Chapter 4: Causes of hearing loss in adults

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Although patients with hearing impairment may have an obvious local cause for their condition, many will be suffering from a more widespread disorder in which the audiovestibular system is only one of the systems involved. These diseases should be considered when dealing with those complaining of hearing loss as this symptom may be the only presenting feature.

It follows that a diagnostic label of either idiopathic hearing loss or presbyacusis can be applied only after careful investigation to exclude the conditions discussed below.

Hereditary hearing loss with onset in adulthood

Several conditions fit this description, the mode of transmission being X-linked, autosomal dominant or recessive. The hearing loss is usually progressive and can be conductive, sensory or neural. In addition, some of the progressive inherited hearing losses of childhood may not develop auditory difficulties until adult life, although they should have been diagnosed in childhood (see Volume 6). The degree of hearing loss in any individual condition is often variable and there is a dearth of audiometric data in most of these.

Konigsmark and Gorlin (1976) compiled information on these conditions into an excellent book. They classified them according to which other systems, if any, were involved. There is obviously some overlap between groups as some diseases affect more than one system outside the labyrinth. They did not discuss the possible mechanisms which allow a congenital defect to express itself after a latent interval of up to 60 or 70 years as in Paget's disease. One could look at most of these conditions as degenerations being either primary or secondary to, for example, inborn errors of metabolism. Primary degenerations with manifestations in late life have been termed abiotrophy (Jahn and Noyek, 1981), that is the cells function normally at first but have only a limited life span, possibly because of faulty genetic coding. In the future, several of the primary degenerations may become secondary once an underlying cause is found.

Alport's syndrome

This association of nephritis and hearing loss is well known. The disease is inherited as an autosomal dominant trait and usually presents with haematuria in the first or second decade of life, although it can occur in infancy. The renal disease is progressive resulting in chronic renal failure. It is more common in men.

Forty-five per cent of patients have a progressive sensorineural hearing impairment which starts before the age of 20 years. The remaining 55% maintain normal hearing. Where site of lesion testing has been performed, it has indicated a cochlear loss (Konigsmark, 1975a). The high frequencies tend to be involved first although occasionally the mid-frequencies are worse (Flower, 1964).
The underlying problem is an enzyme defect which, in the kidney, results in the formation of an abnormally splitting glomerular basement membrane and, in the cochlea, leads to degeneration in the stria vascularis (Arnold, 1984). The strial abnormality causes secondary changes with atrophy of the spiral ligament, loss of hair cells and a reduction in the numbers of cochlear neurons.

There has been speculation as to the effect of renal transplantation on the hearing loss of Alport's syndrome. McDonald et al (1978) produced 'substantial improvement' in one out of seven cases following transplantation. Jordan and Newlin (1984) compared four patients with renal transplant and three kept on long-term dialysis for 3-10 years after initial pre-treatment audiometry. These seven patients all had a sudden onset of hearing loss 0-8 years after the diagnosis of nephropathy which rapidly progressed and then stabilized. At the final assessment two patients in each group showed no change in hearing, one in each group was worse and the final subject in the transplanted group had a 10 dB improvement.

Less frequent findings in Alport's syndrome include ocular defects such as cataract, spherophakia, anterior or posterior lenticous, myopia or scotomata in 10% (Konigsmark, 1975a; Konigsmark and Gorlin, 1976) and thyroid and parathyroid involvement (Jordan and Newlin, 1984).

Phytanic acid storage disease (heredopathia atactica polyneuritiformis; Refsum's disease)

This is an autosomal recessively inherited, inborn error of metabolism. There is a failure of alpha-oxidation of dietary phytanic acid to pristanic acid resulting in an accumulation of the former in tissues throughout the body. The presenting feature is night blindness or polyneuropathy at age 4-7 years. The eyes show optic atrophy, retinal pigmentation and posterior cataracts in 80% of cases. Later cerebellar degeneration with ataxia, and occasionally anosmia and external ophthalmoplegia develop. The cochlear hearing loss is present in up to 80%, usually begins in the second and third decades and is slowly progressive. Less constant features include ichthyosis, cardiomyopathy with prolonged P-Q interval, skeletal anomalies such as exostoses and spondylitis, and fixed pupils (Walton, 1977).

The neurological changes may improve with a diet low in phytanic acid, and in two cases such a diet has been shown to arrest the deterioration of hearing for 15 years (Djupesland, Flottorp and Refsum, 1983). It is important to maintain an adequate caloric intake while on this diet to prevent the breakdown of subcutaneous tissue with the subsequent release of the accumulated phytanic acid.

Kearns-Sayre syndrome

This syndrome also has pigmentary retinal degeneration, sensorineural hearing loss, cerebellar ataxia and cardiac lesions, but the serum phytanic acid is normal and there is no neuropathy. Other features include external ophthalmoplegia, ptosis, bulbar weakness, proximal limb girdle myopathy and growth failure. The heart lesion is bundle branch block in most patients and this often progresses to complete heart block requiring a pacemaker. The hearing loss is probably retrocochlear at least in part (Jensen and Courtois, 1985). The disease
is probably one of the mitochondrial myopathies, but as yet there is no clear pattern of inheritance. The temporal bone has shown cochleosaccular degeneration with absence of the organ of Corti, diminution of spiral ganglion cells and nerve fibres in the spiral lamina (Lindsay and Hinojoa, 1976). The brainstem has not been studied.

**Osteogenesis imperfecta**

This condition affects approximately 1 in 20,000 births (Fialkow, 1980). The classification into osteogenesis imperfecta congenita and tarda no longer holds good and there are now four types.

Type I is autosomal dominant and includes 80% of cases. Fractures occur mainly in childhood and stature is usually normal. The main brunt of the disease is on the extraskeletal collagen with blue sclerae, hearing loss with onset usually in the third decade, thin aortic valves and hypermobile joints with tendon ruptures. This is the form that presents in adult audiology clinics.

Type II is usually lethal in utero or perinatally and is possibly autosomal recessive although the risk to future pregnancies is less than 25% (Smith, 1984).

Type III is also probably a recessive trait in which there are severely affected infants with limited growth, expanded cystic ends of long bones, kyphoscoliosis, large skull and usually white sclerotic. These children also develop a hearing loss.

Type IV is a rare autosomal dominant condition with short stature, more severely affected bones than type I with short stature, and dentinogenesis imperfecta is more common than in type I.

The basic defect is in collagen, which does not mature past the reticular stage. There is thus a faulty framework for the deposit of hydroxyapatite crystals during ossification. Although the total calcium and phosphate content of bone is reduced, the calcium/phosphate ratio is normal and, despite the brittle bones, the fractures heal normally.

The hearing loss occurs in 25-60% of cases (Reidner, Levin and Holliday, 1980; Cohen, 1984) and is mainly conductive, although mixed losses have been described (Pedersen et al, 1985). Von Haake (1984) has found evidence of hearing impairment in 6-8% of patients under 20 years old rising to 75% at 50 years.

The features are similar to otosclerosis but there are several differences. Carruth, Lutman and Stephens (1978) found no biphasic stapedius reflexes and high resting admittance in osteogenesis imperfecta, the latter suggesting at least that changes occur in the tympanic membrane making it hypermobile. Histologically, there is more structural disorganization with larger resorptive spaces than in otosclerosis (Pedersen et al, 1985).

**X-linked hypophosphataemic rickets**

This is an X-linked dominant defect in cellular transport in the renal tubule resulting in a diminished resorption capacity for phosphate. There is a subsequent hypophosphataemia
with normal serum calcium, alkaline phosphatase and vitamin D despite osteomalacia. Davies, Kane and Valentine (1984) have shown hearing impairment in 25 patients from 16 families, the effect being most marked at frequencies below 1 kHz. Of these 25 subjects, 19 had cochlear losses and three conductive hearing impairment. Patients may develop ankylosis of the spine with cord compression which led Wier (1977) to speculate that the hearing loss was due to compression of the eighth nerve and the internal auditory meatus. However, Davies, Kane and Valentine (1984) found normal internal auditory meatus in all eight of their patients undergoing tomography of the temporal bones, and O'Malley et al (1985) found no evidence of retrocochlear pathology in 21 cases at electrocochleography. Indeed, 14 of the 21 had an increase in the summating potential/action potential ratio to greater than 30%, a finding of interest as two patients of Davies, Kane and Valentine (1984) had Ménière's syndrome.

**Mucopolysaccharidoses**

The hearing loss in Hurler's syndrome is well known (see Volume 6), but hearing loss with onset in adults has been described in two of these syndromes (Konigsmark and Gorlin, 1976). Of patients with Scheie's (MPS 1S) syndrome, 10-20% have a mild mixed loss in middle age. As in Hurler's syndrome this is an alpha-L-iduronidase deficiency. The main features are joint stiffness, corneal clouding and aortic incompetence.

Most patients with Morquio's syndrome (MPS IV) have a mixed hearing loss beginning in the second decade. The enzyme deficiency is in galactosamine 6-sulphatase sulphatase. There is odontoid process hypoplasia with the possibility of cervical dislocation, aortic incompetence and other bony anomalies.

**Ocular albinism**

This is distinct from the more usual oculocutaneous albinism, as in the latter there is also hypopigmentation of the skin. Winship, Gericke and Beighton (1984) described seven subjects from 29 persons in four generations of one family. All had blue irises, horizontal nystagmus and high frequency hearing loss with the average age of onset 45 years. As all seven were male, X-linked inheritance is suggested. Lewis (1978) has described one family with autosomal dominant transmission of a similar syndrome except that the hearing loss occurred in childhood.

There is one report of a familial syndrome comprising corneal degeneration, abnormal calcium metabolism and hearing loss which occurred in three brothers over 45 years of age (Hallerman and Doering, 1963).

**Hereditary sensorineural hearing loss with no associated defect**

Of the six syndromes described by Konigsmark (1975a), only one has its onset after childhood. In the second decade, the loss is most marked in frequencies below 1 kHz but the high frequencies are progressively involved resulting in a 'flat' audiogram. This is said to be an autosomal dominant trait, although Parving (1984) could find no constant mode of inheritance. The loss is cochlear and may be unilateral.
Muckle-Wells syndrome

This syndrome consists of recurrent inflammatory episodes with urticaria and pain. A progressive sensorineural hearing loss develops usually peri-pubertally, although it can occur in childhood. There is generalized amyloidosis and N-terminal amino acid sequencing has shown this to be of the AA type (Linke et al, 1983). The erythrocyte sedimentation rate is usually high during attacks and cerebrospinal protein and white cell counts have both been elevated. Attacks may be precipitated by stress, menstruation, canned food and during the summer months (Linke et al, 1983). The disease is inherited as an autosomal dominant condition with incomplete penetrance, although sporadic cases do occur.

Friedreich's ataxia

The mode of inheritance is autosomal recessive in most cases, although both autosomal dominant and sporadic cases occur. The ataxia begins, and is always worse in, the legs. There are associated upper motor neuron signs, loss of deep reflexes and loss of the deep sensory modalities of vibration and proprioception. Pes cavus and scoliosis are constant features. There is often a cardiomyopathy which may give heart block or heart failure and diabetes mellitus occurs in 10-20%. Rarer associations include optic atrophy, ophthalmoplegia, spina bifida occulta, ptosis and muscular atrophy.

