Pertinent observations regarding otology with particular emphasis upon otitis media

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Pertinent Observations Regarding Otology

with

Particular Emphasis Upon Otitis Media
Foreword

It is not the purpose of this paper to present a lengthy symposium on the subject of Otology - but rather to discuss some of the more interesting and yet important phases of middle ear involvement. For this purpose then, an effort has been made to investigate the history of the subject as it appears in the literature and present it as such. In a like manner the etiology and bacteriology of aural disease - with particular reference to otitis media - have been studied and recorded. As an added feature, the relationship of middle ear disease to three new and scarcely understood phases of Medicine - namely endocrinology, vitamins and allergy - has been dealt upon as they appear in the literature of the present decade. A discussion of the symptomology and treatment of ear disease has not been included in the present paper. Too often it is that the physician confines his efforts to these phases of the disease, often forgetting or ignoring that where an effect comes about a cause must be existent. This statement brings to mind the words of that beloved Sage of Medicine - Oliver Wendell Holmes:

'Disease, being always an effect, is ever in exact proportion to the sum of its causes. The one prevalent failing of the Medical Profession is to neglect the cause and quarrel with the effect!'
In a discussion of the history of Otology, it must be borne in mind that advances in the knowledge of the anatomy, physiology and pathology of the ear have not exceptionally been due to the efforts of any one particular individual. As a rule, a great number of observers and investigators from all parts of the World since the beginning of Civilization have shared in a revelation of the new knowledge. Very often general practitioners, surgeons, specialists and research workers have contributed information regarding the subject - and so it has grown.

The age of Otology is not known, but it is conjectured that involvements of the ear have existed since the Birth of Man, many centuries ago in the dim past. A fragment of a prehistoric skull has been unearthed in Peru, which displays undoubted evidence of a widespread mastoiditis with an abscess perforating outward and inward through the temporal bone. The exhibit displays indications that good drainage existed, continued over a long period of time. Evidences of partial healing of the process may be noted. Investigators are of the opinion that the mastoiditis complicating a middle ear involvement was not the immediate cause of the demise of the individual. It would be interesting to know the cause of his death and just how long he lived with so extensive ear pathology.

A knowledge of the anatomy of the ear far antedated and superseded satisfactory and intelligent treatment of ear conditions. This was probably due to the lack of comprehensive knowledge of the physiology of the organ. Even in the time of the Ancients there was ample material for dissection and experimentation, so that an insight into anatomical structure was obtained over a
period of many centuries as a result of the work of many brilliant investigators.

(3) Empedicles of Greece in 400 B.C. first described the cochlea. He said that it was a 'snail shaped cartilage, the true organ of hearing, vibrations of which give forth a tone which is perceived by the soul.' The Eustachian tube was discussed by Alcmaeon in 570 B.C., who described it as 'an opening from the tympanic cavity to the pharynx.' Aristotle probably had a knowledge of this structure as early as 322 B.C. The first accurate and clear description of the Eustachian tube was given by Bartholomeus Eustachius in 1604. His description was so accurate and precise that the tube now bears his name. The Acoustic Nerve was first described by Erasistratus, an Egyptian, during early dissection carried on in the time of the Ptolemys. The helix, lobule, tragus and antitragus were first named and described by Ephinis in 100 B.C., and the nomenclature that he used is that of the present day. Marinus, a preceptor of Galen, believed the Trigeminal Nerve and Auditory Nerve to be a single nerve. Galen corrected this error and showed that the Auditory Nerve entered the internal auditory canal. He was the first to call the internal ear a labyrinth. Galen believed however, that the external auditory canal ended in the dura mater. Following his death, little additional research work or discovery was made up to the Fifteenth Century due to the fact that he was regarded by those who lived after him during this long period of time as an unquestioned authority and few efforts were made to further investigations. During the Fifteenth Century however, interest was stimulated afresh and new anatomical discoveries again presented themselves.

Alexander Achillini, an Italian anatomist, working in conjunct-
ion with Jacob Berengario, first described the auditory ossicles but they did not include the stapes in their discussion. Berengario described the tympanic membrane as well, but thought its origin to be in the Auditory Nerve or meninges. Andreas Vesalius during his lifetime described the long process of the malleus, Eustachian tube, vestibule and semicircular canals. At about the same time Ingrossia described the stapes. Gabriel Fallopius, who lived during the early and middle part of the Fifteenth Century, showed that the mastoid cells communicated with the tympanic cavity and gave his name to the canal through which the Facial Nerve runs in its passage through the tympanic cavity. He also described the tympanic cavity rather concisely, as well as the two fenestrae and their communications with the vestibule and cochlea. Bartholomeus Eustachius, during the middle part of the same century, described the tensor tympani and stapedius muscles and the cochlea as well. Stenson in 1665 described the function and physiological action of the ceruminous glands.

In the Eighteenth Century Valsalva devoted more than sixteen years of his life to the study of the ear and dissected approximately a thousand heads for the purpose of its investigation. He discovered the muscle that opens the Eustachian tube and lifts the palate and showed the fenestra ovalis to be covered by a membrane. Valsalva did not think the auditory ossicles to be covered by periosteum, but this error was corrected by Frederick Ruysch in 1718. Casselbohm in 1730 described the auditory apparatus in the fetus. Catheterization of the Eustachian tube was first undertaken by Guyot, a Frenchman, in 1724 and first successfully accomplished on living persons by Archibald Cleland in 1741. Dominic Cotugno in 1761 discovered the fluid in the labyrinth and
for this contribution was selected for the Chair of Anatomy at Naples. Antonio Scarpa wrote an extensive work on the ear, an excellent piece of work for that period. Alexander Munro in 1797 first traced the Auditory Nerve within the cochlea, vestibule and semicircular canals.

As has been previously mentioned, treatment of ear conditions did not keep pace with anatomical discoveries. It is probably true that intelligent therapy has not existed until the last two or possibly three centuries, although considerable knowledge of anatomy was present, as has been seen, for many centuries before that time. A Greek Medical Papyrus of the Second or Third Century mentions some favorite remedies for earache. Of course, earache might be construed to mean any of a number of possible ear involvements, and was treated as follows:

'Procure some Egyptian alum and insert into the ear an amount equal to the size of a pea - thoroughly moisten a flock of wool with the gall of an ox, roll up and insert - rinse the ear with warm onion juice - syringe the ear with warmed gall of a bull, sheep or goat - apply salt in heated wine to the ear.'

Truly these were heroic measures, but undoubtedly gained good results in some instances. However, the psychic factor probably played a large part in ear treatments. Hippocrates knew very little of the Anatomy of the ear, although he used empirically some of the remedies of the present day, such as heat and cold. One of his favorite remedies for ear pathology was the instillation of warm water into the external auditory canal. He was at the same time a strong believer in mental suggestion, as is instanced by the following:
If any person has a pain in the ear, the physician should roll a bit of wool about the finger, then pour some warmed oil into the ear. He should then take the wool into the hollow of his hand and show it to the patient, so that he will think it came from out his ear. In order to make the deception complete, the wool should be thrown into the fire.

This great man understood the significance of treating his patient rather than his patient's disease. The patient probably got relief in many instances, not from suggestion alone but from the heated oil as well.

Herachides of Tarent advised caustics made of verdigris, copper filings and honey for granulations arising from abscesses in the ear. Apollonius recommended burned opium in castoreum for earache and removed foreign bodies by means of special spoons, hooks and probes wound with wool. He removed hardened cerumen with a solution of saltpetre in vinegar. Asclepiades stated that instillations of oil in which three or four cockroaches or an African snail were cooked, followed by a piece of henbane in oil or roses or woman's milk was perhaps the best treatment for ear conditions. Cornelius Celsus, during the First Century recommended vigorous injections of water for the removal of foreign bodies from the external ear. In obstinate cases he suggested that the patient be placed on a table with the affected ear down, held in that position and the physician was meanwhile to strike the table soundly with a heavy hammer in order to dislodge the foreign body by concussion. Archigenes seemed to have some idea of pain in the ear and used venesection, purgative enemata and warm water.
to the ear itself. About the time of Galen, Marcellus gave a popular notion of the ear remedies of the day. Frog's fat was recommended for pain in the ear and the urine of pigs, children and men or the blood of young chickens were stated to be remedies for ear ulcers. Guido Guidi in 1595 used leeches in the nostrils for middle ear inflammation. The Arabian physicians used warmed mother's milk instilled into the ear of children for the relief of earache. If the male was affected, the milk should come from a mother nursing a female child and vice versa. From such nonsense as this it is evident that ear medication until the Sixteenth Century was in reality an enormous amount of humbug. It is surprising to note that adequate ear therapy was so sadly lacking and yet many intelligent and brilliant anatomical findings had been made and recorded.

