ful pressure by bandaging was employed in order to prevent the formation of a hernia, but without success. Pressure from this cause may have originated the attack of violent convulsions.

The gauze strips soon ceased to serve as effective drains, and the secondary discharge of cerebro-spinal fluid always issued from a very small aperture situated at the centre of the hernia. This is not the position it would be expected to escape at if it came from the sub-arachnoid space. The position suggested that its origin was from the fourth ventricle. In a previous case under the care of my colleague, Mr. Hugh E. Jones, a very similar hernia followed the evacuation of a cerebellar abscess, and the museum specimen shows a tract communicating with the fourth ventricle. The mother of my patient reported in September 1912 (nearly three years after the operation), that he was quite well and working. No pad or bandage was used after the wound was firmly healed.

DIFFUSE OSTEOMYELITIS FROM NASAL SINUS SUPPURATION.

By Dan McKenzie, M.D., F.R.C.S.E.,
Surgeon, Central London Throat and Ear Hospital.

"In the pleasant orchard closes
'God bless all our gains,' say we.
But, 'May God bless all our losses,'
Better suits with our degree."

Diffuse osteomyelitis of the bones of the cranium is one of the rarest complications of nasal sinus suppuration. But it is the commonest serious sequela of nasal sinus operation.

Within the last seven or eight years several important treatises on the disease have been published abroad, based, for the most part, upon collections of the isolated cases and groups of cases that have, from time to time, appeared in the medical periodicals. It is to the work of Schilling, Röpke, Gerber and Luc that we are indebted for these papers upon which our present knowledge of nasal sinus osteomyelitis so largely depends. So far as I am aware no systematic discussion of the disease has hitherto appeared in English. This hiatus in our literature is my excuse for the present disquisition on the subject, to which, as a matter of fact, my attention was first drawn by the occurrence of a case of the disease in my own practice.

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History.

Prior to the antiseptic era, osteomyelitis of the skull was a common consequence of open injuries of the cranial bones. It is easy to gather, for example, from the case-narratives in such books on surgery as that of Fabricius Hildanus, that the disease must have been a familiar experience with the surgeons of the seventeenth century. Its true nature was, of course, unsuspected, and even its most striking feature, the association of pericranial abscess with extra-dural abscess, remained unknown until Percival Pott, in 1760, first drew attention to what came to be afterwards known as "Pott's puffy tumour." That these para-osseous abscesses depend upon a disease of the bone was first discovered by von Bergmann and Lannelongue in 1879, but it was not until nearly twenty years later, until 1897–98 to be exact, that the occurrence of osteomyelitis as a complication of nasal sinus suppuration was first detected by Tilley.[1] Before that event osteomyelitis of the cranial bones had been generally ascribed to some systemic malady of the septicæmic order, such as measles, typhoid fever, erysipelas, carbuncle, and so on. But since then the cases reported in the literature have been for the most part referred to nasal sinus or aural suppuration.

In 1904 Schilling's classical monograph appeared. It was based upon a series of nine cases, and of these only five were rhinogenic. In Gerber's collection the number of rhinogenic cases had risen to 29, while in Luc's paper, which appeared in the same year, 25 cases were collated, and as 10 of his records were additional to those of Gerber, the total number reached 39.

From that number I am compelled to deduct one, that of Dr. Scanes Spicer (1905, see appendix), which proved to be syphilitic and not septic in nature. And to that number I am able to add seven others from the literature, one reported by Logan Turner in 1905, and detailed in the appendix to the present paper; one by Van den Wildenberg in 1909; two by Von Eicken in 1909; one by Wolff Freudenthal in 1910; one by Charters Symonds in 1911; and one by Walker Downie in 1911. Finally, I report in the appendix three others; one a case under my own care; one a case of Mr. E. J. Davies; and the third a case of my colleague's Dr. Andrew Wylie. In Andrew Wylie's case the disease definitely originated in the maxillary antrum; and it is apparently the only instance recorded having this origin, with the possible exception

[1] Luc shares with Tilley the honour of this discovery, both of their cases being described in papers read before the British Medical Association in 1889. Luc's case occurred in 1898–99, however, the year after Tilley's.

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of one by Claoué (1905), and another by StClair Thomson (1905).[1] Thus I am basing my remarks upon the records of 48 cases in all.

These figures do not, I am constrained to say, by any means represent the total number of cases of osteomyelitis that have occurred in the practice of recognised rhinologists within recent years, for there are very few specialists of position who have not, at some time or another, experienced one or more of these cases.

Pathology.

Septic osteomyelitis, which is, in reality, an infective inflammation, not of the marrow only, but of all the constituents of bone, presents several different varieties. The most familiar type is the osteomyelitis which attacks the vascular epiphysial line of the long bones during the period of growth. With this type before their minds, Schilling and the other earlier writers on sinus osteomyelitis of the cranial bones were inclined to draw a sharp line of distinction between the disease as it affects the long bones and the disease as it affects the skull. First of all, it was said, osteomyelitis of the long bones is a disease of childhood and early youth, while osteomyelitis of the cranial bones is most frequent in the second, and especially in the third decades of life. Again, osteomyelitis of the long bones was described as a circumscribed and self-limiting process, while osteomyelitis of the cranium is progressive and illimitable.