The auditory system is involved in a mild to moderate sensorineural hearing loss. Nevertheless, of 10 patients with no subjective hearing impairment only one did, in fact, have normal hearing in both ears (Ell, Prasher and Rudge, 1984). Brainstem evoked response audiometry has shown decreased amplitude of waves I, II and III in a family with autosomal dominant disease (Shannon, Himelfarb and Gold, 1981), although the patients in the study by Ell, Prasher and Rudge (1984) had abnormalities of later waves. Of the seven subjects investigated in this latter group one patient had a normal study, one had wave V delay and the other five had the unusual finding of wave IV dominating the wave IV/V complex. The findings of these two groups of workers correlate well with Spondlin's (1974) pathological findings of neuronal loss in the cochlear nuclei and superior olivary complex.

Peroneal muscular atrophy (Charcot-Marie-Tooth disease)

The commonest form of this disease is of autosomal dominant inheritance. There is a hypertrophic, demyelinating peripheral neuropathy with Schwann cell proliferation and onion bulb formation. There is a mixed motor and sensory neuropathy which never progresses proximally beyond the lower third of the thigh or beyond the elbow. Pes cavus and heart block have been described.

The cranial nerves are usually normal but optic atrophy and trigeminal neuralgia may occur. Hearing loss is not common in this condition but there are sporadic reports of this. Musiek, Weider and Mueller (1982) describe one patient who complained of speech discrimination problems especially in noisy situations and on the telephone. Pure-tone audiometry revealed a 'mild' sensorineural hearing loss. There was evidence of abnormal auditory adaptation both on Békésy audiometry and by Carhart's test. There was stapedius reflex decay, absent auditory brainstem responses at 80 dB sensation level, and abnormal central speech tests indicating a retrocochlear pathology.
Hereditary sensory radicular neuropathy
(Denny-Brown syndrome)

This is another autosomal dominant condition. The onset is in the second or third decade with a purely sensory neuropathy which becomes complete below the knees and wrists. The hearing loss is more common than in peroneal muscular atrophy. Temporal bone findings have been reported by Hallpike (1967). There is degeneration of the stria vascularis and loss of hair cells in the organ of Corti.

Fascioscapulohumeral muscular dystrophy

Meyerson, Lewis and Ill (1984) described a high frequency hearing loss in two generations of one family with this condition. The mother of two children had mild disease and a previously undetected mild hearing loss. Taylor et al (1982) have reported Coats’ syndrome associated with this disease, that is retinal telangiectasia, exudation and detachment with deafness.

Another dominant muscular dystrophy with late onset and hearing loss in some families is the oculopharyngeal muscular dystrophy (Walton, 1977).

Hereditary hearing loss with epilepsy

There are two autosomal dominant conditions in this category. One, first described by May and White (1968), has myoclonus, ataxia and high frequency cochlear hearing loss; the other (Herrmann, Aguilar and Sacks, 1964) has no ataxia but diabetes mellitus and progressive cerebral atrophy with onset in the fourth decade.

Other syndromes associated with ataxia

Several of the conditions already discussed in this section have ataxia as one feature. There are three others not mentioned so far (Konigsmark and Gorlin, 1976). Ataxia, hyperuricaemia, renal insufficiency and sensorineural deafness are associated with onset of a cochlear high frequency hearing loss in the 20-40 year age group. In view of other diseases of urate metabolism such as Lesch-Nyhan syndrome, studies have been carried out seeking an inborn error of metabolism to explain this condition. None has so far been found.

Ataxia, cataract, psychosis and/or dementia have been reported in a kindred with progressive adult onset hearing loss resulting in profound loss by the age of 40 years. The syndrome is inherited as an autosomal dominant trait.

Finally, an autosomal recessive condition associating adolescent onset hearing loss with ataxia and pes cavus has been described.

Miscellaneous degenerations

Anhidrosis has been associated with progressive sensorineural hearing loss beginning at age 35-45 years (Helweg-Larsen and Ludvigsen, 1946). The syndrome was inherited in an autosomal dominant fashion. Hereditary Ménière's syndrome is discussed in Chapter 5, and
sickle-cell disease in the vascular section of this chapter. They are mentioned here for completeness.

Conditions characterized by either an excess of normal tissue or by abnormal tissue growth can be defined as dysgenerations (Jahn and Noyek, 1981). This would include both Paget's disease and otosclerosis as well as some less well known conditions.

**Otosclerosis**

This is an autosomal dominant inherited condition with a penetrance of approximately 40%. Early signs include the 'on-off' effect on stapedial reflex measurements, where there is a deflection in the opposite direction from normal at the beginning and end of the reflex, a biphasic stapedial reflex, the 'cookie-bite' audiogram and the Carhart notch. The 'cookie-bite' is a sensorineural hearing loss in the mid-frequencies with normal hearing at low and high frequencies. The Carhart notch is a dip in the bone conduction at 2 kHz. It is only after this early otospongiotic stage of the disease that any air-bone gap opens as otosclerosis supervenes (Causse and Causse, 1985); however, 'pure' cochlear disease has been described with no conductive component (Balle and Linthicum, 1984).

Tympanometric screening for otosclerosis has recently been questioned (Browning, Swan and Gatehouse, 1985), as although mean compliance values are lower in otosclerotic subjects, there is considerable overlap with the normal range, and it is, therefore, impossible to diagnose individual patients accurately. However, if otoadmittance measures are included, using a probe tone of 660 Hz, then 65% of subjects give abnormal results (Shone and Moffat, 1986), although no control group was included in this study.

A fuller account of otosclerosis is given in Volume 3, Chapter 14.

**Paget's disease of bone**

Paget's disease has been estimated to occur in 3% of the UK population over the age of 40 years (Krane, 1980), and possibly accounts for 1% of all adult hearing loss (Stephens, 1983). There is evidence that this is an autosomal dominant condition with incomplete penetrance (McKusick, 1972). The onset is possibly precipitated by an abnormal immunological response to contact with a virus, and measles has been implicated (Evans and Stevenson, 1981); inclusion bodies have been found in the nuclei of osteoclasts in pagetic bone (Krane, 1980).

The disease is characterized by an increase in bone turnover. Initially, bone resorption predominates and the bones are very vascular. There follows the mixed phase when bone resorption is balanced by new bone formation and finally the osteosclerotic phase predominates. The increased bone metabolism is characterized by an elevated serum alkaline phosphatase and a marked elevation in 24-hour urine hydroxyproline excretion.

Most patients are asymptomatic and are only diagnosed by biochemical or radiological screening.
The hearing loss is more prevalent in patients with skull disease and affects up to 50% of those with an abnormal skull X-ray (Walker et al, 1979). Although the loss can be conductive, sensory or neural, a mixed pattern is usual and it can be due to bony overgrowth of either the external or internal auditory meatus, to ossicular chain problems especially at the stapes, or to a cochlear hearing loss. Baraka (1984) found the rate of progression of the hearing impairment to be 2 dB/year (average loss at 0.25, 0.5, 1, 2 and 4 kHz) in six out of eight affected ears. The other two ears had no progressive hearing loss attributable to Paget's disease.

Modern drug therapy of Paget's disease consists of calcitonin or diphosphonates. Calcitonin has been reported as 'markedly improving' the low frequency hearing of one patient (Moffatt, Morrow and Simpson, 1974), although Walker et al (1979) found no effect. Of the diphosphonates, dichloromethylene diphosphonate probably has fewer drawbacks than disodium etidronate, although both are effective. Neither of these drugs has been evaluated in the management of hearing impairment in Paget's disease, although they are useful in the treatment of other neurological complications.

Neurofibromatosis (Von Recklinghausen's disease)

This is another disease inherited as an autosomal dominant trait. The hearing is affected only in those patients who develop eighth nerve schwannomata. The 4% of subjects with acoustic neuroma who have bilateral tumours generally have this condition. The audiometric features of these patients are the same as in other patients with vestibulocochlear neuromata (schwannomata) (see elsewhere in this chapter).

Associated features include 'café-au-lait' spots which vary in size from pinhead to palm-of-hand size and have regular outlines. The presence of five or more such spots is highly suspicious of this condition. The finding of multiple cutaneous fibromata is pathognomonic when present and although more numerous on the trunk there is usually at least one on the face (Walton, 1977). Neurofibromata are often palpable in superficial nerves of the neck and extremities, kyphoscoliosis is common and hyperostosis may occur in facial and long bones. Ophthalmoscopy may show phakomata or optic atrophy.

The syndrome first described by Garner and Frazier in 1930 (see Konigsmark and Gorlin, 1976) is identical except for the 'café-au-lait' spots and cutaneous fibromata. This is probably a forme-fruste of neurofibromatosis.

Apert syndrome (acrocephalosyndactyly)

The salient features of this rare disorder are craniosynostosis, syndactyly of hands and feet, progressive synostoses of hands, feet and cervical spine and various bony ankyloses. The inheritance is probably autosomal dominant with a high spontaneous mutation rate. Because of a high neonatal mortality, the incidence in the general population is probably 1 per 2 million rather than the 1 in 160 000 live births by Gorlin, Pindborg and Cohen (1976). There is often a mild degree of intellectual handicap, the palate is high arched and often has a marked median furrow.
There is a conductive hearing loss in 10-20% of patients, which may become severe, and is a result of fixation of the stapedial foot-plate (Bergstrom, Neblett and Hemenway, 1972). The hearing loss begins peripubertally.

**Hyperostosis corticalis generalisata (Van Buchem's syndrome)**

In this condition there is hyperplasia of the diaphysal cortex of both long and short bones together with osteosclerosis of flat bones. The skull is thickened with foraminal narrowing resulting in bilateral progressive neural hearing loss with facial palsy in 90% of cases (Konigsmark, 1975b) from compression of the seventh and eighth cranial nerves in the internal auditory meatus. The onset of the auditory defect is usually peripubertal.

**Frontometaphyseal dysplasia**

This results in a conductive hearing loss with onset in the second decade. The hallmark of the condition is the pronounced supraorbital ridge with a widened nasal bridge. There are associated cervical spine deformities with secondary wasting of the small muscles of the hands. The inheritance is not fully understood.

**Otodental dysplasia**

This is an autosomal dominant condition in which dental abnormalities are associated with a high frequency sensorineural hearing loss with onset at any age from early childhood to middle age. The hearing loss may reach 65 dB at 8 kHz (Jorgenson, March and Farrington, 1975). The main dental problems are delayed eruption of deciduous teeth, absence of premolars, and abnormal crowns on the molars.

There is a report of a family of three brothers with short-limbed dwarfism, metaphyseal dysostosis, mild intellectual impairment and conductive hearing loss (Rimoin and McAllister, 1971).

Finally, there are reports of an abnormal dominantly inherited susceptibility to streptomycin.

**Infection and hearing loss**

Otitis externa, acute otitis media and chronic otitis media are important causes of hearing loss in adults. These conditions are discussed in Volume 3.

Intrauterine infections and congenital hearing loss are described in Volume 6.

**Viral infections**

Viruses cause between 7% (Mattucci and Bachoura, 1982) and 13% (Graham, 1981) of sudden sensorineural hearing loss. Perhaps the best known association is with mumps parotitis. This is mainly a disease of childhood with a peak incidence between the ages of 6 and 10 years, although young adults can also be infected. In a study of 298 service men with mumps, Vuori, Lahikainen and Peltonen (1962) found 13 to have a binaural high frequency
hearing loss. Six patients recovered completely, six were left with almost normal hearing and one had a residual unilateral severe hearing loss.