It was during the Sixteenth Century that the first inklings of modern therapy may be detected. Peter de la Cerdita was the first to use any sort of ear speculum in order to open the external auditory meatus for inspection of the external auditory canal, and to observe the ear drum in this manner. Fallopius during the early and middle part of the same century made exhaustive investigations and was led to believe that ear discharges in children should have no intervention, because in doing so Nature's efforts to throw off the morbid material would be seriously interfered with. Chronic otorrhea he believed to be a discharge from the brain and attempted to remedy it by the use of mild cleansing remedies. In the latter part of the Sixteenth Century, Lusitanus stated that the cutting off of the ears of criminals rendered them sterile, due to the division of the veins behind the ears. In this way he explained that the semen in the head could
Guyot in 1724 described thickenings, ulcers and cicatrices of the tympanic membrane and pronounced deafness arising from the nerve or labyrinth to be incurable. Hercules Sassonia originated the fallacy that destruction of the tympanic membrane necessitated a complete loss of hearing. Eli is credited with the first perforation of the tympanic membrane, which he did in 1760 for the relief of deafness. Ambrose Pare was the first to use a syringe for cleaning the ear. Valsalva demonstrated that the tympanic membrane would heal itself and showed that hearing was merely impaired but not lost by perforation of the tympanic membrane. He gave to posterity the method of inflating the ear through the auditory tube and this procedure is named after him. Valsalva was able to show by this method that an Eustachian tube that was not patent was one of the causes of deafness. Archibald Cleland in 1741 first inflated the Eustachian tube through the nose and was the first investigator to use artificial light to illuminate the ear. About the same time Petit trephined the mastoid tip for necrosis of the temporal bone and devised the operation primarily for the drainage and catheterization of the Eustachian tubes. Julian Busson proposed a perforation of the tympanic membrane for the relief of pus in the tympanic cavity. Thus, the last quarter of the Eighteenth Century marks the dawn of intelligent ear therapy.

The mastoid operation was first referred to in the literature by Johannes Riolanus, who wrote as follows:
Joining the tympanum toward its upper part is seen a small and very narrow opening which gradually opens out and passes into a cavity of considerable size, which presents everywhere little depressions like the cells of a honeycomb filled with air. It happens when this air, which should always be still, is stirred up in the ear by the impact of a fresh air current that the ears buzz continually. How may we get rid of this air which is such a source of trouble? There is certainly no other way except trephining the mastoid process. When the Eustachian tube has become useless, why should not the cellular end which communicates with the ear be made to serve the same purpose by perforating it with sharp instruments?

The earliest operations, then, on the mastoid process were suggested for the relief of tinnitus or in order to make a new Eustachian tube. It was not until later that the idea was conceived to perform the operation for the purpose of giving outlet to pus. A drawing dated 1524, made by Von Leyden and known as 'The Surgeon', depicts a surgeon making an incision behind the ear of a patient, showing the patient seated in front of him on the floor. Another picture dated 1650 and drawn by Jan Havickz Steen represents a like procedure. Very possibly there were mastoid operations and if so, the first actual operation must have antedated the above description by a good many years. Petit in 1740 probably first performed an operation on the mastoid for the evacuation of pus, he advised an early operation and is quoted as follows:
'These abscesses may persist for a long time before they cause death, but from the first few days of their formation they ought to be opened!' This was in truth a remarkable degree of insight and does not differ markedly from the modern conception. In 1776 Jasser operated on the mastoid in order to evacuate pus and to cure deafness. He bored a hole in the bone, fitted the nozzle of a syringe in this hole and forced in a lotion in order to drive out the pus. The procedure was repeated for twelve successive days. Following these remarkable advances in the field of mastoid surgery the operation fell into disrepute owing to the death of Berger, the Danish court physician, on whom it was performed for the relief of tinnitus and deafness. It was nevertheless occasionally performed for suppurative conditions of the mastoid process but it was not until a much later date, in 1868 or 1870, that the operation was again looked upon with favor by the majority of physicians.

(6) The first treatise on diseases of the ear was written by Jean Marc Gaspard-Itard in 1821. This was followed by papers by numerous other investigators, among whom were Joseph Toynbee, Anton Friedrich von Traltsch, Laurence Turnbull, Sir W. B. Dalby, St. John Roosa, Adam Politzer, Victor Urbantschitsch, Friedrich Bezold and others. The latter men are those belonging to a comparatively modern period of otologic history. Max Schultze described the nerve endings of the labyrinth in 1858 and to Helmholtz is given the credit for the first accurate description of the ossicles and tympanic membrane, which he completed in 1869. Stanislav Stein in 1894 demonstrated the functions of the different portions of the labyrinth and Adam Politzer first obtained pictures of the
tympanic membrane by illumination in 1865. Transmission of sounds through the cranial bones in diagnosis of aural diseases was originally begun by Johann C.A. Lucal in 1870. Friedrich Bezold in 1877 gave the first modern description and scientific knowledge of the mastoid operation, as well as a consideration of mastoiditis. The pioneers in aural surgery in the Nineteenth Century were Sir Astley Cooper and Sir William Wilde. The most important surgical work on aural involvements was that of James Hinton of Guy's Hospital, London. The late surgery of the ear and mastoid has been materially aided by the work of many eminent German investigators. These men begin with Herman Schwartz in 1873. Adolph Eysell first described the method of opening the mastoid process by chiseling and Emanuel Zaufel in 1884 and Ernst Kuster in 1889 materially improved the mastoid technique. Ludwig Stacke introduced excision of the ossicles in 1890 and greatly improved the surgery of the middle ear by numerous other new operative procedures. In the Twentieth Century the advance has been exceedingly rapid in the development of Otology, as is true of other branches of Medicine as well.

(7)(8)

Until the last few years it has not been the custom for many men to confine their practice solely to diseases of the ear, nose and throat. Joshua L. Cohen was the pioneer in this endeavor. He lived in the middle of the Nineteenth Century. At this time the specialty was regarded with indifference by hospitals and teaching schools. It had no locus standi in the general hospitals and patients received treatment at the hands of junior physicians on the staff. Its study was unknown in the Medical Curriculum, so that students interested in the subject were of necessity required to avail themselves of the instruction to be gained in private and
special hospitals in existence as the time. Unfortunately these institutions were small in number and meagerly equipped. In the United States however, by the year 1875, the teaching of the subject had been added to the instruction of the Harvard Medical School. It was not until 1882 that the first instruction was given along this line in England, at St. Thomas Hospital. With these new developments, the opportunity for study of the ear increased. At the aforementioned institutions, such as the Pennsylvania Infirmary in Philadelphia, Massachusetts Charitable Eye and Ear in Boston, New York Eye and Ear in New York City, there was coming to be more ample opportunities for instruction and definite training. The results of the new line of endeavor soon became manifest and special departments began to appear in increasing numbers in the large hospitals, many of them staffed by men who had received their earlier training in the special hospitals. Nevertheless, the subject of Otology was an optional one in the curriculum of most medical schools. As time went on however, the need for more accurate training along the line of ear work became more manifest. As a result Otology became a compulsory study and took its proper place along with the other subjects in medical instruction.