It is obvious that the antithesis here constituted lies between osteomyelitis of the epiphysial line of children, a common and well-known disease, and sinus osteomyelitis of the skull of adults, a rare disease. And the natural inference to be drawn from that antithesis is, that osteomyelitis when it affects the cranium behaves in a fashion altogether unlike its habit when it attacks the bones of the skeleton, and that osteomyelitis of the cranium is, therefore, a pathological entity separate and distinct in its nature from osteomyelitis elsewhere.

Such, however, is not the case. If we compare nasal sinus osteomyelitis, not with epiphysial osteomyelitis, but with another type of the disease, with what is known as "chronic diffuse osteo-

[1] We shall have occasion from time to time to refer to Claoué's and StClair Thomson's cases. They occupy a doubtful position in that the disease followed operation on the maxillary antrum, but appeared first in the ethmoidal and frontal regions.

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myelitis" of the long bones, we shall find so many features (rarity, chronicity, intermissions, etc.), clinical as well as pathological, common to both, that the essential identity of the two processes will become visible at a glance. Whatever diversity may exist between them is due, not to any inherent and radical difference in nature, but solely to dissimilarity in environment and anatomical structure.

The most striking diversity lies in the fact that the diffuse osteomyelitis of the cranium is referable in the vast majority of cases to some contiguous infective focus in the ear or nasal accessory sinuses. (In this paper I propose to confine my attention chiefly to the latter.) "Idiopathic" cranial osteomyelitis has no doubt been recorded by several trustworthy observers, among others by Fischer and Schilling. (Schilling's case gave no evidence of tuberculosis or tabes; the ears were normal; and the disease was of a fulminating character, ending fatally in seven days.) But these idiopathic fulminating cases are extremely rare, and obviously do not invalidate the comparison we have drawn between chronic diffuse osteomyelitis of the long bones and nasal sinus osteomyelitis of the flat bones of the cranium, which also merits the title "chronic diffuse." To it we now turn.

The Sinus of Origin.—Of the thirty-eight valid cases collected by Schilling, Gerber and Luc, thirty-six originated in the frontal sinus and two in the maxillary antrum. If to these we add the cases appended to the present paper, we shall find forty-five originating in the frontal sinus and three in the antrum.

In speaking of osteomyelitis as originating in one or other of these sinuses, we do not mean to imply that the frontal sinus or the antrum was the only sinus diseased, for in nearly all of the cases the sinus suppuration was multiple, but, as the first sign of bone-disease appeared in the frontal bone or superior maxilla respectively no doubt is left in our minds as to the actual site of origin.

With regard to the ethmoidal cells as the starting-point of osteomyelitis, the only indication of such an event that I can find in the literature appears in Van den Wildenberg's case (No. 2 of my list; see appendix), in which a small sequestrum of the os unguis was first removed by the surgeon, and fourteen days later a large sequestrum comprising the crista galli and the lamina cribrosa of the ethmoid. In the reporter's opinion, however, the disease began in the frontal sinus. In one of Sir StClair Thomson's cases also the "traumatism caused by the Caldwell-Luc operation" was held to have "stimulated the latent suppuration in the ethmoid," as well

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as in the frontal sinus. With these equivocal exceptions, the records are silent as to the onset of osteomyelitis from ethmoidal cell suppuration. Nevertheless in all probability a spreading bone infection starting in this region does occur. The proximity of the ethmoid to vulnerable parts of the meninges, however, will lead to the onset of meningitis before the disease in the bone can declare itself, or, at all events, before it becomes so obvious as to be readily recognised *post-mortem*, and the case will pass into history as one of an intra-cranial complication pure and simple, the osteomyelitis being overlooked.

A study of the literature, indeed, brings to light many cases in which the importance of osteomyelitis as the stepping-stone to the final stage of infection failed to obtain due appreciation. Guisez it was who first drew our attention to this error. He does not, however, apply his remarks to the ethmoidal cells.

As an illustration in defence of this reasoning we may cite the instructive case recently recorded in the JOURNAL OF LARYNGOLOGY, RHINOLOGY AND OTOLOGY by Dr. Gregory, of Highgate, in which a perforation of the cribriform plate, *the bony edges of which were discoloured*, led to the terminal event.

When we turn to the sphenoidal cells, we find here also an absence of any record of osteomyelitis. Whether or not the argument we have led concerning the ethmoidal cells is applicable also to the sphenoidal, time alone will show.

In considering the frequency of osteomyelitis as a complication of nasal sinus suppuration, it must not be forgotten that bone infection with caries or necrosis is frequently encountered in the bony wall of the sinus in which surgical intervention of a comparatively simple kind leads to rapid cure. But in these cases the disease is limited to the osseous walls of the sinus (the so-called *sinusitis abscedens*), and shows but little tendency to overstep these limits. In other words, this type of osteomyelitis is, as a rule, discrete and self-limiting. Consequently, it does not come under the heading of "diffuse" or progressive osteomyelitis, the outstanding and distinctive feature of which is the extension of the disease beyond the boundaries of the affected sinus.

Here, on the very threshold of our inquiry we are met with the question: Why is frontal sinus suppuration more prone to lead to osteomyelitis than is suppuration in the maxillary antrum?