The herpes zoster virus can cause a hearing loss secondary to either chickenpox or shingles. Chickenpox is not further discussed here as hearing loss is rare after childhood. There is an association of facial palsy, hearing loss, vertigo and herpetic vesicles in the external auditory meatus and on the tongue, at one time thought to be the result of herpes zoster infection in the geniculate ganglion (Ramsay Hunt syndrome). Pathological studies have failed to confirm this and neuritis has been seen in the vestibulocochlear nerve and elsewhere in the facial nerve. However, sensorineural hearing loss has been associated with ipsilateral herpes zoster ophthalmicus (Scott and Scott, 1983) and has also been diagnosed serologically in otherwise idiopathic sudden hearing loss (Rowson, Hinchcliffe and Gamble, 1966).

Other viruses associated with sudden hearing loss include the Epstein-Barr virus (infectious mononucleosis) in which hearing loss may be the presenting feature (Erzums, Kalavsky and Watanakunakorn, 1983), the polio virus, adenoviruses, parainfluenza virus types 1 and 3, columbian SK virus, yellow fever virus and the measles virus (see Rowson, 1973; Jaffe, 1978).

Bullous myringitis is usually considered to be a benign condition of either viral or mycoplasmal origin. The bullae may be single or multiple and contain clear, haemorrhagic or yellow fluid. Pain is the usual presenting feature. Hearing loss has been described in 14 out of 15 patients (Hoffman and Shepsman, 19830. One-half of these cases had a mixed loss and the other half a purely sensorineural impairment. Recovery was complete in only eight of those affected.

Bilateral total hearing loss has been reported following herpes simplex encephalitis (Montano, Melley and Karam, 1983).

Bacterial infections

Bacterial meningitis

In adults this is usually due to infection by either \textit{Neisseria meningitidis} (the meningococcus) or \textit{Streptococcus pneumoniae} (the pneumococcus). Hearing loss may be the presenting feature of meningococcal meningitis (Abad, Ng and Somasunderam, 1983) and may precede signs of meningeal irritation by up to 3 days (Sandyk and Brennan, 1984).

Studies have not been carried out on the incidence of hearing loss following meningitis in adults. However, in a large retrospective study of 547 patients of all ages, 110 out of 236 survived bacterial meningitis, and of these 21% had a complete cochlear hearing loss (Nadol, 1978). Of 304 cases of viral meningitis in this series, none had hearing loss whereas three out of seven with fungal meningitis had auditory dysfunction.

Rarer causes of meningitis with hearing loss in adults include group B streptococcal meningitis (Horburg et al, 1984), \textit{Streptococcus suis} type II infection in a pig meat handler (Shneerson et al, 1980) and \textit{Cryptococcus neoformans} infection (Igarsh et al, 1975).
Syphilitic hearing loss

The inner ear is more commonly involved in late congenital syphilis than in acquired disease, and although it most commonly presents as Ménière's syndrome, the diagnosis should be excluded in both sudden and progressive idiopathic hearing loss. Rosenhall, Lowhagen and Roupe (1984) studied the pure-tone audiogram and auditory brainstem responses of 26 patients with early disease before and after treatment. No fewer than 50% had sensorineural hearing impairment on pure-tone audiometry and this improved in only two cases following treatment. However, only seven cases had an abnormal auditory brainstem response which was permanent in four.

Steckelberg and McDonald (1984) examined 79 subjects with the combination of late syphilis and cochleovestibular disease. After excluding 41 cases with another known cause for hearing loss they were left with 38 subjects with cochlear hearing loss due to Treponema pallidum infection. One-half of these patients presented with sudden hearing loss and a total of 42% had episodic rotatory vertigo. The hearing loss was asymmetrical in 30 cases but unilateral in only seven of these.

Syphilis probably accounts for between 2 and 4% of all cases of sudden hearing loss and, in a series of 306 patients with sensorineural hearing loss of all types, the diagnosis was made in 6.5%, compared with 2% of controls (Zoller et al, 1978).

Except for the rare gummatous involvement, the mechanism for the hearing loss is probably due to the generalized vasculitis that can occur in late syphilis.

Yaws is another treponemal infection that has been associated with hearing impairment (Block, Gibson and Capper, 1982).

Other bacterial infections

Sensorineural hearing loss has been reported during the course of both brucellosis (Elidan et al, 1985) and typhoid fever (Escajadillo, Alatorre and Zarate, 1982).

A hearing loss may also result from tuberculosis, but this is usually a conductive loss associated with infection of the middle ear cleft (Ramage and Gerther, 1985). Sensorineural hearing impairment is very rare in this disease and is secondary to tuberculous meningitis.

Fungal infections

Mention has already been made of sensorineural hearing loss following fungal meningitis, and mycoses are a well known cause of otitis externa.

Helminth infections

In tropical regions these conditions enter the differential diagnosis of acute conductive hearing loss, albeit rarely.
Endocrine disorders

The endocrine glands are those which secrete hormones into the bloodstream. They are the hypothalamus, the pituitary, the thyroid, the parathyroids, the adrenals, the gonads and the pancreas. Of these, only the parathyroids and the gonads are not directly involved in disorders associated with hearing loss. Several conditions are associated with congenital or early childhood development of hearing impairment (see Volume 6), but there are four diseases which, if they affect the auditory system, do not do so until adult life.

Diabetes mellitus

The term 'diabetes mellitus' should be regarded with the same diagnostic imprecision as anaemia. It indicates that the major abnormality is hyperglycaemia, but gives no clue as to the cause or prognosis. In the UK over 1% of the population is diabetic (Baird and Strong, 1977); thus it is the commonest of the endocrine disorders. Its association with hearing loss also has the longest historical discussion, dating from Jordao in 1857.

The basic problem is a deficiency or diminished effectiveness of insulin, a hormone produced by the beta cells of the islets of Langerhans in the pancreas. The disease can be secondary to a long list of conditions, but most cases are primary and divide into insulin-dependent or non-insulin-dependent types.

The insulin-dependent type tends to have its age of onset under 40 years, often in childhood or adolescence and is commoner in males. It is associated with a higher incidence of HLA types B8 and BW15 and to a lesser extent DW3 and Dw4. In sibships, those with diabetes tend to have similar HLA typing, although the concordance rate for diabetes in homozygous twins is only 50% suggesting an environmental trigger. In this context the role of viral infection has been implicated. There is a seasonal variation in the onset of the disease with peaks in October and June. Antibodies to coxsackie virus B4 have been found in the serum of newly diagnosed individuals more often than in controls, and researchers in North America have thought that mumps virus is a possible trigger (Foster, 1980). One other feature suggesting a viral aetiology is that if siblings are going to develop the disease they usually do so within 6-9 months of the first affected family member.

Whatever the trigger, the mechanism of expression is probably autoimmunity. Diabetes coexists with the other organ-specific autoimmune diseases more commonly than by chance. Other organ-specific autoantibodies are commoner in diabetes; antipancreatic antibodies have been found in the sera of diabetics as have T cells sensitized to pancreatic extract and, in the initial stages of the disease, there is a lymphocyte and plasma cell infiltration in the pancreas (Baird and Strong, 1977).

The commoner non-insulin-dependent diabetes by contrast tends to occur in the older age group and, indeed, 80% of all diabetes occurs after the age of 50 years. Females are affected more often than males. There is no HLA association, no association with viruses and there is much greater evidence for an autosomal dominant inheritance with the concordance rate in homozygous twins being virtually 100%. The illness may be precipitated by obesity and, here, the insulin levels are often normal or high and insulin resistance is the main problem.
The hearing loss can be conductive secondary to the increased incidence of external and middle ear infections, or sensorineural. This discussion will be confined to sensorineural losses and the reader is referred to Volume 3 for further details of conductive losses.

There is a wealth of literature on the probable involvement of the inner ear in diabetes. Although some studies still deny the relationship between diabetes and hearing loss, most find that the auditory system can be involved. The incidence is still controversial being quoted variably from 0 to 93% (Taylor and Irwin, 1978). Histopathological studies have shown:

1. microangiopathic changes with PAS positive precipitates in the stria vascularis, the internal auditory artery, the modiolus, the vasa nervorum of the eighth nerve and the spiral ligament (Jørgensen, 1961; Costa, 1967; Makishima and Tanaka, 1971)

2. haemorrhages in endolymph and perilymph (Kovar, 1973)

3. loss of hair cells, atrophy of the spiral ganglion, demyelination and beading of the eighth nerve and degenerative changes in the brainstem and cerebellum (Reske-Nielsen, Lundbaek and Rafaelsen, 1965; Makishima and Tanaka, 1971).

The hearing loss typically described is slowly progressive, bilateral and sensorineural, a typical 'presbyacusis' in a younger age group. However, the loss can be of sudden onset, unilateral or predominantly low frequency (Jørgensen and Buch, 1961; Friedman, 1976; Taylor and Irwin, 1978). Although as a group the impairment of hearing is usually not severe, in individual subjects it can be profound.

As one might expect from the widespread nature of the histopathological alterations, the audiometric findings can be sensory, neural or show a mixed pattern. Even the finding of normal pure-tone thresholds does not exclude abnormalities of the auditory pathway in this disease. For example, Snashall (1977) found excessive abnormal adaptation at 8 kHz in nine out of nine diabetics with normal pure-tone audiograms when compared to a control group; Marullo (1974) found 30 out of 60 subjects to have abnormal sensitized speech discrimination when 35 out of 60 had normal audiograms; Colletti et al (1985) found abnormalities in the stapedial reflex in 34% of subjects when only 15% had abnormal audiograms, and Martini et al (1985) found evidence of brainstem involvement using auditory brainstem evoked response in 26 'normally hearing' diabetics.

Other evidence for diabetes-induced hearing impairment is from studies such as that of Martin, Boulud and Martin (1975) in which 30% of 317 cases of 'accelerated presbyacusis' had abnormalities of glucose tolerance testing.

Interestingly, there is no consistent correlation between the degree of hearing loss in diabetics and the presence of other complications such as retinopathy, neuropathy and nephropathy, although sporadic reports of such associations do exist.
There are six possible mechanisms for diabetic labyrinthopathy:

1. microangiopathy of the cochlea
2. neuropathy, either as the mononeuropathy equivalent to sudden foot drop, or third canal nerve palsy or via vasa nervorum pathology
3. brainstem involvement
4. the metabolic effect of the hyperglycaemia, or the consequent hypertriglyceridaemia
5. vascular problems secondary to the hyperviscosity that occurs and/or the abnormal platelet aggregation
6. any combination of the above.

The effect on the ear of well-controlled diabetes is not yet known.

_Hypothyroidism_

Thyroxine deficiency is most commonly the result of a condition within the thyroid gland, but occasionally occurs as a result of thyroid stimulating hormone deficiency in pituitary or hypothalamic disease. Myxoedema is the accumulation of hydrophilic mucopolysaccharides in the dermis and other tissues which is unusual in deficiency of thyroid stimulating hormone.

In adults, hypothyroidism may occur as a result of radioactive iodine therapy or thyroidectomy for thyrotoxicosis, from irradiation of the neck in lymphoma or laryngeal carcinoma, or from drugs such as cobalt, lithium and phenylbutazone, but a primary idiopathic form is also common.

Primary idiopathic hypothyroidism is usually a disease of middle-aged women, although it does occur in any age and in men. Its commonest form is Hashimoto's thyroiditis, one of the organ-specific autoimmune disorders, with serum antibodies present either to thyroglobulin or to the microsomal fraction of thyroid cytoplasm and often with gastric parietal cell antibodies as well.

Clinically, the onset is gradual and notoriously often missed unless a high index of suspicion is maintained. The cardinal early features are the dry skin, hoarse voice, coarse dry hair, sensitivity to cold, and slowness. Other features range from menorrhagia, to congestive cardiac failure to psychosis. Anaemia is common either as primary feature or because of concurrent pernicious anaemia.