Thus, Otology has been followed from its earliest known beginnings and carried through the ages of wonderful discovery. Too often it has been hindered and retarded by superstition, humbug and quackery but eventually intelligent and common sense therapy in keeping with the wonderful anatomical discoveries, which have existed for centuries, came to the fore. In our own century the development has been astonishingly rapid and the subject has grown a hundredfold in all its aspects. It has become a firmly established branch of the Science of Medicine. The Twentieth Century is an
age of specialization and so it is that treatment of aural conditions in most instances has passed largely from the hands of the general practitioner into those of the aural specialists, who have increased in number from a mere scattered handful to many thousands. These men may be found everywhere throughout the civilized world, actively engaged in the practice of their art. At the meeting of the American Medical Association in Chicago in 1908, out of a total of 6200 physicians registered, 1200 were Otolaryngologists. At the same time it is important to consider that the general practitioner has been the backbone of the Science of Medicine and without him and his work, medicine as such could not exist. To quote B.R. Shurly:

"The practical doctor for the past decades, with his time honored preceptor has made, established, maintained and sustained the glory and honor of the American Medical Profession."

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Involvements of the middle ear may occur at any age, in people of any strata of society and in any geographical location. There are however several factors that definitely predispose to the development of the condition. There are certain embryological and physiological considerations which must be thought of in the establishment of the degree to which the ear becomes involved in disease processes from infancy to adult life, because of variations in these conditions in the ear, nose and throat. We are indebted to Adair Dighton of Liverpool for his description of the embryological relationships as a factor in middle ear involvements:

"The pharynx and nasopharynx are developed from the
anterior end of the foregut. In the embryo the walls of the pharynx and nasopharynx are bounded and formed by visceral arches and clefts which lie behind them. From the clefts all the more important structures of the nasopharynx arise. Each cleft is lined with hypoblast continuous with that lining the primitive pharynx and this grows outward from the pharynx until it meets the epiblast or epithelial covering of the body, which dips in to meet it. From the inner cleft recess the Eustachian tube and tympanum arise and from the first external cleft depression the external auditory meatus is formed. The junction of the two forms the tympanic membrane. The roof of the osseous portion or outer third of the Eustachian tube is formed by a growth forward of the petro-mastoidal bone. The floor is formed by the tympanic plate arising from the pterygo-palatine bar of the maxillary process. The cartilaginous portion or inner two-thirds of the Eustachian tube is developed from the first cleft recess. The lining of the pharynx, nasopharynx and Eustachian tube is continuous and practically all hypoblastic in origin.

This embryological connection is of great importance in predisposing the ear to involvement by continuity from a pathological process arising in the nasopharynx. In any marked swelling of the nasopharyngeal mucous membrane, as is found so frequently in a pronounced degree in children, a number of abnormal conditions may exist in the middle ear without its being primarily diseased. Hyperplastic and inflammatory affections of the tonsils and adenoids closes the tubal orifices by pressure upward, resulting
in a chronic stasis of the blood vessels and acting as a continual source of irritation to all neighboring structures. As the nasopharynx, in which the Eustachian tubes originate, are part of the respiratory apparatus abnormalities here may affect the middle ear and the character of the inspired air may influence the mucous membranes of the nasopharynx and thus indirectly the ear as well. During blowing of the nose, sneezing, coughing, vomiting or nursing in children the Eustachian tubes are opened and air may be forced into the middle ear through them. Water may enter in a similar manner during diving or swimming. Infection in this way may come about. J.D. Heitger was led to believe that the middle ear in children in the later months in utero, during birth and for the first part of their external existence may be easily subjected to disturbances in nutrition and circulation and often exposed to important degrees of pathological involvement. The middle ear of sucklings and the newborn is subject to a peculiar inflammatory process known as otitis media neonatorum. The condition is latent in character and may not be guessed present. Salowzon believes that 90% of newborns are subject to this condition. It is not believed to be a true otitis, but considered as a reaction to a foreign body as amniotic liquor, vernix caseosa or meconium which gains an entrance to the middle ear by way of the Eustachian tube.

Some investigators are prone to account for the prevalence of tubal involvement in young children leading to middle ear involvement on the basis of an anatomical danger in the structures from that of the adult. The Eustachian tube connects the cavity of the tympanum with that of the nasopharynx and forms an important part of the sound conducting apparatus. In the adult the
Eustachian tube is 31 to 38 mm in length, of which one-third is osseous and two-thirds is fibrocartilaginous. At the junction of the two portions an obtuse angle is formed, pointing downward. The pharyngeal mouth of the tube in the adult is not less than 10 mm above the hard palate. In the infant the tube is 14 to 15 mm in length. The tympanic orifice and the caliber of the bony tube is quite as large as in the adult, so that the whole canal in proportion to its length is much wider than in the adult. The two portions of the tube are more nearly in the same straight line, there being no angle at their point of junction. The tube is nearly horizontal in direction and the pharyngeal mouth of the Eustachian tube of the infant at term is on the same level as the hard palate. These differences in tubal structure and anatomical relationship have been stressed by numerous investigators, among them D.R. Heetderks, as important factors in the consideration of a prevalence of tubal and middle ear involvements in young children.

(12)(13)

The role played by the mucous membranes of the ear, nose and throat is of primary importance in a consideration of middle ear involvement. The mucous membrane is of paramount importance to the individual, exceeding the skin proper in its value as a body protector and preserver against the inroads of disease. For its functional activity it is necessary that the mucous membrane retain its natural moisture and for this purpose mucous secretion is being constantly poured over it. This secretion contains mucin, which has a barrier action against the toxic ferment entrance into the system as a result of its wonderful chemical composition. Mucin renders the mucous secretion non-fermentable and unaffected by the oxidizing and dissociating ferments of animals. It is also highly resistant to putrefaction. The moist and sticky surf-
ace of the mucous membrane catches up innumerable particles of dirt and bacteria entering with the inspired air, being armed with the mucous secretion and ciliary action to carry out this purpose. Robbed of these defenses, the mucous membrane is no longer protective and bacteria and their toxins are likely to penetrate to the epithelial cells. By a solution of these cells thru the production of enzymes, they may thus pass into the circulation.

The Eustachian tube and tympanic cavity are lined by a mucous membrane which is common with that of the nasopharynx. At the pharyngeal end of the Eustachian tube the mucous membrane is ciliated, thick and vascular and has numerous lymphatics and mucous glands. Here it acts as a veritable lymphatic gland, being a true policeman at the entrance of the tube. It effectively stops, destroys and carries away any septic organisms which may try to work their way to the tympanic cavity when it is normal and unaltered by pathological alterations. As the Eustachian tube progresses toward the tympanum, the defensive mechanism become more and more inadequate. The mucosa thins out, the mucous and lymphatic glands diminish in number and the ciliated condition becomes more and more feeble. As the middle ear is reached the protective mechanism is practically non-existent. Thus it is, that pathological processes are enabled to progress with such rapidity and without interference once the tubal barrier at the pharyngeal portion of the tube is overcome. Nearly all affections of the middle ear, according to W. Stuart-Low, result from sepsis introduced from bacteria introduced in the pharyngeal extremity, passing upward into the Eustachian tube. The mucous and lymphatic structures situated at the lower end of the tube when rendered useless fail to protect the vulnerable middle ear, because the tube is opened as a clear passageway for infection to travel to this structure.
Probably the commonest factor in the development of middle ear involvement is that of traumatism. Injury to the middle ear may come about as the result of either direct or indirect violence, as for instance fractures of the temporal bone, fractures and dislocations of the ossicles, wounds and contusions of the soft tissues, burns, scalds and escharotics, wounds and contusions of the soft tissues, impact of foreign bodies into the bony and soft tissues, or concussion from loud noises, falls, blows or explosions. All of these accidents destroy the normal physiological and anatomical relationships of the aural structures and predispose to the entrance of pathogenic bacteria.