Before we attempt to answer the question, let us examine the presumed fact. That frontal sinus suppuration leads to fatal osteomyelitis more frequently than does maxillary antrum suppura-

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tion is certain. The figures we have given leave no room for doubt upon this score. But to the unrestricted question as to whether osteomyelitis, localised as well as progressive, is more common in the frontal sinus, the actual statistics at our disposal supply no answer. It is possible that localised osteomyelitis may occur not infrequently in the walls of the maxillary antrum, but that the anatomical and particularly the vascular arrangements about that cavity, permit of an easy cure of the disease. One may wonder, also, whether the fatal septic "pneumonia" which occasionally follows operation upon the maxillary antrum is not sometimes due to osteomyelitis and septic thrombo-phlebitis arising therefrom.

At the same time, while making every allowance possible for surmise and speculation, most rhinologists will, I think, agree that in their experience the frontal sinus is undoubtedly the more common site of origin of osteomyelitis, both localised and diffuse.

Further, most writers explain this emphatic preponderance by referring it to the readiness with which the infundibulum can be obstructed and the drainage of the cavity prevented.

Process of Infection.—As a matter of fact, from none of the cases so far recorded and described is there any information to hand regarding the route by which the bone received its infection from the suppurating sinus. This, the first stage in the evolution of the disease, still awaits demonstration. Consequently the opinions that have been formed about it largely depend upon analogy with similar processes of bone infection in the ear and elsewhere.

Two methods of infection are presumed; first, direct invasion by the organisms of the osseous spaces, canalicular and medullary, of the bony wall of the sinus; and secondly, primary infection of the small efferent veins of the lining membrane of the sinus with subsequent infection of the bone from the veins. In my opinion the former is the more important, but it is obvious that both methods may act in combination.

In the first method, that of direct infection of the bone from the sinus, it stands to reason that the pyogenic organisms may enter the bone if the defensive powers of the lining membrane are weakened or destroyed by pathological changes, or if the protecting barrier is removed by operative manipulations. As a result, a localised osteomyelitis will be produced. But, before the disease can become progressive and diffuse some other factor must come into play, otherwise osteomyelitis would be much commoner than

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it is. Schilling and others are inclined to suggest that this factor may be found in the disposition of the diploë of the frontal bone with relation to the sinus. According to Schilling, the diploë abuts upon the walls of the sinus, as a rule at one place only; namely, in the neighbourhood of the upper recess where the anterior and posterior walls come together. Occasionally, however, the diploë will be found, on section, to extend down for some distance in the anterior, or, more rarely, in the posterior wall. Variations in this arrangement are often manifested in different parts of the same sinus (see Figs. 1 and 2). The proximity of the diploë in such

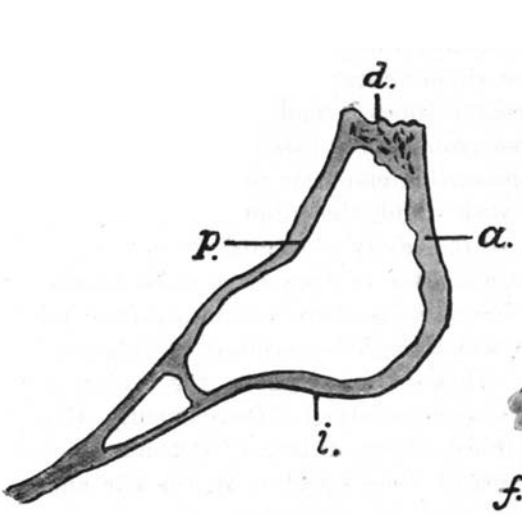


FIG. 1.

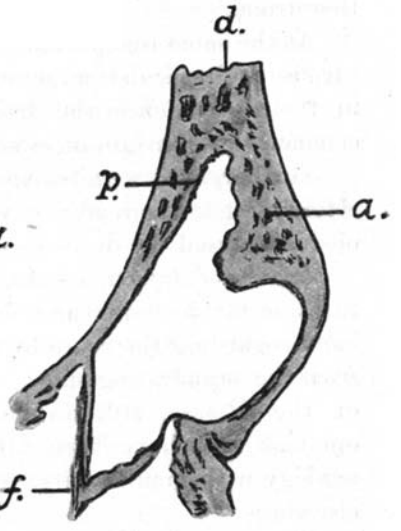


FIG. 2.

Sagittal sections through the same frontal sinus (from Schilling). *a.* Anterior; *p.* posterior; *i.* inferior, walls of the sinus; *d.* diploë; *f.* infundibulum.

cases to the diseased cavity, or its exposure when cut through by the surgeon, lays it open to infection, and the presumption is that those bones in which this anatomical arrangement holds good are thereby rendered specially liable to osteomyelitis.

In this argument, it seems to me, rather too much weight is laid upon the part played by macroscopically spongy or diploic bone. No doubt the infection is able to extend more rapidly when once the diploë has been reached, but in my opinion the essential spreading quality of the disease is not necessarily conditioned, and perhaps not even favoured, by the proximity or the exposure of the diploic medulla.

My reasons for this conclusion are as follows: Osteomyelitis

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(that is, diffuse osteomyelitis) is not limited in its spread to diploic bone and to diploic bone only. As we shall see later on, the disease extends, not infrequently and quite early in its course, to involve the thin hard bones of the ethmoid, lachrymal bone, nose and orbit. Moreover, in its extension the disease does not spare the frontal eminences, where the diploic tissue is attenuated or altogether deficient. Finally, as every operator knows, a spongy or diploic structure of the anterior wall of the frontal sinus is by no means an uncommon finding, whereas spreading osteomyelitis is an extremely rare disease.