Reports of hearing loss in hypothyroidism date from Bircher (1883), and in a major text on the thyroid, De Groot and Stanbury (1975) quoted auditory involvement in one-third of all cases. Bhatia et al (1977) found 43% of their subjects to be hearing impaired.
There are no temporal bone studies in hypothyroidism in man, although there are several in animals after experimentally induced thyroid deficiency which show changes in the middle ear and cochlea. Ritter (1969) found a conductive loss in rats with myxoedematous infiltrates in the mucosa of the middle ear and eustachian tube and De Vos (1963) found changes in the spiral ganglion in rats, mice and hamsters.

Audiometrically there is little doubt that a conductive hearing loss can occur in humans with myxoedema (Bhatia et al, 1977) but, more commonly, any hearing loss is sensorineural. Using a variety of tests of central auditory function including auditory brainstem response, and cochlear tests such as remote masking and critical band width, Quaranta et al (1985) found no central abnormalities although sensory function was abnormal in six out of six subjects, brief tone audiometry being the most frequently abnormal. Cochlear losses were also found by De Vos (1963) and by Bhatia et al (1977) in 18 out of 33 and 31 out of 72 cases, respectively. On the other hand, Stephens (1970) found absence of recruitment and the presence of abnormal auditory adaptation at 8 kHz using Carhart's modified tone decay test, suggesting a retrocochlear pathology.

The effect of therapy is of proven benefit so far as the general condition of patients is concerned. However, the effects of thyroxine on the 'myxoedematous' ear are more controversial. Certainly, abnormalities in both electrocochleography (Rubenstein, Perstein and Hildesheimer, 1975) and cortical evoked response audiometry (Nishitarie and Koo, 1968) are reversed after treatment. Cody (1971) quoted improvement in hearing in 50% of subjects treated with thyroxine and presented one case of his own. Parving (1985), however, maintained that such isolated reports are not convincing. Indeed none of the hearing impaired subjects in the study by Bhatia et al (1977) showed any objective improvement with therapy.

The classic description of the hearing loss is again, like diabetes, high frequency and 'presbyacusis-like' although flat loss (De Vos, 1963; Stephens, 1970) and even unilateral loss (De Vos, 1963) have been described. The degree of hearing impairment varies from a slight 20-30 dB loss to 'severe'.

Despite the foregoing, both Goodhill (1979) and Meyerhoff (1985) argued that there is no definite proof that sensorineural hearing loss is associated with hypothyroidism. In addition, in a study of 15 proven myxoedematous patients, Parving, Parving and Lyngsol (1983) and Parving (1985) found that, as a group, the patients had a bilateral symmetrical sensorineural hearing loss but when compared with age-matched controls there was no difference on pure-tone thresholds. They also found no change in hearing following treatment.

**Acromegaly**

The excess secretion of growth hormone from an eosinophilic cell adenoma of the pituitary gland results in an increase in the size of the bones and soft tissues of the hands, feet, supraorbital ridges, sinuses and mandible leading to a characteristic appearance. The general metabolism is increased with excessive sweating and hypertension. Nearly one-third (30%) of patients develop carbohydrate intolerance with frank diabetes mellitus supervening and hypothyroidism occurs secondary to pituitary failure as the tumour grows.
The first report of hearing loss in this condition was by Menzell (1966). A 72-year-old male had a low frequency sensorineural hearing loss and the author speculated that bony hypertrophy of the skull had led to narrowing of the internal auditory meatus, although no site of lesion audiometry was undertaken. Richards (1968) studied 15 acromegalic patients all of whom were hypertensive and four were also diabetic. Three of the 15 patients exhibited a conductive loss in a total of five ears. The tympanic membrane was normal in each case and Richards hypothesized an overgrowth of the stapes as in otosclerosis. When considered as a group, Richards' subjects were also said to show a sensorineural hearing loss worse than that expected by age alone. Doig and Gatehouse (1984) rightly criticize the validity of such broad statements without evidence from concurrently tested, matched controls. Their study on 56 patients showed no significant alteration in hearing levels when compared with careful age- and sex-matched controls. All patients underwent pituitary surgery with no effect on hearing levels.

These conflicting reports stimulated Crosara et al (1985) to investigate 15 patients and 40 age-matched controls. All patients had had pituitary surgery and eight patients were still taking bromocriptine. The investigations included pure-tone audiometry, acoustic impedance audiometry and brainstem evoked responses. When compared with the control group, pure-tone audiometry was abnormal especially at high frequencies where 63.3-66.6% of ears did not have normal hearing. Results of brainstem evoked responses confirmed a brainstem problem in two out of 11 patients and six ears had evidence of a retrocochlear lesion on acoustic reflex tests. All subjects had normal tympanograms. Interestingly the internal auditory meatus were normal in all cases. The authors suggested thickening of vascular walls leading to a cochlear and/or retrocochlear vasculopathy as the cause of the hearing loss which varied from mild to a 90-115 dB loss in the left ear and a 65-85 dB loss in the right in a 64-year-old female.

**Hypoadrenalism (Addison's disease)**

In the UK, 78% of cases are autoimmune, 21% tuberculous and other causes are rare, although often well known - the Waterhouse-Friderichsen syndrome in meningococcal septicaemia for example. The commonest type is an organ-specific autoimmune disease with females affected twice as often as males. There are adrenocortical antibodies in the serum and an association with the other organ-specific diseases.

The hallmarks of the disease are excessive pigmentation, hypotension, weight loss, tiredness and malaise and it is the pigment that should alert the clinician to possible diagnosis. The auditory system, when involved at all, usually manifests a fluctuating progressive hearing loss with episodic tinnitus and vertigo - Ménière's syndrome (Goldman, 1962; Meyerhoff, 1985).

**Phaeochromocytoma**

This chromaffin tissue tumour excretes catecholamines into the blood and is adrenal in 90% of cases. This lesion is mentioned in addition to the previous four diseases because of its association with multiple neurofibromatosis (Von Recklinghausen's disease) and therefore it may coexist with acoustic neuroma.
Organ-specific autoimmune hearing loss

Several of the organ-specific autoimmune diseases are associated with hearing loss, for example diabetes mellitus and Hashimoto's thyroiditis; these are discussed in the Endocrine section of this chapter. Pernicious anaemia and primary infertility have also been implicated (Veldman et al, 1984) and it is well recognized that the individual conditions often occur together in the same person. One possible conclusion from this is that the hearing impairment in these diseases is a manifestation of another organ-specific autoimmune process - in this case directed towards the inner ear.

McCabe (1979, 1985) has described 56 cases of autoimmune inner ear disease in humans. The hearing loss is sensorineural, bilateral, worse in the high frequencies and progressive over weeks or months rather than hours or years. Vestibular features are absent in this condition. Although the hearing loss can be total and permanent, it is more commonly reversible, at least partially, if treatment is commenced early. In over one-half of those tested the lymphocyte migration inhibition assay is positive when using human inner ear antigen as a challenge.

The role of autoimmunity in Ménière's disease is discussed elsewhere in this volume (see Chapter 5).

Systemic immune mediated diseases

Several conditions with widespread manifestations secondary to systemic vasculitis have been associated with sensorineural hearing loss. All of these conditions are associated with circulating immune complexes which are also present in the autoimmune hearing loss described above (Hughes et al, 1984) and in steroid-responsive sensorineural hearing loss of unknown aetiology (Kanazaki and O-Uchi, 1983). The erythrocyte sedimentation rate is elevated in all of these conditions, but other manifestations of autoimmunity vary.

Systemic lupus erythematosus

This illness most commonly presents with fever and migratory arthralgia. Rashes are common including the 'butterfly rash' which gives the disease its name. Raynaud's phenomenon and splinter haemorrhages are frequently seen but the pattern of the organ involvement varies from case to case, the kidney and nervous system being the most constant. The age of onset is usually between 20 and 40 years and 90% of patients are women.

A high frequency cochlear hearing loss has been described in systemic lupus erythematous which may be of sudden onset and may respond to immunosuppression or plasma exchange (Hamblin, Mufti and Bracewell, 1982).

Rheumatoid disease

This is another condition that is more common in females, the cardinal feature being a chronic polyarthritis affecting principally the proximal interphalangeal joints and spreading to the wrists, ankles, knees, elbows and shoulders. Rheumatoid nodules are present in 10-20% of cases and a systemic vasculitis is usual in those with nodules. Goodwill, Lord and Knell-
Jones (1972) found a higher than usual incidence of sensorineural hearing loss in subjects with nodules. Interestingly they also report changes in the lenticular process and in the long process of the incus in one of three cases at postmortem.

**Polyarteritis nodosa**

This is predominantly a condition of 20-50-year-old men. There are multiple nodules on small arteries with the underlying vessel wall infiltrated by polymorphs. Systemic features such as malaise, weight loss, fever and tachycardia are accompanied by symptoms of local ischaemia including abdominal pains, angina and peripheral neuropathy. The renal vessels are usually involved; asthma may occur as may hypertension and eosinophilia.

Pietersen and Carlson (1966) reported hearing loss in five out of 21 subjects with polyarteritis nodosa and Jenkins, Pollak and Fisch (1981) described the histological findings in a case with sudden unilateral hearing loss. The cochlea showed loss of the organ of Corti with strial atrophy and decrease in the numbers of spiral ganglion cells, worse in the basal turns. There was also new bone formation in the scala tympani - a finding suggestive of sudden arterial occlusion (Belal, 1980).

This condition may also affect the middle ear with granulations and a conductive hearing loss (Lucente, 1974).

**Systemic sclerosis (scleroderma)**

This is a disease of collagen fibres of the dermis, gastrointestinal tract, lungs, myocardium and kidney. There is a systemic vasculitis with marked thickening. At first symptoms are confined to the hands.

Tosti, Patrizi and Veronesi (1984) investigated 22 women, aged 37-75 years, with systemic sclerosis. Thirteen of these patients had abnormal hearing, one had a severe sensorineural hearing loss, two had a 'significant' mixed loss and the remaining 10 had a mild impairment which was unilateral in three. In systemic sclerosis, antinuclear antibodies are present in 40-60% (Hughes and Lanham, 1981), but this finding was present in 12 of these 13 cases.

**Giant cell arteritis**

This is a generalized disorder of medium-sized vessels and can be associated with polymyalgia rheumatica. The vascular wall is infiltrated by giant cells, plasma cells and mononuclear cells. These changes usually affect the scalp vessels but can be widespread and the complication of sudden visual loss is well reported. An equivalent sudden hearing loss has been described (Cooke et al, 1946; Cody, 1971; Francis and Body, 1982). Patients may also have a hearing loss with gradual onset. Kinmont and McCallum (1965) found this type of loss in eight of their 59 cases and Malmvall and Bengtsson (1978) in five out of 68 patients.
**Sjögren's syndrome**

Xerostomia is the commonest feature of this chronic inflammatory autoimmune disorder of the exocrine glands. The condition may be a feature of other autoimmune diseases or may occur as an isolated condition. A conductive hearing loss has been described in Sjögren's syndrome (Lucente, 1974; Veldman et al, 1984).

**Other conditions associated with vasculitis**

**Cogan's syndrome**

This syndrome comprises a non-syphilitic interstitial keratitis and acute onset of progressive cochlear hearing loss with vestibular symptoms (Cogan, 1948). The onset is usually before the age of 30 years and men are affected as commonly as women. Several cases reported in the literature have been associated with other diseases causing a systemic vasculitis. Smith (1970) reviewed the literature to that date and, of the 46 cases reported, five had polyarteritis nodosa, one had sarcoidosis, three occurred after vaccination for smallpox and five had symptoms suggesting polyarteritis nodosa.