The influence of cold as a factor in the development of otitis media has probably been overestimated. All authorities agree that the entrance of cold water into the middle ear never produces purulent inflammation there per se, except when a perforation of the tympanic membrane already exists. Neither is it possible to induce middle ear inflammation by exposure of the ear to a draught of cold or damp air, although such an exposure may result in a general cold for the individual concerned and from this an otitis may result. There are extensive references in the literature to the influence of diving and swimming on the development of otitis media. W.C. Phillips stated that the incidence of the involvement following swimming or diving may be accounted for by the more or less violent attempts to blow the surplus water from the nose and nasopharynx. As a result micro-organisms are forced through the Eustachian tube into the tympanic cavity, setting up a middle ear involvement in a large number of cases. R.A. Fenton related that public bathing was practiced in the time of Rome and that the Crusaders undoubtedly brought the practice
back to Europe with them, learning it from the Saracens. He believed that the great plagues of the Fourteenth and Fifteenth Centuries were spread by means of the public bath houses in existence at that time, as they were widely patronized by everyone. The loss of body heat from continual body exposure and chilling tends to lower the bodily resistance, especially in slender persons with little adipose tissue. Salt water appears to be a better bathing medium, due the prohibiting taste which warns the bather to keep his mouth closed, rather than from any fanciful germicidal powers in the salt water itself. He was sure that the newer methods of swimming as the 'crawl stroke' and the craze for diving predispose to aural infection in the method stated above. Any narrowing or obstruction of the nasal chambers or auditory meatus also tends to favor retention of water and delay in its removal and thus works in a similar manner. He believed further that acute or chronic involvements of the middle ear are absolute contraindications to diving or submersion styles of swimming because they tend to expose the individual to situations from which serious complications may develop. He stressed the factor of individual resistance or susceptibility as playing a large role and stated that when chilling, ischemia and mucosal lack of tone come about the bacteria may then enter the intercellular spaces and find an ideal locus to set up middle ear involvement. H. M. Taylor wrote that the Ancients had methods of water filtration as early as 400 B.C. and that the Chinese used alum in their public baths before the Christian Era. He believed that there are other factors to be taken into consideration besides contaminated water. Biologically, all diving mammals as the beaver, seal, walrus and hippopotamus have a musculature or special sphincter with a spec-
ial valvular apparatus for closing the nostrils when diving or swimming. Man is far removed from the aquatic mammals in this respect, having no adequate protection of this sort and with the inrush of water into the nose he allows water to come in contact with the respiratory epithelium. This destroys its protective covering of mucous which inhibits bacterial growth, and lessens the ability of the ciliated epithelium to sweep the mucous in which the bacteria normally become emeshed toward the pharynx to be disposed of. Aquatic mammals, especially those living in cold climates, have a thick layer of blubber which is in reality a kind of dense fat, placed immediately beneath the integument. Others of the water mammals have a dense coat of fur as well. As has been explained man lacks the power of adaptation to cold water and is only able to maintain a proper body temperature for a short time. Prolonged chilling causes a decreased mobility and phagocytic activity of the leukocytes and a loss of tone, which may be enough to cause a change in the equilibrium between the host and the invading bacteria enough to favor infection of the middle ear.

G.B. McAuliffe questioned the famous amateur swimmers of the New York Athletic Club and examined them for involvements of the middle ear. He found that those individuals who did not blow their noses after coming out of the water, but rather let it drain away exhibited no evidences of aural conditions. On the other hand, the swimmers who did not take these precautions showed involvement of the middle ear, almost without exception. G.C. Saunders was enabled to study and examine 10,000 swimmers and found the greatest incidence of middle ear involvement among the beginners and in those who were experienced divers and swimmers, plungers or polo players. He concluded that the former class might attribute
their involvement to a lack of knowledge of swimming hygiene and the latter class from continued and constant contact with the water over long periods of time.

(14) Postnasal adenoids often act as an obstructive lesion in the nasopharynx and tend to interfere with nasal respiration. At the same time, the rough, irregular and corrugated surface of the lymphoid mass favors the growth and retention of pathogenic microorganisms. W.C. Phillips thus concluded that adenoids interfere with the normal tubal ventilation and at the same time expose it to infection, from which a middle ear involvement may come about. P.S. Stout had the opportunity, along with his co-workers, of examining 975 freshmen at the University of Pennsylvania and found that 12% of these individuals had diseased tonsils, 9% had hypertrophied tonsils and 15% demonstrated defective hearing. A large number of these students had middle ear involvement, which he concluded was probably the result of the tonsillar pathology present. C.E. Sidwell demonstrated that it was not difficult for infection to reach the middle ear in infants due to the fact that the Eustachian tube is short and more or less straight, so that it favors the entrance of infectious material. In the majority of his cases he found the adenoid tissue to be hypertrophied, preventing drainage and aeration of the nasopharynx so that as a consequence bacteria were enabled to find conditions suitable for growth in this location. A.J. Wright was of the opinion that middle ear disease in adults had its origin in childhood and that infection associated with enlarged tonsils and adenoids was responsible for such disease in the majority of cases. He was interested in determining whether or not excision of the tonsils and adenoids would prevent the development of otitis media and for this purpose con-
sulted his private case records for the years 1910 to 1926 inclusive, a total of 1077 cases being reviewed. His findings were charted as follows:

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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As a result of Wright's investigations he concluded that there was no diminution in the incidence of cases of middle ear involvement as a whole in the adult as compared with that in children. His results were somewhat disappointing because he fully expected to find that removal of tonsils and adenoids during childhood would result in a diminution of the relative number of cases of otitis media during adult life. The charted figures demonstrate that, while there was a decided diminution in the incidence of cases of chronic non-suppurative middle ear disease, there was an increase in the number of acute suppurative cases, so that the gross total number of cases remained unaltered. Fortunately the acute suppurative processes seldom lead to deafness and concurrently there was a decreased number of cases of adult deafness, as would be expected. This then was Wright's strongest plea for the removal of tonsils and adenoids during childhood - not to necessarily decrease the number of cases of middle ear involvement but to bring about a diminution in the number of cases of adult deafness which would come about were the tonsils and
adenoids not removed early in life.

The influence of heredity upon the development of middle ear involvement, either through congenital defects in the auditory apparatus or inherent tissue susceptibility is always worthy of thought. D. E. S. Wishart concluded that conditions of lowered resistance, particularly in infants, was an important feature to consider as well. As a result of five years study he decided that an overwhelming majority of infants, sick for a long period of time, developed an otitis media in one or both ears, particularly in cases where there was lowered resistance from acute or chronic disease. L. W. Dean did extensive investigation along the same line and quoted Herrmann and Freysing as saying that involvement of the middle ear occurred in perhaps 90% of young children, with severe exhaustive disease states, the patient's weakened organism probably furnishing a condition which enabled the bacteria to become active. Rene Arbeltier concluded that otitis media was existent in 70% of seriously sick infants. W. C. Phillips concluded that individuals who are continually subjected to filth of the body and daily surroundings, vitiated air and a lack of proper nourishment have oftentimes a feeble resistance to middle ear involvements and thus the effect of environment is undoubtedly a fairly important factor in the consideration of etiology of aural diseases.

W. C. Phillips stressed the importance of general systemic diseases such as tuberculosis, diphtheria, syphilis, scarlet fever, measles, typhoid fever, small pox, influenza and lobar pneumonia as strong predisposing factors in the development of otitis media. He found them many times to be the causation of pathological alterations in the tympanic cavity and concluded that they brought about pathological alterations either by lowering the local and
general resistance and vitality of the tissues as a result of introduction of poisons into the blood stream and thus increasing the vulnerability of the cells to the point where the ever present bacteria may begin to thrive, or as a result of infectious metastasis through the blood lymphatics, or finally by bringing about local nerve paralyses resulting in interference with the normal physiology of the part. F.V. Gowen studied 15000 cases of acute exanthemata at the Philadelphia Hospital for Contagious Diseases. In this 1000 bed hospital it was found that 10% of the scarlet fever cases, 10% of measles, 4% of pertussis, 2% of smallpox, 40% of scarlet fever with measles, 75% of scarlet fever with measles and chicken pox and 50% of scarlet fever with measles and diphtheria cases developed an otitis media. C.E. Sidwell reported a large incidence of otitis media following acute colds and influenza. D.T. Smith recorded the effect of associated disease upon the incidence of otitis media as follows:

<table>
<thead>
<tr>
<th>Disease</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>56%</td>
</tr>
<tr>
<td>Scarlet Fever</td>
<td>16%</td>
</tr>
<tr>
<td>Dyensentery</td>
<td>50%</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>29%</td>
</tr>
<tr>
<td>Rickets</td>
<td>60%</td>
</tr>
<tr>
<td>Premature Infants</td>
<td>15%</td>
</tr>
<tr>
<td>Diphtheria</td>
<td>36%</td>
</tr>
<tr>
<td>Feeding Regulation</td>
<td>33%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>20%</td>
</tr>
</tbody>
</table>

E.A. Linell and H.H. Burnham conducted animal experimentation to determine the incidence of middle ear involvement in rabbits, following the injection of a dilute broth culture obtained from human scarlet fever cases into the tympanum of the animals. The animals became affected in most instances, but invariably recovered.
Succeeding injections in a similar manner demonstrated a lengthened period of recovery from the process, tending to show an increase of toxic absorption from an already damaged mucous membrane. In 1928 Hempstead and Adams published a report from the Mayo Clinic at Rochester, showing a surprising number of cases of middle ear involvement in diabetic individuals. Out of a total of 416 diabetics there were 141 aural complications. J. B. Beck obtained like results, finding that 14 out of 74 cases of diabetes displayed definite evidence of middle ear involvement. Their results have never been satisfactorily explained, but it is assumed that the otitis media is either a causative factor in the development of diabetes or that the diabetes as a result of tissue alterations and consequent lowering of resistance predisposes to aural complications.

