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BY D. WHITTERIDGE, F.R.S., AND P. A. MERTON, F.R.S.

Charles Skinner Hallpike was born in Murree, a hill station and health resort now in Pakistan. His father, Frank Hallpike, and the family came back to London when Charles Hallpike was three years old. During his childhood Hallpike developed Perthes disease of the hip, and spent long periods on his back during his school life. He had continuing and severe pain from this condition throughout his life until finally he had his hip arthrodesed.

At St Paul’s School he became a classical scholar and entered Guy’s Hospital with a scholarship in Arts in 1919. He studied physiology under Pembrey, who stressed the contribution that physiology could make in the study of disease. He obtained the Beaney Prize in Pathology and qualified as M.R.C.S., L.R.C.P. in 1924, and took the M.B., B.S. of London in 1926 and F.R.C.S. England in 1931.

He was House Surgeon to the Ear, Nose and Throat Department at Guy’s and the Cheltenham General Hospital and began his life’s work by becoming Bernard Baron Research Fellow at the Ferens Institute of the Middlesex Hospital in 1929. It is remarkable that he had developed his bent for describing and measuring the physiological processes concerned in hearing and balance in simple physical terms in spite of a rather limited formal instruction in physics and physiology, which was only that usual in the premedical and medical course in a hospital which then prided itself on a practical rather than an academic approach.

He was awarded the Duveen Travelling Studentship in 1930 and the Rockefeller Travelling Fellowship in 1931, and he used these to visit the U.S.A., Canada and Europe. In Witmaack’s clinic in Berlin he learnt the methods of microscopy of the temporal bone, a technique he was to make peculiarly his own. From 1937 to 1940 he held the Foulerton Research Fellowship of the Royal Society.
THE FERENS INSTITUTE, 1929–40

In this period of his life, while Hallpike was a young research worker at the Ferens Institute of Otology in the Middlesex Hospital, most of his publications were on the physiology of hearing, but he also kept clinical and pathological interests going, writing on hearing tests and hearing aids and other topics. This side of his work led to his epoch-making discoveries in Ménière’s disease, to which we shall come later.

At the Ferens, Hallpike and his collaborator, Ashcroft, were some of the first people to master the technique of recording action potentials from sensory nerves, in the manner that Adrian had developed a few years before. In those days all the equipment had to be made by the experimenter, valves were hopelessly microphonic and the difficulties faced are hard for us to appreciate fifty years later. Hallpike first tackled the otolith organ in the inner ear known as the saccule. To add to everything else the nerve to the saccule was short and difficult to get at. Hallpike learnt the dissection from W. J. McNally of Montreal. Contrary, perhaps, to what might be expected of an otolith (but in accordance with the views of McNally & Tait (1925)), the saccule of the frog did not respond to tilting or rotating the animal, but proved very sensitive to vibration. This was a pioneering and important piece of work, but it was not followed up, possibly because Hallpike became interested in the famous Wever & Bray effect of the cochlea, which had been discovered in 1930.

Wever & Bray had found that they could pick up a quite large potential (by electrophysiological standards) from anywhere close to the cochlea, whose shape was later shown to match the shape of the pressure wave of the sound that caused it; this led to the term ‘microphonic’ potential introduced by Adrian. Hallpike (with A. F. Rawdon-Smith) first used the Wever & Bray potential as a tool, in a neat little investigation of the function of the tympanic muscles. In the first half of the nineteenth century the great Johannes Müller had suggested that these minute muscles of the middle ear had the function of stiffening-up the suspension of the ear drum and ossicles when loud sounds fell on the ear, and so reducing the sound energy reaching the inner ear. Hallpike & Rawdon-Smith (1934) arranged matters by clever dissection so that they could watch the contraction of the tensor tympani (the larger of the two muscles) through a microscope, at the same time as they recorded the Wever & Bray potential from the cochlea. They used lightly anaesthetized cats, in which they were able to see a reflex contraction of the tensor tympani to loud sounds. As the muscle contracted, the amplitude of the Wever & Bray potential fell from its initial level observed immediately after the sound began. This was the first objective proof that the tympanic muscles did have the protective function they had long been credited with.
The real interest of the Wever & Bray effect, however, lay in the clues it might yield about the intimate mechanism of the cochlea. Here Hallpike and Rawdon-Smith made an important advance. As implied above, the Wever & Bray potential is widely distributed around the cochlea; at a single site, responses to sounds of widely varying frequency can be recorded. By drilling down through the petrous temporal bone with a dental burr, to get electrodes close to the top and the bottom turns of the cochlea, Hallpike and Rawdon-Smith were able to show that in the top turns the Wever & Bray potential to low notes was several times larger than the response to high notes of similar intensity. At the bottom turn the situation was reversed. This was the first electrophysiological evidence for the view that different locations in the cochlea respond preferentially to particular frequencies of sound; evidence, that is to say, for the ‘place’ theory of pitch discrimination. It anticipated the similar findings of Hallowell Davis and his group. It was originally published under the title ‘The Helmholtz resonance theory of hearing’ (1934) but, in fact, as Hallpike probably soon appreciated, it did not throw any light on the question whether localization of different pitches to different regions of the cochlea is achieved by local resonance or by some other mechanism.