Fisher and Hellstrom (1961) described a systemic vasculitis and Edstöm and Vahlne (1976) have shown transient impairments of cell-mediated immunity and evidence of complement utilization.

Histological studies have demonstrated endolymphatic hydrops, atrophy of the spiral ganglion, strial cysts and oedema of the spiral ligament (Wolff et al, 1965). In addition, Zechner (1980) found calcification in the scala vestibuli, again suggesting sudden arterial occlusion (Belal, 1980).

**Vogt-Koyanagi-Harada syndrome (uveomeningoencephalitic syndrome)**

This is the association of meningism, uveitis, retinal detachment, alopecia, poliosis, vitiligo and hearing loss. It is commoner in Japan and tends to occur in the third decade. The usual presentation is with headache, fever, nausea, vomiting and orbital pain. Uveitis supervenes after about 2 weeks with impairment of visual acuity. The hearing loss occurs with the uveitis in 50% of cases, can be cochlear or retrocochlear (Dickson, 1973) and is often profound. The vision and hearing losses tend to improve 2-6 weeks after their onset and may return to normal. The cerebrospinal fluid shows a lymphocytosis, an elevated protein level and a normal sugar concentration (Maxwell, 1963).

Evidence is accumulating to suggest an autoimmune mechanism in this disease. Uthoff, Mueller-Ruckholtz and Boeke (1979) demonstrated antibodies to uveoretinal tissue homogenate and Hammer (1975) showed leucocyte migration inhibition using uveal pigment as a challenge. Hammer (1975) also found antimelanin antibodies in melanin-sensitized lymphocytes. In Japan there is an association with HLA BW22, (a unique Japanese variant of BW22) and with HLA DWa (Tagawa, Sugiura and Yakura, 1977).
**Sarcoidosis**

Sarcoidosis is a systemic granulomatous disease of unknown aetiology. The lesions resemble tuberculomata but there is no caseation and no tubercle bacilli have been found. Chronic beryllium poisoning produces a disease clinically and histologically indistinguishable from sarcoidosis (Grant, Horne and McHardy, 1977).

A bilaterally symmetrical hilar lymphadenopathy is a well known feature, but superficial lymph nodes can also be involved. Of the other organs, the lungs, liver, spleen, skin, eyes, parotids and phalangeal bones are most commonly affected.

Neural manifestations occur in 5% of cases and are due to direct infiltration of nerve sheaths or roots. Seventh cranial nerve palsy is the most common central nervous system manifestation and hearing loss is the fourth commonest (Babin, Liu and Aschenbrener, 1984).

The hearing loss may be secondary to cochlear degeneration, but this, itself, is probably secondary to eighth nerve involvement. Babin, Liu and Aschenbrener (1984) have reported lymphocytic infiltration of the intraneural microvasculature in the internal auditory meatus, while Thorp and Pfeiffer (1969) suggest that the hearing loss can also be secondary to the granulomatous leptomeningitis that can occur.

**Behçet's syndrome**

The aetiology of Behçet's syndrome is not known. It is commoner in the Middle East and Japan (where the prevalence is 1:10.000) than it is in the UK (0.64:100.000) (Gilliland and Mannik, 1980).

The hallmarks of this disease are orogenital ulceration and inflammatory eye disease. There is also a vasculitis of small and medium-sized vessels with a predominantly lymphocytic infiltrate into the perivascular tissues as well as the vascular walls. Approximately one-half of the patients have an asymmetric polyarthritis involving the large joints. The central nervous system is involved in 25% of cases. This tends to occur late in the course of the disease and is characterized by exacerbations and remissions.

The hearing loss also occurs late in the disease; it is sensorineural and progressive and usually symmetrical. However, Brama and Fainary (1980) presented one case with unilateral cochlear involvement from a group of 16 consecutive patients, nine of whom had auditory dysfunction. The hearing loss may also be central (Hughes and Lehman, 1979).

**Wegener's granulomatosis**

This is primarily a disease of the respiratory tract and kidneys. It is probably a hypersensitivity reaction with systemic vasculitis and glomerulonephritis as well as granulomata, although the antigen responsible is unknown. There is evidence for circulating immune complexes being involved in some patients (Wolff, 1980).

The lesions commonly occur in the sinuses, lungs, kidneys and skin. The ear is involved in up to 35% of cases (Fauci, Haynes and Katz, 1978) and, although most are
conductive losses secondary to otitis media (Watanabe, 1975), purely sensorineural losses have been described (Blatt and Lawrence, 1961; Leone, Feghali and Linthicum, 1984).

Histological changes in the inner ear include degeneration of outer hair cells and oedema of the spiral ligament (Friedmann and Baur, 1973), new bone formation around the labyrinth (Blatt and Lawrence, 1961) and haemorrhages into the peri- and endolymphatic space (Watanuki, Kawamoto and Kakizaki, 1975).

**Relapsing polychondritis**

This is a disease of unknown aetiology which results in inflammation and then destruction of cartilage. There is a lymphocytic and plasma cell infiltration of affected cartilage particularly of the ear and nose, which are involved in 80-90% of cases. Episcleritis occurs in 60% (Arkin and Masi, 1975). Systemic vasculitic diseases (such as systemic lupus erythematosus) have been found in 30% of cases (McCaffrey, McDonald and McAffrey, 1978).

The hearing loss is usually cochlear (the cochlea being involved in 46% of all cases; McAdam et al, 1976) although conductive losses secondary to inflammation of the eustachian tube cartilages have been reported (Cody and Sones, 1971). The hearing loss may be sudden (Kimura, 1978; Hoshino et al, 1980) or unilateral (Cody and Sones, 1971), but is often progressive and symmetrical.

Hoshino et al (1980) presented one patient with temporal bone histology. There was ossification and fibrous tissue in the perilymph space (a finding described by Belal, 1980, in sudden arterial occlusion) and a degeneration of the organ of Corti with well preserved neural elements.

**Eosinophilic granuloma of the temporal bone**

Although this is usually a disease of children it may occur in adults and may cause a sensorineural hearing loss (Fradis et al, 1985).

**Ulcerative colitis**

There are three case reports of a high frequency sensorineural hearing loss in this disease (McCaffrey, McDonald and McAffrey, 1978; Weber, Jenkins and Cohen, 1984; Bulman, Kane and Srivastva, 1985).

**Metabolic disorders associated with hearing loss**

**Hyperlipoproteinaemia (hyperlipidaemias)**

The hyperlipoproteinaemias are classified into six types (Fredrickson's types I, IIa, IIb, III, IV and V) according to criteria agreed by a World Health Organisation Committee (Beaumont et al, 1970). Each type may be either a primary condition or secondary to some other disease. The commoner conditions associated with secondary hyperlipidaemia include
diabetes mellitus (which leads to a type IV hyperlipidaemia), hypothyroidism (type IIa), and the nephrotic syndrome (type IIa or IIb).

For most clinical purposes, primary hyperlipidaemia can be divided into three groups (Baird and Strong, 1977). In group I the serum is clear, the triglyceride level is normal but the serum cholesterol and beta-lipoproteins are increased (Fredrickson's type IIa). This disorder is a risk factor for ischaemic heart disease and is probably influenced by diet. There is a subgroup with autosomal dominant inheritance in which the clinical stigmata of hyperlipidaemia are common (tendon xanthomata, arcus senilis and xanthelasma). One-half of these patients have ischaemic heart disease by the age of 50.

In group 2, the serum is cloudy and the triglycerides and beta-lipoproteins are elevated with normal or near normal cholesterol (Fredrickson's types IIb, III, IV and V). There is often impaired glucose tolerance, elevated uric acid and obesity and there is a strong association with ischaemic heart disease.

Group 3 is Fredrickson's type I, a rare disorder resulting from deficiency of extrahepatic lipoprotein lipase leading to chylomicronaemia.

Considerable evidence has accumulated over the last 24 years that hyperlipidaemia is associated with a sensorineural hearing loss. In this context the work of Rosen has contributed greatly to our understanding and knowledge. Interest was stimulated by his work with the Mabaan people of Sudan in the 1960s. They have no noise exposure, are vegetarian and have a diet containing no saturated fats. Hyperlipidaemia and hypertension are unknown and coronary heart disease is very rare. At the age of 70-79 years, subjects had normal pure-tone thresholds from 125 Hz to 2 kHz and at 6 kHz the maximum hearing loss was only 25 dB.

Then, in an elegant study in 1970, Rosen, Olin and Rosen looked at the effects of diet on hearing loss in two institutions for long-stay patients in Finland. One group had their diet altered to reduce the polyunsaturated fat intake while the other carried on with the 'normal' high fat Finnish diet. After 5 years the study group had significantly lowered serum cholesterol levels, less electrocardiographic evidence of ischaemic heart disease and significantly better hearing. At 5 years, the diets were reversed and the populations restudied after a further 3.5 year period. The cholesterol levels were again lower in the group on the low fat diet and there was no difference in mean hearing levels between the groups. The pattern of hearing loss found was typical of what is known as presbyacusis.

Evidence for the association between sensorineural hearing loss and hyperlipidaemia has also come from studies of the hearing impaired. Booth (1977) investigated 44 subjects aged 25-55 years, with symmetrical sensorineural hearing loss of unknown aetiology and found nine (38%) to have abnormally high lipids. Of these, six were either Fredrickson's type IIb or IV. Spencer (1983) studied 300 patients, including himself, who had symptoms or signs of otherwise unspecified inner ear disease. He found 127 of them to have unquestionably elevated serum lipids and a further 26 to have borderline results - a total of 51%. In a comparative group of patients attending an otolaryngology clinic for other reasons only 19.3% had lipid abnormalities. This is despite the fact that this group included only those who were overweight or had a family history of either diabetes mellitus or coronary heart disease. Of the 127 with definite abnormalities 108 had Fredrickson's type IV hyperlipidaemia.
The effect of hyperlipidaemia on noise-induced hearing loss has also been studied in chinchillas (Morizano et al, 1985) and humans (Axelsson and Lindgren, 1985) and in both species those exposed to noise, whether experimental or occupational, are more likely to develop hearing loss if they are also hyperlipidaemic.

**Chronic renal failure**

The association of hearing loss and chronic renal failure in Alport’s syndrome is well known (see elsewhere in this chapter), but sensorineural hearing loss has also been reported in 40-47% of patients with renal disease, whatever the cause (Arnold, 1984). The hearing loss again affects predominantly the high frequencies (Sittoni et al, 1985) and there are occasional reports of mixed hearing impairments (Johnson, Wathen and Mathog, 1976). The effects of dialysis and transplantation on the hearing loss have not been established and the literature abounds with conflicting reports.

There are good theoretical reasons why patients with chronic renal disease should have hearing impairment. Electron microscopy has shown that the marginal cells of the stria vascularis are similar to the tubular cells of the proximal loop of Henle in containing large numbers of mitochondria and having a high oxygen consumption. In addition, both of these structures have epithelial crests with ionic exchange functions (Arnold, 1984). Certain tissues of the inner ear and kidney also have remarkably similar immunological reactions suggesting a shared antigenicity (Quick, Fish and Brown, 1973; Quick, 1975).

There are several changes secondary to the chronic renal failure which may affect hearing:

1. there may be a direct effect of uraemia or other toxins
2. the fluid retention and hyponatraemia may effect the inner ear fluid dynamics
3. hypertension is common and has been associated with hearing loss (see elsewhere in this chapter)
4. the ear could be affected by the generalized capillary fragility and platelet abnormalities that occur in chronic renal failure.