(29) Scarlet fever was named by A. B. Lefler as a frequent cause of deafness, perhaps 10% of deaf mutes being from this cause. Ellison Ross summarized the literature as to the number of cases of chronic otitis media due to the disease. His findings were as follows:

<table>
<thead>
<tr>
<th>Author</th>
<th>Cases of otitis media</th>
<th>Cases due to scarlet fever</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>May Schmaltz</td>
<td>2500</td>
<td>137</td>
<td>5.5</td>
</tr>
<tr>
<td>May-Yearsley</td>
<td>544</td>
<td>27</td>
<td>5.0</td>
</tr>
<tr>
<td>May-Burkhardt</td>
<td>1950</td>
<td>85</td>
<td>4.3</td>
</tr>
<tr>
<td>Marian-May</td>
<td>5613</td>
<td>572</td>
<td>10.2</td>
</tr>
<tr>
<td>Bezold</td>
<td>623</td>
<td>89</td>
<td>14.3</td>
</tr>
<tr>
<td>Sprague-Beau</td>
<td>4045</td>
<td>55</td>
<td>3.9</td>
</tr>
<tr>
<td>Weil-Burkhardt</td>
<td>4309</td>
<td>488</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Lefler concluded that 4 to 15% of all cases of chronic otitis media were due to scarlet fever from Ross' figures. Her own inves-
tigations revealed the fact that out of a total of 473 scarlet fever cases at the Los Angeles General Hospital, 58 or 12.5% developed otitis media and out of 16 cases of scarlet fever and diphtheria combined, 7 patients or 39% developed middle ear involvement.

(11)

D.R. Heetderks summarized the possible causes of involvement of the Eustachian tube and middle ear. He named among the predisposing causes all conditions interfering with normal nasal respiration such as adenoids in children, hypertrophic rhinitis, septal deflections and ecchondroses in adults. The exciting causes included 'cold in the head' or acute nasopharyngitis, acute exanthemata, careless use of the nasal douche and diving or swimming under water. In a head cold he concluded that the middle ear became involved by direct extension, there being an inflammation of the mucous membrane with an associated inflammation of the lymphoid tissue within the Eustachian orifice, which might extend along the lymphoid tissue found throughout the length of the tube. He found that, in forcible insufflation as in blowing the nose the air in the pharynx and nasopharynx was condensed and found its way under pressure through the Eustachian canals to the middle ear cavity, where an otitis was apt to be set up providing the factors were favorable.

(30)

F.J. Bishop made a summarization of the possible causes of middle ear involvement. Under constitutional causes he included tuberculosis, syphilis, diabetes, anemia and neuroses. The local causes included pharyngeal adenoids, acute contagious diseases such as measles, scarlet fever, diphtheria, mumps, influenza and gripppe, acute rhinitis, hypertrophic and infected tonsils, nasal obstructions, hypertrophied turbinates, sinusitis, foreign bodies, et cetera.
He stressed the importance of bad hygienic surroundings and lowered vitality and head trauma as well. Among other factors mentioned by Bishop were climatic conditions, seasons, age, occupation and clothing. Chemicals, drugs, alcohol and tea, dust, sudden shock, constant loud noises, explosions, altitude, acute intoxication and focal infection, tumors, abscesses, meningitis, lethargic encephalitis, nasal packs and swimming or diving were mentioned as other possible etiologic factors.

---

The study of the bacteriology of otitis media has been undertaken by numerous investigators. The bacterial flora in most instances has been obtained either from the discharge obtained following a paracentesis of the drum membrane or through the unruptured drum membrane by means of a long hypodermic needle. The actual experimentation work was divided into two groups, that done by investigators using test animals such as the rabbit and the rat as subjects and on the other hand the findings obtained from cultural investigations of the human middle ear. One of the purposes was to determine the most frequent bacterial offender in middle ear involvement. Animal investigation and experimentation has always proven itself a valuable and instructive adjunct in the Science of Medicine, and it is no less valuable in ear study than elsewhere. William Gilbert (1544-1660) is quoted as saying:

'In the discovery of the secrets and the investigation of the hidden causes of things, proofs are afforded by trustworthy experimentation rather than by probable guesses and opinions'.

(31)

J.B. Nelson and J.W. Gowan used the Norway rat in their investigations. Organisms isolated from the tympanum of these animals who...
developed middle ear involvement were as follows:

<table>
<thead>
<tr>
<th></th>
<th>adult rat</th>
<th>young rat</th>
</tr>
</thead>
<tbody>
<tr>
<td>bacillus actinoides</td>
<td>44%</td>
<td>diphtheroids</td>
</tr>
<tr>
<td>streptococcus</td>
<td>32%</td>
<td>streptococcus</td>
</tr>
<tr>
<td>diphtheroids</td>
<td>24%</td>
<td>bacillus actinoides</td>
</tr>
<tr>
<td>small coccus</td>
<td>19%</td>
<td>small coccus</td>
</tr>
<tr>
<td>gram negative bacillus</td>
<td>9%</td>
<td>gram negative bacillus</td>
</tr>
<tr>
<td>bacillus proteus</td>
<td>11%</td>
<td>bacillus proteus</td>
</tr>
<tr>
<td>bacillus tetraginus</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Friedländer's bacillus</td>
<td>1%</td>
<td></td>
</tr>
</tbody>
</table>

The significant features of these investigations was the high incidence of the streptococcus, bacillus actinoides probably not being a human invader.

J.H. Fisher studied 46 cases of middle ear involvement and in 15 of these the pathogenicity of the isolated bacteria was observed by intranasal injection of broth cultures in rabbits. In a total of 15 rabbits, 11 developed otitis media. In the total of 46 cases of human middle ear involvement, the following pathogenic micro-organisms were isolated:

- streptococcus hemolyticus 74%
- staphylococcus 16%
- pneumococcus 6%

As a result of Fisher's experimentation, streptococcus hemolyticus was found to be the predominating micro-organism.

F.J. Bishop named the predominating pathogenic micro-organisms isolated in the middle ear discharges as streptococcus, pneumococcus, staphylococcus, influenza bacillus, Friedlander's bacillus, micrococcus catarrhalis, bacillus diphtheriae, bacillus pyocyaneus, bacillus proteus, tubercle bacillus and treponema pallidum.
Perhaps the most complete investigation of the bacteriology of middle ear involvement carried on by experimental work on animals is that of W. Valentine. She reviewed the literature and discovered that there was some divergence of opinion as to the organism occurring most frequently and accounted for this by an explanation that the predominance of certain varieties of bacteria and their virulence might vary from time to time. She quoted the figures of former investigators as follows, in the order of predominance of the various strains of pathogenic bacteria involving the middle ear:

<table>
<thead>
<tr>
<th>Reik</th>
<th>Phillips</th>
<th>Albert</th>
<th>Neumann and Ruttin</th>
</tr>
</thead>
<tbody>
<tr>
<td>pneumococcus</td>
<td>pneumococcus</td>
<td>streptococcus</td>
<td>streptococcus pyogenes</td>
</tr>
<tr>
<td>streptococcus</td>
<td>streptococcus pyogenes</td>
<td>staphylococcus</td>
<td>streptococcus and other organisms such as staphylococcus</td>
</tr>
<tr>
<td>staphylococcus</td>
<td>staphylococcus</td>
<td>pneumococcus</td>
<td>staphylococcus</td>
</tr>
<tr>
<td>Friedländer's bacillus</td>
<td>diphtheroid bacilli</td>
<td>Neumann and Ruttin</td>
<td>staphylococcus</td>
</tr>
<tr>
<td>Kummel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>streptococcus pyogenes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>streptococcus mucosus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bacillus lancilatus</td>
<td></td>
<td></td>
<td>Armstrong</td>
</tr>
<tr>
<td>staphylococcus aureus</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The important feature of these figures is the large incidence in every quotation of streptococcus, pneumococcus and staphylococcus. As a result of extensive experimentation and investigation, Valentine concluded the incidence of various pathogenic micro-organisms to be as follows:
An additional feature of Valentine's work was an investigation of the relationship of the bacterial flora of the nasopharynx and that of the middle ear in involvement of that structure. She concluded that the tonsil crypts and surfaces were frequent reservoirs of hemolytic streptococcus, but that the beta hemolytic streptococcus was found in the nasopharynx in diseased conditions of the throat alone as in acute tonsillitis or nasopharyngitis. As a result of the bacterial findings in middle ear infections she found beta hemolytic streptococcus to be the most frequent offender and determined by investigation that where an involvement of the middle ear existed, the same organisms might be isolated from the throat in the majority of cases:

<table>
<thead>
<tr>
<th>micro-organism</th>
<th>ear</th>
<th>throat</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>beta hemolytic streptococcus</td>
<td>44</td>
<td>39</td>
<td>90</td>
</tr>
<tr>
<td>pneumococcus - type 4</td>
<td>7</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>alpha streptococcus</td>
<td>3</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>staphylococcus</td>
<td>20</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>diphtheroid bacillus</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>staphylococcus and diphtheroid</td>
<td>3</td>
<td>1</td>
<td>25</td>
</tr>
</tbody>
</table>

Serologic, agglutination and fermentation tests proved that the strains of beta hemolytic streptococcus involving the throat were the same as those found in involvement of the middle ear when
the two co-existed. This feature of her experimentation demonstrated the probability that infection of the middle ear in most cases was the result of nose and throat involvements, due to the similarity of the causative bacteria in both regions when they existed together.

(37)
V.K. Hart made bacteriologic studies of 13 cases of otitis media in order to determine the incidence of the different types of micro-organisms. His investigations were conducted during an epidemic of acute ears in 1927:

- pneumococcus 5
- pneumococcus and micrococcus catarrhalis 4
- pneumococcus and streptococcus 3
- staphylococcus 4
- streptococcus 2
- bacillus subtilis 2
- micrococcus catarrhalis 2

These tabulated results show that he found pneumococcus and pneumococcus plus micrococcus catarrhalis to be the predominating invaders of the middle ear.

(25)
D.T. Smith investigated 225 cases of middle ear involvement occurring among 613 consecutive hospital admissions and recorded the incidence of the different pathogens as follows:

- hemolytic streptococcus 25
- hemolytic streptococcus and bacillus pyocyaneus 2
- hemolytic streptococcus and bacillus coli 1
- staphylococcus aureus 5
- staphylococcus aureus and bacillus influenzae 1
- bacillus coli 4
bacillus vulgaris
bacillus lactis aerogenes
bacillus diphtheriae
diphtheroid bacillus
pneumococcus and diphtheroid bacillus
fusiform bacillus and spirilla of Vincent's angina
mixed

Streptococcus hemolyticus seemed to be the favorite offender in the large majority of cases.

Harry Boyd-Snee cultured the exudate removed from the tympanic cavity in the presence of an acute inflammatory reaction, examining the discharges in 285 persons ranging from 6 months to 60 years in age. He found streptococcus to predominate in the cultured material, followed by streptococcus with staphylococcus and pneumococcus or bacillus influenza, bacillus pyocyaneus and diphtheroid bacillus.

W.C. Phillips made smear examinations of paracentesis material or obtained cultures by tapping the intact drum membrane and found streptococcus to be the most frequent offender, followed in order of frequency by pneumococcus, staphylococcus, Friedlander's bacillus, tubercle bacillus, bacillus diphtheriae, bacillus influenzae, meningococcus, typhoid bacillus, bacillus coli, gonococcus, Vincent's spirillum and smegma bacillus. He considered streptococcus pyogenes, the hemolytic streptococcus, to be the most virulent and destructive agent both to bony and soft tissues. Unfortunately, it is the most frequent invader found in middle ear disease. The pneumococcus is frequently seen, especially in children. Although it is not as virulent as the streptococcus it is often attended with serious complications. This is due no doubt to its inherent tendency whereby the original site of attack may rapidly clear up, but simultaneously the micro-organisms establish themselves in nearby spaces, there set-
ting up a new infection. Thus, there results a series of infected foci, which produce symptoms as they successively become involved. For example the tympanic cavity may become cleared up and at the same time the mastoid process still exist as a site of pneumococ-cic invasion. Staphylococcus is the least active and destructive agent of any of the more common micro-organisms invading the tympanum. Meningococcus occurs with considerable frequency and causes a rather severe involvement. The tubercle bacillus is rarely observed and even its presence is not absolute proof of the tuberculous nature of the involvement. It is however an important possible cause of otitis media when the bacilli are obtained from scrapings gotten from the walls of the tympanic cavity. The diphtheria bacillus may at times be demonstrated as a causative agent and invariably becomes located in the middle ear as a result of direct extension of nasal or pharyngeal diphtheria along the mastachian tube to the middle ear.

(39)(40)(41)

Considerable investigation from time to time has been undertaken in order to determine the relationship of the glands of internal secretion or the endocrines to middle ear involvement. The results present an interesting phase of the subject. However, the endocrine question is a debated affair and so far has proven itself to be a too little understood bugbear in Medicine. A.J. Carlson, working at the University of Chicago (Rush), has undertaken rather extensive experimentation on the subject of endocrinology and his investigations have included interesting studies of the endocrines as related to aural involvements. He included among the endocrines the ovaries, testes, suprarenals, pancreas, thyroid, parathyroids and hypophysis. The spleen, thymus, pineal body, liver and parts of the liver and brain he thought might be considered as
glands of internal secretion because some of their properties seemed to indicate and demonstrate an endocrine function. However, he desired to leave his analysis open to question, subject to further research and investigation. In Carlson's investigations the endocrines were removed from healthy animals and the history of the sequelae noted. This procedure was followed by feeding or injecting the animals with various preparations of the organ removed and determining the change which occurred, if any. This experimental data was checked up on patients whose symptoms pointed to a hypofunction or hyperfunction of a specific endocrine. The gonads were soon eliminated from the discussion, as they seemed to have no or at least a very insignificant relationship to middle ear pathology.

The cortex of the suprarenal gland was found to be necessary for life but Carlson could perceive no relationship between it and the study of middle ear involvement. Epinephrin, the product of the medullary portion of the gland, he stated as maintaining the normal vascular tone, capillary permeability and blood pressure. Experimentation revealed that in Addison's disease, due to a deficiency of this secretion, there was no characteristic ear pathology although vertigo and noises in the ears might at times be present. Further, Carlson was convinced that there was no evidence that a chronic excessive output of epinephrin, even assuming that it was capable of producing circulatory disturbance, had any relationship to middle ear involvement.

His studies of the pancreas made him conclude that, although a marked failure in the endocrine function induced diabetes mellitus with an impairment of tissue repair and decreased resistance to infection, there did not seem to be an unusually high percentage of aural involvements in diabetic individuals. As regards the hypophys-
is, his conclusions were that disorders of the ear were not necessarily sequelae of either acromegaly or Fröhlich's syndrome. Deafness and tinnitus might accompany acromegaly, the latter probably resulting from vascular disturbances as a result of high intracranial pressure. Complete extirpation of the gland in animals did not result in characteristic ear disorders, nor did the continued feeding of anterior lobe substance produce distinctive ear lesions. Pituitary extract, a product of the posterior lobe, were found to have a distinctive and definite action on the circulatory system and might possibly therefore have some effect in cases where there were neurocirculatory disturbances in the ear. Apart from this supposition there were no positive findings discovered relative to the hypophysis.