Indeed, one might just as reasonably assume that frontal bones of unusually dense consistence were, by reason of their very poverty in blood-vessels, more prone to undergo necrosis and to become the starting-point of a spreading osteomyelitis than those bones and parts of bones which are more highly vascular and so more able to oppose the invading organisms. And one could cite in support of this theory the relative infrequency of osteomyelitis in the maxillary antrum, the bone of which is thinner and more vascular than that of the frontal!

It should be remembered that osteomyelitis is an infection, not of the bone-marrow only, but of every constituent tissue of the bone.

So that—and this is, after all, tacitly admitted by Schilling and the other writers—the question is not one solely of the structure of the bone adjoining the sinus. Some other factor must be necessary (see "Ætiology").

The second method of origin, that of infection through the veins of the accessory sinus, speaks for itself. But here, again, the existence of venous infection would not necessarily entail progressive or diffuse osteomyelitis. We recur to this topic below.

The Spread of the Disease in the Bone.—By what path soever the infection reaches the bone, it tends to spread, this, as we have so often remarked, being the essential characteristic of diffuse osteomyelitis; and the extent to which the cranial bones may become affected is practically unlimited. Thus in Tilley's case, the necrosis involved the whole of the cranial vault, and the infection spread down to implicate the petrous portion of the temporal bone. Similar findings are recorded in many other cases.

This unrestricted extension is generally attributed (partly, at all events) to thrombo-phlebitis of the diploic veins, and in support of this view there may be cited an interesting case of Laurens, in which thrombosis of the diploic veins was found far in advance of the general bone disease.

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While venturing to express a doubt as to the importance of the diploë as the prime factor in the production of spreading osteomyelitis, I nevertheless admitted that the loose structure of the diploë and its medullary spaces must favour the rapid extension of the disease in any particular bone.

In like manner we may regard the part played by the veins. No doubt, when the infection reaches the interior of the veins its rapid extension is facilitated. And as the diploic veins traverse the cranial sutures the infection is thereby rendered independent of these barriers. But it must also be remembered that although the diploë is interrupted by the sutures, nevertheless in adult life there is direct continuity of the osseous tissue of all the bones of the skull, the sutures notwithstanding, so that apart from any venous route, the infection would be capable of passing from one bone to another across the sutures. For as we see, the skull is, for pathological processes, equivalent to one continuous bone, and it behaves as such. In a long bone chronic diffuse osteomyelitis is limited by the articulations. In the skull there are no such divisions, and the spread of the infection throughout the whole of the osseous structure, whether by dense bone or by veins, is not prevented by any natural impassable barrier.

That the infection makes a general advance and does not select any particular path is shown microscopically. In sections made of the bone at the edge of the disease in the frontal bone from Wylie's case, cocci (? staphylococci) can be seen in the Haversian canals under the periosteum, as well as in the diploic spaces and tissues.

Direction of the Extension.—As we have already indicated in one of the foregoing paragraphs, the spread of the disease is not limited to the cranial vault, although its favourite extension would seem to lie in the upward direction. But the nasal bones, the ascending process of the superior maxilla, the ethmoid with its cribriform plate (van den Wildenberg's case, No. 2 of my list), the delicate bones of the sides and roof of the orbit—any one or all of them may be invaded from above, and extension from the squamous to the petrous portion of the temporal bone is by no means unusual.

Pathological Anatomy : Macroscopic.—The affection of the bone is a purulent rarefying osteitis, or pan-osteitis, leading to more or less extensive destruction of all its constituent elements.

The appearances vary with the stage of the disease. In the earliest stage, such as is represented in the section from Wylie's

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case referred to above, the bone presents no naked-eye abnormalities, although during life the diploë might perhaps show some congestion. In the next stage the diploë on section is seen to be markedly hyperæmic and to be interspersed here and there with drops of pus. This is followed by the conversion of the medullary tissue of the diploë into granulation-tissue bathed in pus, which, on section of the bone, exudes copiously from the cut surfaces. Sometimes thrombosed and purulent veins may be seen occupying channels in the osseous tissue. The purulent secretion, finding its way to the outer and inner surfaces of the bony cranium by the vascular channels which penetrate the osseous tables, collects to form abscesses between the bone and the pericranium on the one hand, and between the bone and the dura on the other—the *para-osseous* abscesses. There can be no doubt that pus may also form primarily in the deeper layers of the periosteal membranes, whether dural or pericranial.

The pericranium, raised off the surface by the accumulation, quickly undergoes dissolution, so that the abscess collection comes to lie in the soft tissues of the scalp. Here, however, no delimiting abscess wall is formed, although the pericranial abscesses are, when they are multiple, quite discrete and separate from each other. In this way are produced the doughy or puffy swellings of the scalp, which form a striking clinical feature of the disease.

Unlike the pericranium, the dura shows little or no tendency to break down, and, for considerable periods of time, it opposes a persistent barrier to the infection. This is one of the most interesting and instructive facts in the pathology of osteomyelitis, illustrating as it does the extraordinary powers of the dura to protect the soft membranes and the brain from the action of septic organisms, even after the more obvious osseous defences have been destroyed. Granulations sprout from the outer surface of the dura, and, aided by pseudo-membranous adhesions binding its deep surface to the arachnoid (Jacques), generally succeed in keeping the infection at bay. In some cases, comparatively few in number however, the local defences instituted by the dura are penetrated, and direct infection of the brain or its membranes ensues.