Patients suffering from this condition frequently receive ototoxic drugs, especially aminoglycosides and loop diuretics. However, Kligerman et al (1981) found that, although 49% of their subjects with hearing loss had received ototoxic drugs, 50% of those with normal hearing had also received such therapy. Overall 52% of these patients with chronic renal failure had hearing impairment, most had sensorineural hearing cochlear loss at frequencies above 2 kHz only and this was unilateral in 14 out of 35 patients and mixed in eight.

**Vitamin deficiency**

Sensorineural hearing loss has been associated with thiamine deficiency (Denny-Brown, 1947), nicotinic acid deficiency (Spillane, 1947) and cholecalciferol deficiency
(Brookes, 1983, 1985), although the latter was not confirmed in a separate study (Irwin, 1986).

**Vasculopathy and hearing loss**

The effects of vasculitis on the inner ear are discussed elsewhere in this chapter. This section encompasses several conditions that are not easily classified elsewhere including vascular occlusion, hypertension and presbyacusis.

Experimental occlusion of the internal auditory artery in guinea-pigs results in patchy degenerative changes in the cochlea especially in the hair cells and spiral ganglion, the hair cell changes being worse in the basal turn. Occlusion of venous drainage in the same species also results in hair cell degeneration, but stria vascularis changes are also common in this condition. In humans sudden total arterial deprivation results in hearing loss followed by permanent disruption of the cochlea with subsequent calcification (Belal, 1980).

More gradual generalized vasculopathies are known to occur in several conditions. Diabetes, hyperlipidaemia, hypothyroidism and chronic renal failure are discussed elsewhere in this chapter. Schnohr and Rasmussen (1980) reported poorer hearing in a group of women surviving myocardial infarction when compared to a random sample of women from the same population. The hearing loss was again high frequency and sensorineural.

**Hypertension**

Only 5% of individuals with elevated blood pressure have an identifiable underlying cause. The remainder have essential or primary hypertension. There exists in a few families an inherited defect in cellular sodium transport mechanisms possibly due to the natriuretic hormone, but most subjects do not have this problem.

A high frequency sensorineural hearing loss has been reported in both rats (McCormick et al, 1982) and humans (Makishima, 1978) in association with hypertension, and histological studies have shown changes in the stria vascularis. However, this association was not found by Hansen (1968) or by Drettner et al (1975).

**Sickle-cell anaemia**

This disease is caused by the presence of the abnormal haemoglobin S. In connection with hearing loss we are only concerned with the homozygous (SS) disease rather than with the heterozygous sickle-cell trait (AS). The abnormal gene has been selected in equatorial Africa as the sickle-cell trait confers a high resistance to falciparum malaria.

Sickle-cell crises occur as a result of thrombosis in the capillaries. Under conditions of poor oxygenation haemoglobin S molecules polymerize to form the pseudocrystalline tactoids which result in deformations of the red cell membrane. The polymerization is reversible but the erythrocyte distortion may become permanent and will result in a sickle cell. Sickle cells increase blood viscosity, traverse capillaries poorly and tend to obstruct flow, thus increasing the sickling of other cells with resulting cessation of flow and thrombosis.
Todd, Serjeant and Larson (1973) and Friedman et al (1983) found a high frequency sensorineural hearing loss in 18 out of 83 and five out of 43 cases, respectively. However, Orchich (1977) and Friedman et al (1980) described sudden severe hearing loss which may be irreversible, as a feature of sickle-cell crises. Those cases coming to autopsy have shown sickle cells in the stria vascularis and hair cell loss (Urban, 1973).

Presbyacusis

The State Hearing Centres of Denmark have defined presbyacusis. It is a symmetrical hearing defect which occurs after the age of 65 years with no underlying cause. Schuknecht (1974) has classified this condition into four types:

1. **Sensory**, in which there is a high frequency loss which progresses slowly and does not involve the speech frequencies. There is associated atrophy of the supporting cells and hair cells with secondary cochlear neuronal loss.

2. **Neural**, in which speech discrimination loss is more severe than the pure-tone loss. It is associated with neuronal loss throughout the cochlea but with more severe changes in the basal turn. There are often other central nervous system changes in these patients.

3. **Strial**, where there is a flat audiometric picture with relatively better preserved speech discrimination ability. Histologically, there are patchy changes in the stria vascularis of the middle and apical turns.

4. **Cochlear conductive**, in which there is a sloping loss, worse at the high frequencies but involving the speech frequencies. This is associated with a histologically normal cochlea. This category has been challenged and could be a result of a central pathology.

In all four types the hearing loss is symmetrical and progressive.

Throughout this chapter many conditions have been described which cause a symmetrical, progressive, high frequency sensorineural hearing impairment. Several of these diseases, for example diabetes and hypertension, increase in prevalence with advancing age, and it may not be unreasonable to expect an underlying cause to be found in many cases of 'presbyacusis'.

Most epidemiological studies show noise-induced hearing loss to be an important cause of hearing loss. For example in a study of men aged 49-69 years, Parving et al (1983) found noise exposure to be the cause in 45% of those with a sensorineural hearing loss. Driscoll and Royster (1984) studied this problem in a different way. They compared the hearing thresholds of an unscreened population who had not been exposed to industrial noise, with four of the 'presbyacusis' data bases, or age-matched hearing curves. They found that after the age of 35-45 years their group had better hearing than the data bases and at the ages of 60-69 years, the mean hearing loss in their group at 6 kHz was only 23.5 dB. These workers suggested that the existing data bases are contaminated by noise effects.
One way to determine the extent of presbyacusis as an entity would be to examine an elderly hearing-impaired population and then to establish a cause for the impairment if possible. Stephens (1982) investigated 172 consecutive elderly patients attending a rehabilitation clinic in the UK. He found an underlying cause for the hearing loss in 81% of patients, the largest single cause being otitis media (33%). This implied a diagnosis of possible presbyacusis in only 19%. Reasons for the hearing impairment were eventually found in a further 12%, leaving only 7% of cases where no actual diagnosis could be made.

Lim and Stephens (1986) undertook a prospective study of 80 consecutive patients over the age of 65 years referred by their primary physician because of increasing hearing loss or for assessment of the need for provision of hearing aids. Only one patient had a purely conductive loss and 56 had no conductive component, the remainder having a mixed loss. Following thorough investigation 83% of subjects were found to have a condition known to be associated with hearing loss. Of the 14 remaining patients, 10 had been incompletely investigated leaving only four (5.7% of those fully investigated) with a diagnosis of presbyacusis. One-half of the subjects in this study had a previously undiagnosed medical condition; 12 had hyperlipidaemia (nine type IV and three type IIb), 11 were hypertensive, 15 had elevated alkaline phosphatase, six had acute otitis and one had chronic anaemia. Alarmingly, 30% were taking medication known to be ototoxic.

Careful studies such as this make it clear that to label, without investigation, all elderly patients as suffering from presbyacusis is not only a misdiagnosis but may result in a treatable medical condition being missed. It is certain that, although presbyacusis may exist as a clinical entity, it is not as common as is often supposed.

**Neurological disorders**

Hereditary neurological diseases associated with adult onset hearing loss (Friedreich's ataxia, Refsum's disease, Charcot-Marie-Tooth disease and the Denny-Brown syndrome for example) are discussed elsewhere in this chapter.

Toxic neurological syndromes with hearing loss include Nigerian ataxic neuropathy caused by thiocyanate, chronic toxic encephalopathy secondary to industrial organic solvent exposure and the neurological syndrome associated with \( n \)-hexane toxicity in glue sniffers. These conditions are discussed more fully in Chapter 5.

Central nervous system neoplasia in association with hearing loss, including acoustic neuroma, is described elsewhere in this chapter and the reader is referred to the vestibular section of this volume for a discussion of vertebrobasilar insufficiency.

This section of this chapter is primarily concerned with the auditory manifestations of multiple sclerosis although other conditions will be mentioned.

**Multiple sclerosis**

This is a disease of unknown aetiology characterized by patches of demyelination and subsequent gliosis. The disease is confined to the central nervous system and is episodic in nature in the initial stages, although a progressive picture is common later in the disease. The
Glial scars, or sclerotic plaques, can occur anywhere in the central nervous system, but there are several sites of predilection including the optic nerves and chiasma, periventricularly in the cerebral hemispheres and subpial in the spinal cord.

The auditory system is usually involved by a pontine plaque involving the vestibular nuclei and adjacent structures and, although less common than vestibular symptoms, hearing loss can be a prominent feature. Daugherty et al (1983) described nine such cases with bilateral hearing loss in two. All had other evidence of brainstem disturbance and there was a tendency for the hearing loss to improve although it did not always return to normal.

Although auditory symptoms are uncommon, auditory system abnormalities are found in a higher percentage of subjects on investigation.

Luxon (1980) found 30 out of 57 patients with multiple sclerosis to have abnormal pure-tone audiograms with 18 of them having binaural impairment. Cohen and Rudge (1984) compared 44 subjects with 44 controls. They found that the subjects had essentially normal hearing but when group means were compared there was a significant difference at 500 Hz in both ears and at 1 kHz in the left ear - the patients having poorer hearing.

Even when the pure-tone threshold is normal, more sophisticated tests can reveal pathology. Grénman (1985) studied 70 patients with multiple sclerosis and, although only 14 of these had abnormal audiograms - nine of whom had alternative aetiologies - 96% of cases had abnormalities on electronystagmography. In addition, 71% had abnormal filtered speech and 56% had abnormalities of brainstem evoked responses. Colletti and Sittoni (1985) found abnormal brainstem evoked responses in 28 out of 37 patients with multiple sclerosis or possible multiple sclerosis, all of whom had normal audiograms.

**Cortical deafness**

This is a rare phenomenon resulting from bilateral embolism of the temporal lobes (Graham, Greenwood and Lecky, 1980) or even less commonly in multiple sclerosis (Tabira et al, 1981). In these patients there is no recordable pure-tone threshold or cortical evoked response, but the acoustic reflexes and brainstem evoked potentials are normal. Graham, Greenwood and Lecky (1980) found that the middle latency evoked responses were absent in their patient, who also had monotonous speech with some elements of dysphasia. He could read phonetically, made spelling errors and could execute no more than simple commands.

Infarction of the midportion of the left superior temporal gyrus may cause pure word deafness or auditory aphasia. In such cases patients may present to the audiologist because of speech discrimination difficulties, but the pure-tone audiogram is normal. The patient can read and write normally and spontaneous speech is unimpaired, but repetition of speech is abnormal. Speech is distinguishable from other sounds but is unintelligible (Coslett, Brashear and Heilman, 1984).

**Myasthenia gravis**

This has been described as causing a non-suppurative otitis media (Brookler et al, 1972) but this was only in those patients who had been ventilated for more than 96 hours.
Myasthenia gravis might also cause audiometric diagnostic confusion if a sufferer is tested for concomitant hearing loss, as it is a cause of stapedial reflex decay.

**Neoplastic and other space-occupying lesions**

The inner ear is one of the very few organs that has no associated primary tumour, a fact which is as yet unexplained. However, the auditory system can be involved in both primary and metastatic neoplasms of the outer and middle ears (see Volume 3) and of the eighth cranial nerve and its central connections.

Neoplasia accounts for only 1% of all sensorineural hearing losses (Hinchcliffe, 1973) although this figure rises to 11% of unilateral cases (Kumar, Maudelonde and Mafee, 1986). Despite their rarity, these conditions are important because of their potentially lethal outcome.

