumatic tissue it is also important to know the age until which we may recognize this tissue in the sphere of the pneumatic system.

Nowadays Wittmaack's view is generally admitted that the pneumatic tissue disappears finally during the fifth year of life, i.e. at the end of the so-called third and last pneumatization phase of Wittmaack. In contrast to this I have found islet-like remnants of this tissue in elderly people. The slides in my possession showing this fact are from a 37 years' old individual. I feel justified in stating that in individuals with normal pneumatization the pneumatic tissue never disappears. This fact appears to be of fundamental significance. All through life the pneumatic tissue has as one of its main functions the challenge to the process of pneumatization.

Ossification and pneumatization are two antagonistic tendencies playing inside the temporal bone. Ossification is a quite general function of bone. It is being taken care of by osteoblasts. Pneumatization is a local specific tendency limited to the bitympanum and serving the pneumatized sound-transmitting apparatus. The state of normal pneumatization of the temporal bone is the result of equilibrium between functions of osteoblasts on one side and the pneumatic tissue on the other side. The relative strengthening of osteoblasts or a weakening or destruction of the pneumatic tissue leads to osteosclerosis (eburnation). This means that the pneumatic tissue does not represent only a factor of keeping the above mentioned equilibrium under physiological conditions, but also that it plays an important rôle in pathological processes. The bitympanic epithelium when destroyed by inflammation is renewed by this tissue. After spontaneous sequestration of the temporal bone as well as after oto-surgical bone-operations the remainder of the pneumatic tissue of this region represents a source for regeneration of the lost epithelium (epithelization) and also for renewed pneumatization-tendencies.

The epithelization of a cavity following a radical operation might develop according to this point of view not only from the ectoderm of the external auditory meatus, as is the general belief to date. It should be admitted that also the mesenchymal endothelium and even remnants originating from pneumatic tissue or marrow tissue participate to some extent in this epithelization process.

In the same way as inside the bitympanum the bony tissue with its osteoblasts and the pneumatic tissue, so also the whole of the tubo-tympanic tissue forms an equilibrium system of two structures which are essentially different in every respect, i.e. in their histogenesis, morphology

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and function. *The tube* is the product of the first branchial cleft provided with entodermal epithelium. *The bitympanum* on the other side is a mesenchymal product which according to the studies of Frazer, is derived from the second branchial cleft and develops its tissue from the marrow of the temporal bone.

The tube performs the twofold function of protecting the perfection and integrity of the acoustic work of the bitympanum, i.e. the equalization of air pressure and the defence, the first of them being performed by the cartilaginous-muscular apparatus, the second one by its highly developed mucous membrane with its glands and lymphoid tissue and by its cilia. *The bitympanum* with its delicate endothelial covering is adapted to the acoustic functions only.

5. The pathogenesis and some clinical aspects of middle-ear diseases

The artificial separation of the bony tube from the pneumatic middle-ear region and its incorporation in the conception of the tube could not help leading to some continuous confusion of ideas in the clinic of the tube and of the pneumatic middle-ear spaces. It made it *a priori* impossible to settle rational clinical entities. This feeling of unclearness grew during my many years of clinical otological practice and was the stimulus for these morphological studies.

What I hope to obtain by means of the changes proposed here, is some improvement in clear-cut distinction between clinical disease-pictures which are essentially different in their symptomatology, pathogenesis and therapeutic indications. Here, too, as in the former section, I might start by proposing some innovations in the nomenclature. The conception of otitis media as a single entity has to be subdivided in accordance with our new division principle. The inflammatory diseases of the tube (as it is understood by me) will be described as " *Eustachitis* " and the diseases of the bitympanum as " *Bitympanitis* ".

Eustachitis is a typical disease of the mucous membrane comparable with tracheitis, pharyngitis, rhinitis. It is closely related to them clinically and is frequently their consequence. Eustachitis has to be diagnosed, as far as possible, in conjunction with the above mentioned diseases by direct examination of the nasopharynx as well as of the tube, through the ostium pharyngeum and possibly has to be treated in the same way. This has been already raised, to some extent, by Gyergay and other authors. The condition of eustachitis shows besides the general symptoms also some special peculiarities which are conditioned by the cleft-like structure and the hidden position of the tube as well as by its function in respect to the bitympanum. These peculiarities are, shortly, (1) continuous gapping or occlusion of the tube, (2) propagation of catarrhal or suppurative infections from the nasopharynx and the

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tube into the neighbourhood and especially into the bitympanum, into the cartilaginous tissue or into the muscles of the tube.