The formation of pericranial and extra-dural abscess precedes and accompanies the third stage of the disease, which consists in the destruction of the tables of the skull, the external usually giving way before the harder vitreous. By this time more or less extensive areas will have undergone necrosis, and, if time permits, they

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proceed to exfoliate as sequestra, sometimes of a considerable size, but usually in small flaky fragments, which present the familiar eroded or worm-eaten appearance characteristic of bone undergoing molecular disintegration and absorption by granulation-tissue. In this manner the entire outer table may come to be shed, and during the process it looks "like lace-work" (Tilley), or

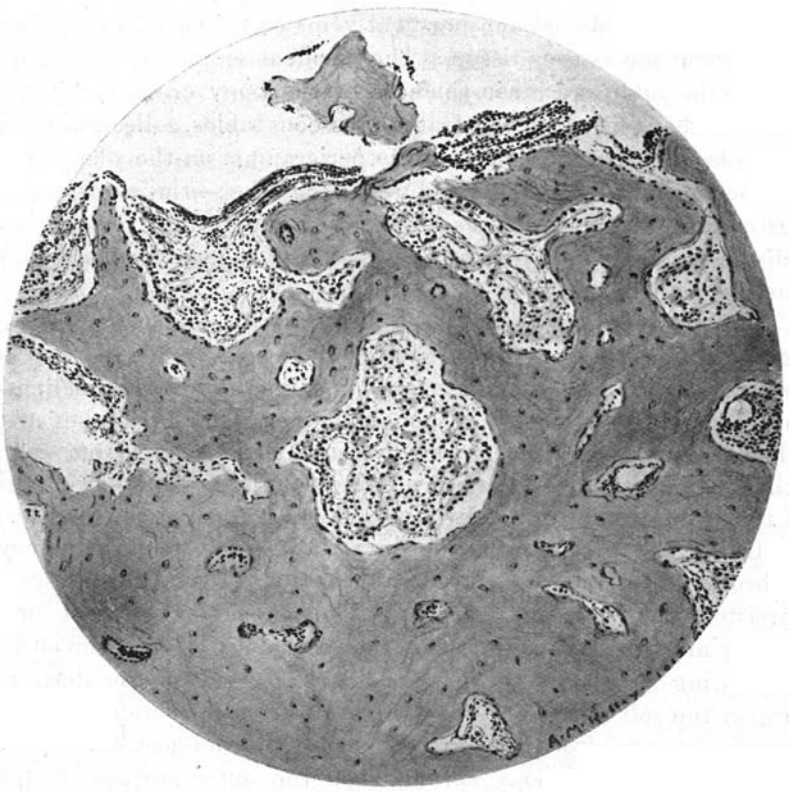


FIG. 3.—Diffuse osteomyelitis of frontal bone. Bone from neighbourhood of extra-dural abscess, showing round-cell infiltration of medullary and canalicular spaces. Erosion commencing.

as if it had been "corroded with an acid" (Luc), or small islets of necrosed bone may be seen lying in flat masses of granulation-tissue.

By the older writers the necrosis of bone was usually attributed to the isolating effect of the granulation-tissue masses, or to the separation of the pericranium and the dura, but modern pathology regards necrosis as an early event in the course of the disease, produced partly by inflammatory obstruction of the osseous vessels

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in the rigid Haversian canals, and partly by the direct action of the bacterial products upon the cell element.

New formation of bone, which occurs with such rapidity and exuberance in epiphysial osteomyelitis, either does not appear at all, or is scarcely perceptible. On microscopic examination some little attempt at regeneration may be visible, but it is entirely overshadowed by the processes of destruction. Indeed, in this respect, as in many others, the reactive efforts of the tissues seem to be feeble and incompetent.

At the same time, it is only during the active period of the disease that this absence of regeneration is to be observed. In favourable cases, when the osteomyelitis has been brought to a final standstill by the natural or surgical removal of all the necrosed bone, the gaps made in the skull by the ravages of the disease are almost entirely filled up again by the formation of new bone.

Microscopically, early specimens show that the first changes consist in an invasion of the bone spaces by micro-organisms, with round-cell infiltration of the medullary spaces, the walls of which, at this period, are still quite smooth, or are only just beginning to show some signs of lacunar absorption (see Fig. 3). The later changes, which we may regard as secondary to the necrosis of the bone, consist in the replacement of the bone-marrow by granulation-tissue, with absorption, erosion, and finally disappearance of the bony trabeculæ of the diploë. The outer and inner tables withstand the eroding action till a still later period, so that extensive sheets of granulation-tissue develop between the still intact, though lifeless tables. The blood-vessels contain thrombi more or less infiltrated with pus-cells, and signs of peri-vascular inflammation accompany the thrombosis when it progresses in advance of the general bone-disease.

Extension of Infection beyond the Bone.—We have already described the extension of the septic process from the bone to the neighbouring soft tissues of the scalp and to the extra-dural region. It remains to follow the infection in its migrations to other tissues and organs.