Investigations regarding the parathyroid glands led Carlson to conclude that hypofunction or hyperfunction were not factors in hitherto recognized diseases of the ear, even though these glands are concerned in bone and calcium metabolism. Investigations upon the thyroid gland were accorded much more value by Carlson and other investigators relative to middle ear involvements. Carlson stated that the thyroid hormone influenced the metabolism in practically every living body cell, either directly or indirectly. This fact has long been known. He stressed the possibility that the failure of the hormone, because it leads to general metabolic impairment of tissue, might produce serious disturbances in the ear. However, he found that in cretins or myxedema middle ear involvement did not necessarily exist. Experimentally a lowered resistance did exist, and to this extent then hypothyroidism might favor ear infection and the use of thyroid extract tend to relieve or diminish it. Palta demonstrated that in complete absence of the thyroid gland from
birth, middle ear involvements or abnormalities were not always to be found. Schatz reported a case of tinnitus due to middle ear involvement successfully treated by the administration of thyroid extract. T. P. Sprunt carried on investigations along the same line and found that marked deafness or difficulty in hearing might be present in hypothyroidism. He believed the etiology of such an alteration to be obscure, although he thought it possible in many instances that a myxedematous condition of the mucous membranes of the ear might be the causative factor. In marked cases of myxedema there was a marked pale edema, accompanied by purulent secretion in the mucous membranes of the tympanum and Eustachian tube. At the same time there was a thickening of the cartilages and a narrowing of the orifices. C. E. Harner insisted that the thyroid gland was the most important of any of the endocrines relative to the development of middle ear pathology. He stressed the fact that a hypoactivity of the gland brought about a thickening and inflammation in the ears, accompanied by infiltration and hyperplastic process involving the tympanic membrane, ossicular articulations and mucous membrane of the Eustachian tube. Investigations in portions of Switzerland, where endemic cretinism was so frequently found, led Sprunt to conclude that the numerous cases of deafness which co-existed had some relationship to the glandular deficiency. He explained the coexistence of the two conditions by a description of an alteration existing in the hearing apparatus such as an incomplete ossification of the ossicles or defective development and thickening of the tympanic mucous membrane, which he invariably found present in the deaf mutes with cretinism. Drury stressed the influence of thyroid gland hypofunction upon the incidence of middle ear involvement and presented cases with tinnitus, vertigo, repeated colds and intermittent dizziness which promptly improved under thyroid medication. As has been
shown, the results of various investigators are not all in accord. However, the relationship to the endocrines to middle ear involvement is a confusing affair and this may be expected because the study of the glands of internal secretion is as yet not fully developed and the subject is still in its infancy. Ziegler states:

'The relationship between the endocrine glands is close, for, like a pearl necklace they are all strung on one cord - that of the sympathetic nervous distribution.'

Truly their relationship is close and perhaps they are so intimately inter-related that complete isolation and investigation of the individual members will never be possible.

---

Another subject which merits investigation is the relationship of vitamins and diet to middle ear involvement. This feature has also been the object of rather extensive investigation from time to time. Animal experimentation was carried on by B.R. Shurly. He concluded that there was a definite relationship between the development of middle ear involvement and dietary deficiency, finding the demand of the human economy for iron, phosphorus, calcium, iodine and the vitamins to be present in otologic pathology more frequently than in other deficient parts of the body.

Working with rats, Cramer, Drew and Mattram found that a deprivation of vitamin A did not lead to an atrophy of the lymphoid tissue, not was there any leukopenia. With continued deprivation of the vitamin however, the mucous membranes of the middle ear dried up and this condition tended to favor microbial invasion of the tympanum. Further experimentation along the same line carried on by Emmet showed that rats fed on a diet deficient in vitamin A developed infection of the middle ear. R.A. Barlow used rats for experimental processes in the same manner and concluded that although a depriv-
ation of vitamin A did cause marked changes in the mucosa of the respiratory tract, with edema and even desquamation, there was no evidence of observable ear changes, either grossly or microscopically. He granted that there was a vague possibility that a diet deficient in the vitamin, which was capable of producing so marked a change in the respiratory mucosa, might cause edema of the Eustachian tube and also of the middle ear and thus be an etiologic factor in aural involvement. A.L. Daniels, M.E. Armstrong and M.K. Hatton demonstrated that rats on a vitamin A free diet showed the tympanum to be filled with pus. The exudate literally filled the ears and was made up mainly of polymorphnuclear leukocytes. Rats used as controls showed an absence of ear involvement. They concluded that vitamin A played an important role in the immunity of the organism against pyogenic infections and that the general breakdown of the organism following the ingestion of a diet low in the vitamin was secondary to such infection. They were assured that a diet lacking in vitamin A made possible the bacterial invasion of the mucous membranes of the Eustachian tube and middle ear.

(48)

Cramer, Drew and Mattram demonstrated that diets deficient in vitamin B caused an atrophy of the lymphoid tissues in rats, and an accompanying lymphopenia. There was loss of weight as well, emaciation, abnormal temperature and marasmus in extreme cases. R.A. Barlow was unable to demonstrate any positive pathological findings in deprivation of vitamin B, his results corresponding to those gotten in vitamin A experimentation.

B.R. Shulz found, that a deprivation of vitamin D in the diet of rats resulted in abnormalities of the osseous capsule of the internal ear. This in many cases interfered with the auditory power of the animals or predisposed to infection of the middle ear cav-
ity as a result of lowered resistance. His conclusions regarding the deficiency of vitamins were that errors in diet leading to states of nutritional instability might not cause deficiency diseases per se, but that such diets might be responsible for undermining the resistance to such a degree that infectious processes would be invited. D.T. Smith concluded that middle ear involvements were in some way associated with vitamin deficiency, probably by a lowering of tissue resistance. Nearly all of the children developing otitis media were on artificial feedings and the majority received little if any cod liver oil before admittance to the hospital. A.L. Daniels, M.E. Armstrong and M.K. Hutton found that rats on low calcium diets failed to develop middle ear involvement and suggested the well known lowered resistance of rickets to be a deficiency of vitamin A affair or some substance associated with it. They concluded that the excessive reaction to aural infection taking place in an artificially fed baby was due to the fact that the protective substance, vitamin A, had not been given in sufficient quantities or had not been absorbed from the alimentary tract in adequate amounts.

These results appear rather confusing, there being no agreement among all the investigators as to the relationship of vitamins and diet in middle ear involvement. Experimentation had largely been carried on, using rats as subjects. However, J.A. Stucky used a different method of approach to the subject, using human beings for experimentation. In the mountains of Kentucky he found a large majority of the mountaineers suffering from extreme grades of undernourishment and that they were living unsanitary and unhygienic lives and eating improperly prepared and poorly balanced diets. He discovered an astonishingly high incidence of middle ear involvements among these individuals.
The people in this particular locality had but little milk in their everyday diet and as a result there was very little butter to be had. Much of their food was devitalized by cooking, boiling and frying. In addition, they invariably ate large quantities of super-refined sugars and flours, with cheap canned goods, candies and cookies. Their condition stimulated Stucky to investigate what effect a proper diet would produce. He began to supply mineral salts and roughage in the diets by means of whole grains, leafy vegetables and fruits, realizing that if these articles were furnished in proper abundance the necessary vitamins would be included. Butter and milk, eggs and cereals were also added. In many instances cod liver oil was given to supply vitamin A and dried brewer's yeast to give them vitamin B.

As a result of the innovation of the new diets, the physical economy of these individuals underwent a marked change. Bodily conditions as a whole were vastly improved. A significant feature was the marked decrease in the incidence of middle ear involvements under the new regime. Whereas, in previous years the condition had been almost endemic, but a few sporadic cases were now to be observed. The investigations of Stucky are historical. He was able to demonstrate by means of actual human experimentation that a lack of vitamins or vitamin deficient diets actually predisposed to middle ear involvement and that the innovation of adequate diets containing an abundance of vitamins resulted in a decrease in the incidence of the condition.