In the complex of *bitympanitis* we have to distinguish three principal conditions: (I) A disease of the endothelium of the bitympanum, i.e. of the endotympanum only. It may be called "*endotympanitis*". (II) A disease of the pneumatic tissue and of the marrow tissue which is intimately associated with it. A disease involving only the pneumatic tissue may be called "*pneumitis*", and if it is associated with a disease of the marrow then it may be called "*pneum-osteomyelitis*". (III) The third condition is a disease of the substance of the temporal bone. It may be called "*osteitis*".

(I) *Endotympanitis* to some extent conforms with the clinical conception of otitis media *non complicata* as we have understood it up till now. However, it shows some important differences. Firstly, it includes also the protympanum. Secondly, it excludes any other tubal disease. Thirdly, it is not a disease of the mucous membrane, as any conception of a mucous membrane in the bitympanum has been generally rejected. Endotympanitis, however, is a collective conception of greatly differing clinical pictures and it may be classified under many sub-divisions. It may be acute or chronic—serous, suppurative or plastic, manifest or insidious and even latent. It may attack different parts of the bitympanum or even all of them at the same time. The picture of an affection of the main tympanic cavity comprising the mesotympanum, the hypotympanum and the protympanum is different from that of the epitympanum (attic) and of the mastoid antrum. In the first case the tympanic membrane forms a favourable point of discharge. The picture is different when the attic and the antrum are attacked, while the hiatus epitympanicus is narrow and sometimes closed. Still other conditions are present when the endotympanum of the whole pneumatic system is affected. Yet, all these conditions have a good prognosis, whichever the clinical symptoms, provided that the otologist is enabled to be sure of the diagnosis "endotympanitis", this being essential for both prognosis and treatment. I will not enter here into details of this extremely interesting clinical question. It is proposed to present here only some preliminary remarks on that complex system. They are meant as a starting point, open for question and discussion. Before concluding this section I might devote a few words to the discussion of the histo-pathological process which forms the basis for the endotympanitis. According to the opinion prevailing in these days and especially to Wittmaack, a leading investigator of this fundamental question, one has to deal in the case of otitis media with a *metaplasia* of the one layered flat epithelium of the normal tympanic cavity and of the pneumatic spaces into a cylindrical, mostly ciliated epithelium.

However, this is not so. I have touched on this point earlier in this

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paper. What takes place here really, is a destruction (degeneration, tearing down) of the diseased, extremely delicate and labile endothelium of the bitympanum spaces, i.e. of the endotympanum. Let us recall here that from birth on and actually earlier still, the cylindrical tubal epithelium is found, under physiological conditions, in a continuous advance against the bitympanum, and that the endotympanum grows through it in an islet-like and creek-like manner, so that in the child and still more so in an adult it may advance to distant parts of the bitympanum. In a case of endotympanitis this cylindrical epithelium makes rapid progress and overgrows these regions of the bitympanum which became denuded of the endothelium by the inflammatory process. We are dealing here with a defence-function of the tubal mucous membrane assigned for this purpose. Thus, at the apex of the disease we find in the affected region a layer of cylindrical ciliated epithelium. Also lymphoid tissue from the tube and also other cells derived from the deeper lying marrow-tissue of the temporal bone migrate into the bitympanum. This is the picture of an inflammatory infiltration.

Two alternatives are now to be distinguished :

(*a*) If the damage is overcome regeneration of the endotympanum starting from the pneumatic tissue takes place. At the same time the cylindrical epithelium withdraws into its old or almost old limits. This is the histological picture of a *restitutio ad integrum*. Such a process limited only to the endotympanum, i.e. endotympanitis, has not any influence on the state of pneumatization of the temporal bone, i.e. it does not form any basis of hindering it. Such hindrance could result only from a definite damage done to the deeper layer, i.e. to the pneumatic tissue.