Metastasis to distant parts of the body is common in the osteomyelitis which follows accidental trauma of the skull-bones, but, curiously enough, it seems to be rather rare in accessory sinus osteomyelitis, whether spontaneous or post-operative. In this variety, to borrow an expression from the pathology of tumours, the malignancy is local rather than general. I have not been

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able to find any more than five cases of definite metastasis in the records; in three of these (Macewen-Millar's, cited by Killian, Tilley's and Durand's) the metastasis was secondary to intra-cranial sinus thrombo-phlebitis, and affected the lungs only; in the fourth (Körner's case, No. 9 of Gerber's list, and No. 6 of Luc's) osteomyelitis of the radius occurred as a sequel to the cranial disease—the patient recovered; and in the fifth (Logan Turner's, No. 1 of my list) an abscess formed around the rectum.

Thus we have to deal mainly with local extensions.

The following table, based upon one constructed by Gerber, gives some idea of the variety and comparative frequency of the local extensions and complications. I have omitted pachy-meningitis and extra-dural abscess as they have already been considered.

Subdural abscess	3
Thrombo-phlebitis (intra-cranial) . . .	9
Brain-abscess	10
Lepto-meningitis	15

Thus the most frequent complication is lepto-meningitis. We have seen that lepto-meningitis in consequence of direct invasion through the dura of the vault is unusual. As a rule the stout resistance offered to the infection in that situation staves off this fatal complication for weeks. And meningitis only sets in when the infection, foiled in the frontal attack upon the dura, turns its flank by spreading to the temporal bone and the labyrinth (Schilling's case), or by invading the lepto-meningeal spaces through the nerve-sheaths of the orbit (my own case) or the cribriform plate. In a number of the recorded cases, the route taken by the infection to reach the lepto-meninges could not be determined.

The inference to be drawn from these facts is that the danger-zone lies towards the base of the cranium where so many natural portals pierce the cranial fortifications.

Brain abscess, unlike meningitis, is generally produced by direct extension through the meninges in the manner familiar.

Septic thrombo-phlebitis has been found to affect the superior longitudinal, the cavernous, the circular, the petrosal, and even the lateral sinuses. Its development is, of course, due to the extension of the thrombosis from the diploic veins. Breschet, Zuckerkandl and Killian have demonstrated the free anastomosis, often amounting really to direct communication, which exists between the veins of the frontal sinus, the diploic veins of the frontal

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bone, and the superior longitudinal sinus. And Killian, in 1900, reported a case of thrombo-phlebitis of the superior longitudinal sinus as a complication of frontal sinus suppuration, and collected five others from the literature.

The venous sinuses at the base of the cranium are usually infected by way of the ethmoidal and orbital veins.

We may conveniently repeat here the remark we made in an earlier section that, since attention has been turned to nasal sinus osteomyelitis, we have come to realise that lesions such as those in the cases collected by Killian often really represent the terminal event in a spreading osteomyelitis. We make this comment without in any way throwing doubt upon the evidence in favour of septic thrombo-phlebitis being sometimes due to simple nasal sinusitis.

Care should be taken in performing autopsies upon such cases to note particularly the condition of the bone in and around all the nasal accessory sinuses, and to note carefully pericranial and extra-dural collections of pus—the sign manual of osteomyelitis. The patch of osteomyelitis may be so small as to escape anything but an expectant scrutiny, for the supervention of a fatal intra-cranial lesion may cut short the bone-disease in the very earliest stages of its development.

Bacteriology.

The bacteriological factor in diffuse osteomyelitis of the bony cranium cannot be satisfactorily discussed, for the very good reason that the causal organism is recorded only in eleven or twelve cases. Staphylococci (*albus* and *aureus*) are noted six times, streptococcus five times, and the pneumococcus once. There is an impression prevalent that osteomyelitis from the streptococcus is more pernicious than that due to the staphylococci, but the cases as recorded give no support to this idea. Luc at one time believed that he had had a case which exemplified the greater virulence of the streptococcus, but he has withdrawn the instance as the bacteriological finding, upon which his belief rested, turned out to be erroneous.

In the case of the long bones pathologists generally suppose that, while staphylococcus infection is the most common cause of osteomyelitis, any of the pyogenic organisms may induce the disease. And all the writers on nasal sinus osteomyelitis now agree that so far as the morphological type of the organism is concerned, no light whatever is thrown upon the ætiology of the

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disease. The part possibly played by variations in the virulence of the micro-organisms we shall discuss in a later section.

Ætiology.

Sex.—Schilling found a preponderance of females in his nine cases, the ratio being 8:1. Gerber's proportion was thirteen females to fourteen males. The latter author discredits the value of these figures, seeing that, in osteomyelitis of the other bones of the skeleton, males are affected three times oftener than females. Until a larger assemblage of cases has been made and analysed Gerber's agnosticism may well be imitated, and until that time we shall defer discussing the theory which accounts for a female preponderance by referring it to the greater relative amount of diploic medulla in the female skull.

Age.—The following table has been made up from Gerber's, Luc's, and my own collections:

0–10	years of age	2 cases.
11–20	,, ,,	8 ,,
21–30	,, ,,	18 ,,
31–40	,, ,,	4 ,,
41–50	,, ,,	3 ,,
51–60	,, ,,	0 case.
Over 60	,, ,,	1 ,,

The danger of arguing from the particular to the general, an instance of which we quoted in the preceding paragraph, forbids us to accept these figures as a correct and reliable guide to the age-incidence of the disease. Moreover, the figures, small as they are, must be further subdivided into two separate categories—the spontaneous and the post-operative—before their significance can become evident. This I have done, and although but little weight can be placed upon the result, it is interesting to be able to report that in the second decade of life spontaneous cases preponderate, while in the third decade the post-operative cases form a small majority. Most operations on the frontal sinus are, of course, performed on patients between twenty and thirty years of age.