The auditory pathway may be involved in neoplasms of the blood and reticuloendothelial system as well as in intracranial tumours and by metastatic as well as primary lesions.

**Neoplasms of the blood and reticuloendothelial system**

**Leukaemia**

The most common leukaemia to affect hearing is the acute lymphoblastic form which, although usually a disease of childhood, does present in adults. Acute myeloblastic leukaemia and the chronic types are rarer causes of hearing loss.

Leukaemia is due to the development of a clone of abnormal stem cells in the bone marrow. The diagnosis is made on clinical suspicion, the peripheral blood film and bone marrow aspiration. Although the ear is involved in about one-quarter of cases, it is often unilateral and mild (Paparella et al, 1973) and is overshadowed by more life-threatening symptoms.

Most cases are conductive, usually secondary to haemorrhages into, or direct infiltration of, the middle ear. Otitis media is also more common in these patients. The inner ear can be involved with vestibular as well as auditory symptoms. Histological studies of the inner ear have shown infiltration and/or haemorrhage in the cochlear duct or eighth nerve (Hinchcliffe, 1973).

**Polycythaemia rubra vera**

This is a disease of unknown aetiology affecting patients over the age of 40 years. There is a slight male predominance.

There is extension of the red marrow throughout the long bones with raised red cell, white cell and platelet counts in the peripheral blood. The presentation is with the hyperviscosity syndrome of throbbing headache, tinnitus, fatigue, confusion and retinal vascular changes. There is often an associated sensorineural hearing loss.
Plasma cell neoplasms (paraproteinaemias)

These conditions occur as a result of the proliferation of abnormal plasma cells in bone marrow. The plasma cells arise from a monoclonar B-lymphocyte proliferation and produce immunoglobulins in excessive quantities. The plasma cells may form local tumours of bone which can become widespread as multiple myeloma or myelomatosis.

Myelomatosis is primarily a disease of the over fifties. The immunoglobulin is IgG or IgA in this condition and there is often an abnormal protein in the serum and urine (Bence-Jones protein).

A unilateral hearing loss has been described (Shone, 1985) and indeed this may be the presenting feature of the illness (Marks and Brookes, 1985).

The hyperviscosity syndrome may also occur in myelomatosis but is more common in the IgM form of paraproteinaemia: Waldenström's macroglobulinaemia. Wells, Michaels and Wells (1977) described a cochlear hearing loss of sudden onset in four patients with hyperviscosity secondary to Waldenström's disease. The hearing loss was sequential and bilateral.

An abnormal immunoglobulin that precipitates in cold temperatures (cryoglobulin) may be produced either as primary phenomenon or as part of other paraproteinaemias. Nomura et al (1982) reported a case of bilateral, progressive cochlear hearing loss in essential cryoglobulinaemia. Histology revealed that the organ of Corti had been completely replaced by a featureless mound and that the stria vascularis was atrophic.

Extramedullary intracranial space-occupying lesions

Acoustic neuroma (vestibulocochlear schwannoma)

This diagnosis represents 7-10% of intracranial tumours, the third largest group after gliomata and meningoimagata (Nager, 1985). Because of its anatomical relations, tumours of the vestibulocochlear nerve enter the differential diagnosis of cerebellopontine angle tumours and account for over 75% of such lesions. There is a peak in the age of presentation of 35-40 years and women are affected twice as often as men. Four per cent of cases have bilateral tumours and these patients usually have other evidence of neurofibromatosis.

The tumour is a schwannoma with varying degrees of fibroblastic tissue, the latter being more prevalent in multiple neuromata. Most tumours must be asymptomatic as the clinical diagnosis is made in only 1/100 000 population while the prevalence is 1% at random postmortem examination.

The classic presentation is with a unilateral, progressive, sensorineural hearing impairment of gradual onset. There is often associated unsteadiness of gait, which may be intermittent, and/or tinnitus. Once the tumour has enlarged to involve the fifth and seventh cranial nerves the diagnosis is usually obvious.
Unfortunately, even 10% of large (over 3.5 cm diameter) tumours have an atypical presentation (Morrison, 1974) and, overall, 22% of cases are not classic (Hinchcliffe, 1973). Atypical features include sudden hearing loss (Graham, 1981; Terry, 1985) and even normal pure-tone audiogram in 5% of cases (Flood and Brightwell, 1984).

The audiological investigation of acoustic neuromata should in theory be typical of retrocochlear pathology but, unfortunately, all investigations have a false negative rate and therefore a battery of tests is required. In a study of the literature, Flood and Brightwell (1984) determined the detection rate of the most common investigations. They found 70% of patients with acoustic neuraoma had poor speech reception thresholds, 78% had abnormal auditory adaptation, 85% had elevated acoustic reflex thresholds and 93% had stapedial reflex decay. Evoked response audiometry revealed 12% with normal electrocochleography but 98% with abnormalities of the auditory brainstem response. Caloric tests were normal in 4% of cases although with a fuller vestibular function testing 12 out of 13 proven tumours had evidence of retrolabyrinthine abnormalities (Kumar, Maudelonde and Mafee, 1986).

The radiological investigation of acoustic neuromata is discussed elsewhere.

**Meningioma**

Meningiomata comprise 18% of intracranial tumours and most of these present to neurologists or neurosurgeons. However, in a series of 117 patients with progressive unilateral sensorineural hearing loss, four had posterior fossa or cerebellopontine angle meningiomata (Kumar, Maudelonde and Mafee, 1986). These four patients all had retrocochlear findings on vestibular and audiometric testing.

**Epidermoids**

Intracranial epidermoids (primary cholesteatomata) are unusual tumours that arise from epithelial implantations which occur in embryological development. Approximately 40% of these lesions arise in the cerebellopontine angle. The most common presentation is with a trigeminal neuralgia-like facial pain (Hinchcliffe, 1973), although unilateral retrocochlear hearing loss also occurs. There is usually marked abnormal auditory adaptation in these patients (House and Doyle, 1962; Parker, Decker and Gardner, 1962; Stephens and Snashall, 1975).

**Lipomata**

Pensak et al (1986) have recently reported two cases with cerebellopontine angle lipomata bring the world literature total to 13.

**Vascular anomalies**

The anterior inferior cerebellar artery may loop into the internal auditory meatus in 14-39% of humans (Applebaum and Valvassori, 1984) but this is usually asymptomatic. Occasionally the loop may cause compression of the structures in the canal and produce symptoms. Applebaum and Valvassori (1984) found abnormal loops in 10 of 150 air contrast computerized tomographic meatograms for suspected retrocochlear pathology. All 10 cases
had asymmetrical audiograms, with a profound loss in two ears, and spontaneous nystagmus. Only five patients had canal paresis on caloric testing, the other five having normal studies. Auditory brainstem responses were normal in one of the seven patients tested, the others having bilaterally increased wave I to V latency.

Two of the 117 cases with progressive unilateral hearing loss studied by Kumar, Maudelonde and Mafee (1986) had this diagnosis and the present author has recently seen two cases in which this was the only operative finding in subjects with audiometric results highly suggestive of acoustic neuroma.

**Arachnoid cysts**

During embryological development, the foramen of Lushka in the lateral recess of the fourth ventricle may be incomplete leaving a blind canal. Some individuals develop a diverticulum of this canal which appears in the cerebellopontine angle and may grow large enough to cause symptoms and signs typical of other cerebellopontine angle tumours (Shaw and Alvord, 1977).

**Intramedullary neoplasia**

**Gliomata**

The commonest brainstem tumour is the astrocytic glioma (astrocytoma) of childhood, although this tumour does occur in adults. These tumours are benign and slow growing but, because of their situation, often present early. The auditory system is involved in about one-third of cases with marked abnormal auditory adaptation.

**Ependymomata of fourth ventricle**

The characteristic presentation is with headache, morning vomiting and vertigo. One-half of these patients have a bilateral incomplete sensorineural hearing loss (Hinchcliffe, 1973). In patients over 50 years of age metastatic tumours in the fourth ventricle may mimic this condition.

**Other tumours**

Choroid plexus papillomata of the cerebellopontine angle and pinealomata have both been reported in association with hearing loss.

**Metastatic tumours**

These can cause hearing loss by involving the temporal bone, the cerebellopontine angle, or the brainstem. Temporal bone metastases are rare. The three commonest sites for the primary tumour are the breast, the lung and the kidney. These account for 37% of temporal bone metastases (Kobayashi et al, 1986).
Traumatic hearing loss

Noise

This important cause of hearing loss is discussed in Chapter 18.

Ototoxic chemicals

Ototoxicity is another significant cause of hearing impairment. The main causes are drugs, food contaminants such as thiocyanate, air pollutants such as carbon monoxide, heavy metals such as lead, solvent abuse and alcohol. This topic is fully discussed in Volume 3.

Head injury

Hearing loss following head injury is generally secondary to temporal bone fracture. Most (80%) of these fractures are longitudinal and may result in a conductive hearing loss secondary to ossicular chain injuries. The remaining 20% are transverse fractures and such injuries often involve the cochleovestibular nerve either directly or by shearing forces. The resulting sensorineural hearing loss, like noise-induced hearing loss, results in a 4 kHz and/or 6 kHz notch.

Unfortunately, the picture is not always this clear-cut. More severe head trauma may result in combinations of both types of fracture with a mixed pattern of hearing impairment. Even in supposedly purely conductive hearing loss following incus dislocation, Dommerby and Tos (1983) found over 70% of their 34 patients to have a sensorineural component greater than 10 dB (six cases greater than 30 dB).

Dommerby and Tos (1983) found no progression of hearing loss over a period of 11 years, although either an osteogenic reaction or repeated infections may result in a slow decline in hearing thresholds (Hinchcliffe, 1973).

Not all skull fractures are evident radiologically and Browning, Swan and Gatehouse (1982) have rightly emphasized the importance of otoscopic examination in all cases of minor head injury. They found five unsuspected fractures in a prospective series of 130 patients. All five of these patients had a significant hearing loss on the affected side.

Severe head injury can lead to brainstem damage with subsequent retrocochlear hearing loss (Fourcin et al, 1985).

Blast injury

Otic blast injury is due to explosions. The explosion causes a pressure shock wave which is the primary agent of the damage. There is often rupture of the tympanic membrane and there may be ossicular chain injury. Sensorineural hearing loss also occurs and is more common than conductive loss (see Volume 3, Chapter 7).

One less usual cause of this injury is lightning strike. In a review of this topic, Wright and Silk (1974) reported that the average lightning bolt has a current flow of 10-20 kA, lasts
3 ms with a peak energy in the first 5-10 µs generating a temperature of some 24 000°C. Six of their seven cases had tympanic membrane rupture which was bilateral in two patients. Five patients had a permanent sensorineural hearing loss.

Two of these patients were using the telephone at the time of their injury and this has also been reported by Dreschler (1981) and by Kristensen and Tveteräs (1985). The acoustic pressure at the ear was estimated at approximately 155 dB sound pressure level (Dreschler, 1981) and was sufficient to render the patients unconscious.

_Dysbarisms_

There are several mechanisms by which changes in middle ear pressure as a result of flying and diving may result in auditory dysfunction.

When flying at high altitude the middle ear pressure equilibrates with the ambient cabin pressure and is thus less than the atmospheric pressure at ground level. On descent the eustachian tube may be 'locked shut' by this relative vacuum with resultant negative pressure in the tympanic cleft.