(*b*) Another possibility in the clinical development of the endotympanitis is the irreversible destruction of the endotympanum. In this case the advanced tubal cylindrical epithelium stays permanently. These affected regions, devoid of their normal cover, may be looked at as devoid also of their specific acoustic nature. Now, they are a damaged region provided with heterogeneous tissue : the tubal mucous membrane. Further developments may lead to transformation into plastic and later on into fibrous tissue. This is the histo-pathological picture of the chronic adhesive process. In such cases, also the deeper layer of the pneumatic tissue gradually suffer destruction. This state of things results in the alteration of the pneumatic processes of the temporal bone, which is to be discussed presently.

II. *The condition of the inflammatory diseases of the pneumatic tissue and of the marrow tissue* (*pneum-osteomyelitis*) corresponds in general to the clinical picture of reversible and not necessarily operative mastoiditis. Also here the decursus may display the varieties mentioned in the first group in respect to the slow or quick course, the quality of the exudate

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and the clinical symptoms. All the regions of the bitympanum may be attacked by it including the protympanum (tip of the petrous bone). It is this disease which leads to an alteration of pneumatic processes of the petrous bone, the so-called osteosclerosis or eburnation. This alteration takes place only in this case when the inflammatory disease does not result in a complete regression, i.e. when it leaves permanent damage to the pneumatic tissue. This occurs especially in latent, lingering cases. These are mostly hæmatogenous and not tubogenous cases. Thus, in my opinion, the very cause of the eburnation is in no way a disease of the mucous membrane as is admitted to-day, but an essential damage to that structure which is responsible for the equilibrium between the antagonistic tendencies of ossification and pneumatization, the former belonging to the osteoblasts, the latter to the pneumatic tissue and its mother tissue : the bone-marrow of the temporal bone.

III. *The disease of the proper substance of the temporal bone* corresponds in general to the clinical picture of mastoiditis with an absolute indication for an operative intervention. It develops either—mostly in acute cases—together with the pneum-osteomyelitis and leads soon to destruction of the bone, or it represents a subsequent stage following pneum-osteomyelitis and then it may develop insidiously. It leads necessarily to destruction of the bone.

In the conditions II and III we have to distinguish two types : the tubogenous and the hæmatogenous. While the tubogenous type is usually preceded by an endotympanitis and shows in the beginning the well-known picture of otitis media purulenta with an eventual perforation of the tympanic membrane, the hæmatogenous type does not always follow such a course. On the contrary, this form may progress almost without any of those middle-ear symptoms, and in spite of marked bony changes the osteoscopic findings may be extremely scarce. Only during the later stages of an advancing osteitis there comes sometimes a break through. This may occur into the sinus, the labyrinth and the meninges as well as into the bitympanum. These cases being latent in a strict otological sense demand early diagnosis by following other than purely otological methods.

The conditions of eustachitis and bitympanitis as discussed above do not appear always in their pure form, but frequently associated with each other. However, a careful analysis will find the proper way to work out eventually the clear differentiation of either of the two conditions from diagnostic and therapeutic view-points.

Above I have discussed some otological pictures in order to show by means of an important example that the view-points proposed by me may be useful for otological clinical analysis, and be a springboard for further investigations.

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New Otological Views

Summary

(1) The established division of the middle-ear cavity and Eustachian tube is untenable.

(2) The bony tube being an anterior evagination of the tympanic cavity has to be separated from the so-called tube, i.e. the cartilaginous + bony tube, and incorporated into the tympanic cavity. As integral part of the tympanic cavity it should be called " protympanum " in analogy with the epitympanum and hypotympanum.

(3) The extended tympanic cavity containing the tympanic cavity + protympanum + pneumatic spaces should be called " bitympanum ".

(4) The bitympanum spaces and their covering epithelia do not develop as usually supposed from the tubal duct with its entodermal epithelium. It develops independently from the marrow of the fœtal temporal bone and its mesenchymal tissue. Consequently the union of the early tympanic cavity with the fœtal tubal duct is a secondary process. This mesenchymal origin concerns also the whole of the further process of pneumatization of the temporal bone.

(5) A new conception of the jelly-like tissue of the middle-ear spaces is presented and its rôle in various processes of the regeneration of the temporal bone and of pneumatization is pointed out.

(6) The results of the former investigations lead to a new conception of the pathogenesis of otitis media and its complications and of the eburnation process of the temporal bone.

(7) A new classification of otitis media with broader clinical aspects based upon the new classification is proposed.

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