Schilling believes that age may exercise some moderating influence upon the course of the disease, and selects the difference in years as the reason for the great contrast in rapidity of extension shown by two cases in his collection. Both were ear cases. In the one, a child of nine months, the whole cranium became infected in a few days; in the other, a woman, aged 66 years (Laurens'

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case), the disease ran a course of several months, and ended in recovery.

In starting out to discuss the ætiology of spreading osteomyelitis of the cranium from nasal sinus suppuration, we enter upon the most puzzling, and to us, as practising surgeons, the most important of all its problems.

From the standpoint of general pathology, there is no unusual mystery about the nature of the disease. Nasal sinus osteomyelitis is a septic process, which owes its existence to pyogenic organisms derived from a conveniently situated local focus. So much we know. But when we come to inquire how it is that some patients contract osteomyelitis and die of it; that others contract it and recover; while a third, and much the largest class, in spite, sometimes, of apparently dangerous circumstances, do not contract it at all—then we are confronted with a riddle which still awaits solution.

From a list drawn up by Gerber we learn that influenza, syphilis, trauma, dental disease, "cold," and measles have all been looked upon as having caused the disease, but as each of these is responsible for only one or two instances in his list of twenty-nine cases, we may pass them by as unworthy of further consideration. With regard also to "nasal obstruction and polypi," which is credited with five cases, nothing more need be said. This is only another way of expressing nasal sinus suppuration.

We have to deal with something very different when we come to the final cause in Gerber's list, namely, operation on the frontal sinus or maxillary antrum.

In order to obtain some idea of the significance of operation on the nasal sinuses in the causation of osteomyelitis I have submitted the cases recorded to a detailed scrutiny, excluding doubtful cases, and including only those in which the diffuse or spreading quality of the disease was unmistakable. Forty-one cases in all were deemed valid for the purpose. Of these:

A. In twenty cases osteomyelitis developed after operation.

B. In twenty-one cases osteomyelitis appeared spontaneously; that is, before any operation had been performed.

With regard to the post-operative class a word of explanation is necessary. In several of the instances recorded the disease did not appear until some weeks after operation, and it may be asked whether an interval so long does not exclude the operation from the possible causes of the disease. The doubt may be disposed of when we consider that progressive osteomyelitis is due to a

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tenacious infection, capable of long periods of latency, and an incubation period of several weeks is quite in keeping with the general characters of the disease.[1]

Again, it may be argued that the *post* has been taken for the *propter*, that the onset of osteomyelitis after operation is merely a temporal coincidence, and that the disease would have developed anyhow. But one has only to point to the figures in the above lists to destroy this contention. The proportion of twenty post-operative cases out of a total of forty-one proves the association to be more than a mere coincidence.

As to the nature of the operation that preceded the bone disease, I find that fifteen followed operation on the frontal sinus; two followed operation on the frontal and ethmoidal cells; and three followed operation on the antrum. In two of the records the disease was consequent upon such simple procedures as resection of the anterior end of the middle turbinal (Schilling's case), and removal of nasal polypi by the endo-nasal route (Roth's case).

The connection between operation and disease seems so remote in these two latter instances that one hesitates to regard them as belonging to the post-operative class, but even larger claims are made upon us by another series. The course of events in Claoué's and StClair Thomson's cases have led to the belief that operation upon one sinus, the maxillary antrum for example, may wake up osteomyelitis in another sinus, such as the frontal. The belief is not altogether acceptable, perhaps. In both of these cases an abscess of the floor of the orbit formed quite early in the course of the illness—a circumstance which suggests that the osteomyelitis in the frontal bone may have been secondary to osteomyelitis in the superior maxilla; in other words, that the frontal bone was infected by extension in the ordinary manner. But in a third case (van den Wildenberg's, No. 2 of my list; see appendix) the radical Killian operation on the *left* frontal sinus was followed in three weeks by osteomyelitis in the region of the *right* orbit. In this instance also, however, caution compels us to add that there is a note of an endo-nasal operation on the *right* side—date not mentioned. Thus in none of these cases is the documentary evidence quite unimpeachable. At the same time, the testimony of

[1] In one case, that of Mr. E. J. Davis (No. 9 of my list), I felt some hesitation. Three operations had been performed on the frontal sinus, the last in August, 1910. Osteomyelitis appeared in January, 1911. The interval seems to be too long for us to refer the disease to the operation. On the other hand, to call it spontaneous seems to be stretching a point. I have therefore placed this case among the doubtful cases.

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the authors themselves is expressed quite distinctly on the side of the opinion that the osteomyelitis originated in a sinus untouched by the actual operative manipulations.

Further analysis of the 41 cases brings to light the following remarkable fact:

Of the 21 cases in which osteomyelitis developed spontaneously, 7 recovered after appropriate surgical treatment.

Of the 20 cases which followed operation not one recovered.

Spontaneous osteomyelitis, though not unknown in chronic sinusitis, more frequently follows the acute form, and, indeed, Guisez and other observers hold that the same is true of post-operative osteomyelitis—that is to say, that it is more prone to supervene after operation on an acute than on a chronic case.