Divers can experience pressure effects on ascending, in this case with a positive middle ear pressure and even occasional tympanic membrane rupture. A painful haemotympanum may result, as may labyrinthine window rupture. Divers can also sustain a sensory hearing impairment during the course of caisson disease (decompression sickness). In this condition excess nitrogen, which had dissolved in the body fluids at high pressures, forms bubbles which can then occlude the vascular supply to the ear or brainstem. Divers are also at risk from pulmonary over-inflation on too rapid ascent. This may also lead to air embolism.

_Perilymph fistula_

This usually only thought of in the differential diagnosis of sudden vestibular disturbances following dysbarisms (including exertion), but a recent article on 91 cases by Seltzer and McCabe (1986) has highlighted the protean nature of this condition. Seventeen (18.7%) of these patients presented with hearing loss and tinnitus, or hearing loss alone, and had no vestibular symptoms. The largest single aetiological factor (31 cases) was trauma - direct head trauma in 10, barotrauma in eight, direct ear trauma in two, acoustic trauma in one, straining in six and 'minimal effort' in four cases. Twenty-four patients had had previous ear surgery, 19 of these following stapedectomy. Only three of these 19 cases developed a fistula in the first postoperative week, the remainder occurring between 6 months and 19 years after surgery. The only other large aetiological category was the idiopathic group with 22 cases (24%). The remaining patients were distributed as follows: seven with the Mondini defect, two with other congenital abnormalities, four with upper respiratory infection and one with congenital syphilis. The type of hearing loss varied from fluctuant to stable and from mild to severe, but fluctuating speech discrimination was an important feature. Symptoms had been present for up to 23 years before diagnosis.

Other workers have reported labyrinthine window rupture following nose blowing (Goodhill, 1981) or associated with a hearing impairment of gradual onset (Flood et al, 1985).
Flood et al (1985) reported a test which they found to be positive in 11 of their 14 patients. The patient lies with the affected ear uppermost for 30 minutes. A pure-tone audiogram is obtained before and after this procedure and an improvement in threshold of greater than 10 dB at two frequencies is indicative of a perilymph fistula.

**Direct trauma to the ear**

These patients usually experience a conductive hearing loss although there is often an additional sensorineural component at 2-6 kHz. Blows to the pinna, especially with a cupped palm, cause damage via a pressure effect transmitted down the external auditory meatus. This results in tympanic membrane and ossicular chain injuries.

The insult need not be so violent. Terayama and Matsushima (1983) reported a fracture of the long process of the incus during finger manipulation in the external auditory meatus.

Direct injury also occurs from the injudicious poking of objects down the ear canal. Matchsticks, cotton buds and hairgrips are common culprits, but this type of injury is a potential risk of instrumental wax removal or aural toilet in the clinic. The insertion of ear syringes too far can cause tympanic membrane rupture. This has also occurred when the nozzle of an ear syringe separated during syringing because of a worn screw thread (Stephens and Bellman, 1983; Medical Protection Society, 1985).

Direct trauma to the mastoid is less common but is a risk following the return to earth of bullets fired into the air, as is customary in certain countries during celebrations. Khan et al (1985) report one such case with hearing loss and facial palsy. The facial palsy recovered after the removal of the bullet from the mastoid.

**Postoperative hearing loss**

Hearing loss as a complication of surgery on, or near the middle ear, cochlea or auditory nerve is discussed in Volume 3. Hearing loss following operations on sites remote from the affected ear is considered here.

Perhaps this is best known following cardiopulmonary bypass surgery. This was first described by Arenberg, Allen and De Boer (1972) and an incidence of 1/1000 has been suggested (Plasse, Mittleman and Frost, 1981). The typical picture described is a unilateral severe cochlear hearing loss. However, a prospective study with pre- and postoperative audiometry in 68 cases revealed a much higher incidence (Shapiro, Purn and Raskin, 1981). These workers found nine cases (13%) where the average hearing loss at 2, 4 and 8 kHz had deteriorated by more than 10 dB bilaterally. A further 36 cases had lesser degrees of impairment, again in both ears. Only 23 patients (34%) had no change in pure-tone threshold following surgery. Half of those affected showed some recovery, but in no case was this complete.

The likely cause of both the severe unilateral and milder bilateral hearing loss is microembolism of fat, platelets or air. However, hypotension with subsequent impairment of cochlear blood flow is another possible explanation.
Severe unilateral cochlear hearing impairment has also been reported following acoustic tumour removal from the opposite ear (Clemis, Mastricola and Schuller-Vogler, 1982; De Keyser et al, 1983). Clemis, Mastricola and Schuler-Vogler (1982) also reported a retrocochlear hearing loss 1 week after contralateral tumour removal. This was possibly a hypersensitivity reaction. They described a further case with a middle ear effusion 4 years after contralateral acoustic neuroma surgery, but it is difficult to relate this to the surgery. A more likely explanation is an allergic or infective problem following the ingestion of partially defrosted, frozen, pre-packaged meatloaf.

Other operations can result in a severe cochlear hearing loss, usually with the patient aware of this on recovery from the anaesthetic because of tinnitus. Miller, Toohill and Lehman (1982) described one case each after radical mastectomy, cholecystectomy and pupilloplasty. Jaffe (1967) gives this as a complication of thyroidectomy, pacemaker insertion and abdominal surgery (two cases). The present author has recently examined one case following stripping of varicose veins.

Another anaesthetic-induced hearing loss is the temporary low frequency sensorineural hearing loss following spinal analgesia. A prospective study by Panning, Mehler and Lehnhardt (1983) found this complication in eight of their 100 patients. The hearing loss recovered in 24-48 hours.

**Ionizing radiations**

The auditory apparatus may be in the field of treatment during radiotherapy, primarily for postnasal space tumours. Early conductive losses are common secondary to eustachian tube dysfunction and later radionecrosis of the long process of the incus may occur. Sensorineural hearing impairment has also been described following radiotherapy. Because of the small number of patients in each centre, studies on humans have been retrospective.

Moretti (1976) found 13 subjects with pre- and post-treatment audiograms, eight of whom had a bilateral hearing impairment. Strohm, Ahlemann and Böhringer (1985) found a hearing loss of greater than 10 dB in 46 out of 67 ears which were in the field of irradiation. The hearing loss was worse in the high frequencies and tended to progress.

Bohne, Marks and Glasgow (1985) proved that ionizing radiation could cause cochlear damage by irradiating chinchillas. They found degeneration of sensory and supporting cells with loss of eighth nerve fibres in the organ of Corti. They also found increasing damage with increasing doses of radiation although the relationship of human hearing loss to dose is uncertain.

Histological studies in humans have shown loss of organ of Corti with eighth nerve atrophy (Leach, 1965), or spiral ligament atrophy and strial degeneration (Schuknecht and Karmody, 1966).

Chronic radium intoxication which is either occupational or self-induced, is also associated with abnormal hearing (Sharpe, 1974). This author found that conductive, mixed and sensorineural hearing losses had been much more frequent than expected in 40 cases.
coming to autopsy at least 25 years after exposure. There was also an increased incidence of otitis media.

**Miscellaneous causes of hearing loss**

Five conditions are mentioned here that are not easily classified into other sections of this chapter.

Ménière's disease is discussed in Chapter 5.

*Costen's syndrome*

This is the association of pain in and around the ears, neuralgia of the second and third divisions of the trigeminal nerve, headache, sinus and other facial pains, 'stuffy' ears, hearing loss, tinnitus, vertigo and alteration of the sensation of tongue, throat and nose. The existence of this as an entity has been questioned. Brooks, Maw and Coleman (1980) studied 45 patients 37 of whom had coincidental pathology to account for their aural symptoms. Four of the remaining eight probably had other aural pathology and two further patients were psychiatrically ill.

*Myositis ossificans progressive*

This is a rare, possibly autosomal, dominant condition with widespread ossification of muscles. The disease starts in childhood and, of the three reported cases with hearing loss, one was of an adult with a conductive hearing impairment (Ludman, Hamilton and Eade, 1968).

*Haemophilia*

Fabiani et al (1985) have studied 40 patients with either haemophilia or von Willebrand's disease. Only 17 out of 44 ears of patients with severe haemophilia had no evidence of hearing loss. Two patients needed audiological rehabilitation, two had asymptomatic high frequency hearing loss and a further 12 ears had abnormalities of brainstem evoked responses. Eighteen patients had either mild haemophilia or von Willebrand's disease. In these patients 18 ears had an asymptomatic high frequency hearing loss. A pure cochlear loss was found in nine ears and evidence of retrocochlear pathology was found in a further 15 ears.

Overall less than one-half of these patients had normal auditory pathways.

*Non-organic hearing loss*

In the context of adults this is usually either hysterical or else an exaggeration of a real hearing loss which is usually noise induced. It must be considered as a cause for hearing loss in that it may affect both test results and the consequent treatment and rehabilitation of the patient for whom the effective hearing impairment may be very real.
**Sudden sensorineural hearing loss**

The dramatic nature of a sudden sensorineural loss of hearing sets it apart from most of the conditions which present to the audiological physician. Therefore, although the following diseases are fully discussed elsewhere in the volume, they are presented together below for convenience.

Sudden hearing loss has a reported incidence of 5-20/100,000 (Byl, 1984) and is bilateral in 10-20% of patients (Rowson, Hinchcliffe and Gamble, 1975; Mattucci and Bachoura, 1982). The natural history of the condition is for recovery to the previous hearing level in 45-48% and to at least half of the original hearing level in 70% of cases (Moskowitz, Lee and Smith, 1984).

A history of preceding upper respiratory tract infection is obtained in approximately one-quarter of cases (Rowson, Hinchcliffe and Gamble, 1966, 1975). However, serological evidence of recent viral infection is found in only 5-13%. Bacterial infections may also cause sudden hearing loss and treponemal infection was found in 4% of patients studied by Mattucci and Bachoura (1982).

The largest diagnostic category in sudden hearing loss remains the idiopathic group which accounts for between 35% (Graham, 1981) and 56% (Mattucci and Bachoura, 1982) of cases. In a controlled study Bosatra et al (1985) have found abnormalities of platelet aggregation in idiopathic sudden hearing loss. The oxygenation of the perilymph has been ascertained using a probe through the stapedial footplate (Nagahara, Fisch and Yagi, 1983). These workers found low initial values with a normal response to carbon dioxide inhalation suggesting capillary rather than arteriolar damage.

Vascular causes include hypertension, atherosclerosis, hyperlipidaemia, hyperviscosity, hypercoagulability and vasculitis. All of the conditions discussed in the trauma section of this chapter have been implicated in the aetiology of sudden hearing loss.

Metabolic causes include diabetes mellitus. In a series of 161 cases, Wilson et al (1982) found 16 cases of diabetes and, in six of these, sudden hearing loss was the presenting feature.

Ménière's disease can present with acute auditory failure and this accounts for approximately 5% of cases. There may be a long interval between this presentation and further symptoms.

Acoustic neuroma is the cause in 3% (Byl, 1984) to 6.5% (Portmann, Dauman and Aran, 1985) and a total of 31% of the latter group's patients had retrocochlear pathologies.

Less common causes include ototoxic drugs and chemicals, other tumours, mismatched blood transfusion, multiple sclerosis, vaccination, oedema of the facial nerve and non-organic hearing loss (see Graham, 1981; Byl, 1984).
Conclusions

This chapter has attempted to provide a comprehensive account of the aetiology of hearing loss in adults. It leaves one wondering how it is possible for some people to go through life without ever becoming deaf. Nevertheless, there are patients in whom the cause for their hearing impairment cannot be elucidated. It is to be hoped that in the future fewer people will fall into this category.