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No discussion of middle ear conditions would be complete without an investigation of the relationship between aural conditions and allergy. There are certain characteristics of acute catarrhal otitis media which suggest the absence of infectious etiology and some
are of the opinion that the condition may originate as an allergic phenomenon and subsequently become infectious as a result of secondary bacterial invasion.

Allergy has been stated as a natural and often inherited state of human hyper-sensitiveness to proteins - as opposed to anaphylaxis, which is an experimental condition of temporary character, but having much in common with it as regards symptomology. Allergic tissue reactions may be subdivided into:

- allergy - always inherited
- anaphylaxis - always acquired
- altered reactivity - always acquired

Allergic tissue reactions may be subdivided into:

- allergy - always inherited (protein etiology)
- anaphylaxis - always acquired (protein etiology)
- altered reactivity - always acquired (non-protein etiology)

Regarding the tissue cell itself involved in abnormal local tissue reactions, it is conclusively due to conditions outside the cytoplasm, conditions within the cytoplasm, or both. Allergic cell conditions are always permanent affairs and evidence points to an intracellular locus of the determinant condition or conditions. This is not so probable in regard to anaphylaxis, which is not a permanent condition - nor is altered reactivity.

Allergy as evidenced in humans gives the familiar picture of hay-fever, asthma, eczema, urticaria and angioneurotic edema. These are evidences of cellular hyper-sensitiveness to proteins, be they derived from pollens, foods, animal danders or less common sources. According to certain investigators, there comes about a sensitization of the mucous membranes involved, this resulting in a vasomotor storm characterized by congestion and serous exudation. This phenomenon may extend up the Eustachian tubes and come to involve the middle ear, but as would be expected, the affair cannot be in most instances differentiated from a tubal or middle ear congestion of a low grade bacterial origin. The primary process may in turn be followed by a
bacterial invasion, resulting in the development of otitis media. As a result of the allergic factor, the true character of the process is often overlooked and goes unrecognized, so that much needless and unnecessary therapy is resorted to.

Allergy appears to occur according to Mendel's law, while anaphylaxis and altered reactivity do not. The mating of dominants, recessives and hybrids results, in respect to allergic offspring, as follows:

- dominant plus recessive - no allergy - offspring hybrid
- dominant plus hybrid - no allergy - offspring hybrid
- recessive plus recessive - allergy - offspring recessive
- recessive plus hybrid - allergy - offspring hybrid
- hybrid plus hybrid - allergy - offspring hybrid

Thus, it is possible for an allergic offspring to result from the mating of individuals with a negative history of allergy. At first, the individual is probably not specifically multiple sensitive, but as time goes on and an increase in the number and variety of protein contacts comes about, an increasing number of specific reactions becomes manifest. The individual has become multiple sensitive.

Whatever the condition may be which results in the existence of abnormal tissue reactions, the locus of the condition is undoubtedly intracellular. There is the possibility of an extracellular locus so that investigators have assumed an inconclusive attitude toward this phase of the question. It may be that inherited tissue tendencies have been laid down in the original protoplasm, this possibility accounting for the much disputed phylogenetic explanation of allergy. The use of adrenalin and iodine alters the abnormal tissue reactions and they may operate by biophysical changes induced extracellularly or by biochemical changes produced intracellularly.
or extracellularly. On the other hand, they may incite something within the organism such as endocrine potentialities. What is known of them at present, strongly suggests some sort of endocrine participation in the alterations of allergic reactions observed after their use.

Numerous cases of middle ear involvement on an unquestioned allergic basis have been presented from time to time. Six cases seen and cared for by D.R. Lewis are of interest:

'A male, aged 45 years, who was the son of an allergic (asthmatic) mother and the father of an allergic (asthmatic) son, attended a dinner party where, shortly after being seated at the table, he began to notice an odd sensation in the left ear. This quickly became an increasing earache, throbbing and interfering with hearing. Before the close of the meal, spontaneous perforation with profuse serous discharge had taken place. An examination of the ears prior to the incident revealed an intact, normal tympanic membrane and normal Eustachian tubes. The temperature, pulse and respirations were normal and the upper respiratory tract showed no evidence of inflammation that day or on following days. The discharges were profuse and serous for the first fifteen hours. The patient was kept in bed and given a high fluid intake, with alkalizing citrates and bicarbonates. In thirty-two hours the discharge ceased and the next day an examination and inflation through the Eustachian tube showed the perforation of the drum membrane to be closed.'

'A female, aged 42 years, who was unable to give but very little information concerning the history and health of her progenit-
ors, while shopping one morning experienced an acute right earache without premonitory symptoms of any kind. Examination showed the tympanic membrane to be smooth and pink and spontaneous perforation occurred during the otoscopic examination. This occurred about ninety minutes after the onset of the symptoms, with an abundant, clear and serous discharge. The patient was put to bed at once. Temperature, pulse and white blood cell count were normal. Cochlear examination demonstrated a high degree of sound conduction impairment and general upper respiratory examination revealed no evidence of irritation, except closure of the Eustachian tube. Heat was applied to the right ear, a high fluid alkaline intake given and rest in bed for thirty-six hours recommended. There then resulted an abrupt cessation of the discharge, subsidence of the tympanic swelling and opening of the Eustachian tube, with closure of the perforation in the tympanic membrane. This came about within thirty-six hours of the cessation of the serous discharge. The patient subsequently had a similar experience as that stated herein after she had removed to a nearby city.

Lewis reports four other cases of a like nature. Two of them were in children and the other two in adults. Each case showed an acute earache, marked sound conduction impairment, very early spontaneous perforation of the tympanic membrane and serous discharge. The symptoms ceased completely in every case in from thirty-six to seventy-two hours, with prompt closure of the perforation and return to normal hearing. In none of the cases was the nature of the allergin apparent. The absence of leukocytosis suggested a non-infectious nature of the acute inflammatory process, this being furth-
er borne out by the clinical course of each case. The relationship of allergy to middle ear involvement is an interesting feature and forms an excellent field for further research, because of the possibilities of more than a casual relationship of the two conditions.

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April 12, 1931
Conclusions

1. A scientific knowledge of the anatomy, physiology and pathology of the ear has come about as the result of investigation carried on for many, many centuries. Information regarding the subject has been contributed by general practitioners, surgeons, specialists and research workers.

2. Comprehensive knowledge of the physiology of the ear and treatment of aural conditions has not existed until the last two or three centuries, although the anatomy of the structure was fairly well known for many centuries previous to that. This may perhaps be accounted for by a lack of knowledge of the physiology of the ear and the superstition and quackery which persisted in all branches of Medicine for so long a time.

3. The embryological relationship of the ear to adjacent structures such as the nasopharynx may account to some extent for the frequent co-existence of involvement in the two.

4. Some investigators are prone to account for the frequency of middle ear involvements in young children by the alteration in anatomy existing in them from the adult conditions, rendering the structure more liable to bacterial invasion.

5. The protective role played by the mucous membranes of the ear, nose and throat is an important feature in the prevention of ear involvement. With the loss of this protective function, the ear is rendered more liable to invasion.

6. There are many etiological factors in the development of middle ear involvement, such as traumata, diving and swimming with destruct-
ion of the protective role played by the mucous membranes and the lowering of bodily resistance from cold, postnasal adenoids and tonsils, heredity, lowered resistance from any cause, environment, systemic disease, conditions interfering with normal nasal respiration.

7. Animal investigation and study of the human host in order to determine the most common bacterial offender results in a diversity of opinion as to the predominating organism. This may be accounted for by the particular series of cases studied. The most frequent invaders are probably streptococcus, pneumococcus and staphylococcus.

8. The relationship of middle ear involvement to the endocrines is a confusing one. There have been many interesting findings recorded but the gland having the greatest relationship is probably the thyroid. Hypothyroidism leads to general metabolic impairment of tissue and lowered resistance and may thus favor aural disease.

9. Vitamins have been investigated in order to determine their relationship to middle ear involvement. The experimentation carried on by J.A. Stucky in the mountains of Kentucky is classic. He was able to demonstrate the reduction in the incidence of otitis media in the people residing there after diets adequate in vitamins were furnished.

10. Cases of unquestioned otitis media on an allergic basis have been presented from time to time and there is a well defined relationship between the two. Recognition of the allergic feature is necessary in order to prevent needless therapy.
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