As to the proportion of cases of frontal sinus suppuration which develop osteomyelitis spontaneously we have no figures to guide us. The number recorded is no indication of the frequency of the disease. On the one hand, spontaneous osteomyelitis, when fully developed, is sufficiently striking to secure recognition and sufficiently rare to lead generally to its publication. Against that consideration we must, on the other hand, remember that many cases are regarded as primarily intra-cranial which are, in reality, cases of osteomyelitis.

Further, these figures do not by any means fix the ratio between the numbers of spontaneous cases and of post-operative cases. If all the instances of post-operative osteomyelitis within the last ten years had been published their number would exceed twenty.

On the important practical point of the proportion of cases of operation that fall victims to osteomyelitis, the numbers at our command, thanks to the frank and trustworthy statistics of several of our leaders, are fuller and more informing. Killian's most recent statistics, for instance, amount to 109 radical frontal sinus operations with three deaths, one or two of which were from osteomyelitis. In all, according to the article in Katz, Preysing and Blumenfeld's book, up to a recent date, 375 Killian operations had been recorded with ten deaths—a ratio equal, on the whole, to about 3 per cent.

We come now to discuss what factor it is in the operation that leads to spreading osteomyelitis.

To this question, in spite of much debate and a little investigation, no definite reply has, so far, been forthcoming. What the operative error may be we really do not know. Post-operative osteomyelitis comes like a bolt from the blue—unexpected, inexplicable.

The simple and obvious supposition that the osteomyelitis is due to the bungling technique of an inexperienced operator is disposed

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of by the fact that the disease, as we have just seen, attends upon the skilful no less than upon the tyro. At the same time, as osteomyelitis is a septic disease we may suppose that injudicious bruising of the bone edges by the forceps, prolonged exposure at the operation, careless aseptic technique, and, above all, perhaps, inadequate drainage of the wound area, will predispose to its occurrence. As we shall see in a later section, over-zealous curetting of the walls of the sinus is likewise viewed with a suspicious eye in several quarters.

Unfortunately for prophylaxis, the admission that a weak operative technique will predispose to the disease can only be made on general grounds of probability. We cannot point to the actual error that inevitably leads to the disease. In this respect post-operative osteomyelitis stands in marked contrast to post-operative meningitis, in which injury to the cribriform plate, etc., so clearly and unmistakably betrays the faulty manipulation.

The conclusion is irresistible. What seems to be an irreproachable operation may be followed by progressive osteomyelitis.

(This aspect of our subject is developed more fully in the section on prophylaxis.)

With regard to the exciting cause in spontaneous osteomyelitis we are even more in the dark. Save that the disease is more common in acute than in chronic sinusitis we know very little about its ætiology.

We now proceed to consider the supposition that the indispensable cause of diffuse osteomyelitis lies in some inherent or acquired defect in the patient's resistance to the action of the micro-organisms which evoke the pathological process; or, to state the proposition in another form, in a relatively excessive virulence of the causal micro-organism.

In some way unknown, acute infection in the case of spontaneous osteomyelitis, and traumatism in the case of post-operative esteomyelitis, may so paralyse the defensive organisation, or so enhance the activity of the micro-organisms, that progressive osteomyelitis cannot be prevented, and once started cannot be stopped.

We shall see later on that in these cases the necrotic process is confined to the bone and that the soft tissues of the scalp participate in the disease only in a modified and subsidiary fashion, therefore we must assume that the ætiological factor must operate in the osseous tissue first and foremost. It may seem difficult to assume the existence of a lack of resistance in one type of tissue

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alone. This difficulty, however, is to some extent lightened when we remember that after certain debilitating constitutional disorders, particularly in children, the occurrence of septic processes involving the destruction of connective tissue and sparing the muscular, nervous and vascular structures in the affected region is not unknown. Moreover, such ulceration and necrosis is by common consent referred to defective powers of reaction in the organism. Now we have already drawn attention to the fact that an absence of vigorous reaction is a marked feature in the pathological picture of diffuse osteomyelitis.

In the case I report in the appendix to this paper (No. 7) the patient gave the history and manifested the signs of an attack of post-operative osteomyelitis and necrosis affecting the roof of the maxillary antrum ten years previous to her final illness. It is difficult to explain this double attack, save on the assumption of some inherent defect in resisting power.

The obverse of defective defence is excessive microbic virulence. Clinically, the greater liability of acute sinusitis to induce osteomyelitis may be taken as a point in favour of hyper-active virulence as a cause of the disease.

The problem might be illuminated by an estimation of the opsonic index.

(*To be continued.*)

ELECTRO-DIAGNOSIS IN DISEASES OF THE LABYRINTH.[1]

By Dr. E. Junca,
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Abridged translation by Dr. John M. Darling.

Nature of the Electric Reactions

(1) *Auditory Reactions.*—The cochlear nerve does not react, under normal circumstances, to a galvanic current. If, however, there is a lesion in any part of the ear, a current of from 5 to 6 milliampères may produce the sensation of noise—"auditory hyper-excitability." Faradic stimulation produces no effect on sensory nerves. An auditory reaction is occasionally produced, but this is probably due to stimulation of the tympanic muscles.

(2) *Equilibratory Reactions.*—A galvanic current of from 3 to 5 milliampères passing through the head from one ear to the other causes an inclination of the head towards the positive pole and a

[1] *Rev. Hebdom de Laryngol., d'Otol., et de Rhinol.*, March 30, 1912.

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