After these experiments Hallpike does not appear to have done anything more on pitch discrimination, but turned his attention to the physical mechanism of the Wever & Bray potential. Two lines of investigation were pursued concurrently: responses to phase reversal and degeneration studies. The latter sprang from the observation of Witmaack (1911) that after section of the VIIIth (auditory) nerve inside the skull there is retrograde degeneration of the neural elements in the cochlea. Hallpike hoped to use this fact to distinguish between Hallowell Davis’s view that the Wever & Bray potential was a mixture of nerve action potentials and a second component, probably generated by the hair cells in the organ of Corti, and the alternative theory that it is caused by some more purely physical effect, such as movement of a charged membrane (e.g. Reissner’s membrane separating the scala media of the cochlea from the scala vestibuli). The first experiments (Hallpike 1934) appeared to give a clear answer: the potential disappeared with the neural elements. But in the same year contrary observations were published by Guttman & Barrera. In the end (Ashcroft, Hallpike & Rawdon-Smith 1939) it was concluded that the potential only disappeared in those ears in which there was a long-standing serous labyrinthitis after the nerve section. It was also claimed that in some animals the hair cells degenerated but the Wever & Bray potential persisted, a finding that favoured the charged membrane type of hypothesis. Some further evidence on this point came from observations on the ear of the genetically deaf mouse, the ‘shaker 1’ mouse (Grüneberg, Hallpike & Ledoux 1940). The current view, however, is that the purely microphonic component of the Wever & Bray potential does come from the hair cells.
The other approach derived from Hartridge's argument (1921) that if the basilar membrane resonated, as conjectured by Helmholtz, then suddenly reversing the phase of a pure sine-wave tone by 180° should stop the resonator. There would then be a short pause before it built up again with the new phase. Something of the kind was subjectively audible (Hartridge 1921; see also Rushton 1977). An electronic equivalent of Hartridge's phase-reversal siren was developed and was applied to the recording of the Wever & Bray potential in the cat. It was found, however, that the potential followed the phase reversal faithfully, without a pause. This was taken to show that the Wever & Bray effect arose in non-resonant structures (Hallpike, Hartridge & Rawdon-Smith 1936). On the contrary, electrical records of the mass-discharge from the surface of the mid-brain over the auditory tract did show a pause in the rhythmical response after the phase reversal, which could be interpreted as the pause expected by Hartridge when the resonator was stopped. These experiments led to the tentative conclusion that the Wever & Bray potential arose in non-resonant structures, different from the resonant structures responsible for pitch discrimination.

The weakness of these experiments is that Hartridge's argument only applies to a single resonator. If there is an array of resonators tuned to a scale (as the resonance theory requires) there are no simple expectations for a phase reversal. Also, as pointed out by Gold & Pumphrey (1948), it is a necessary consequence of the fact that the Wever & Bray potential can be obtained for a wide range of tone frequencies (i.e. that the effect has a wide bandwidth) that it will follow transients faithfully. So the faithful reproduction of phase reversal in the Wever & Bray potential tells nothing new about the origin of the potential and, in particular, nothing about the resonance or otherwise of the cochlear elements. There is, indeed, some kind of break in the potential waves from the mid-brain, but, as Hallpike, Hartridge & Rawdon-Smith (1937) realized, it cannot confidently be attributed to stopping a single resonator because phase reversal would be bound to affect many resonators in an array of resonators. Nor were matters really advanced by subsequent experiments that showed that phase reversal during sine-wave electrical stimulation of the cochlea (the 'electrophonic effect') gave the same kind of record in the mid-brain (Hallpike & Hartridge 1937a, b).

Looking back over the physiological side of Hallpike's research at the Ferens Institute, he is seen to have been well in the van in the early years with his work on the saccule and on frequency localization of the Wever & Bray effect to different turns of the cochlea. But afterwards he devoted the great expertise he had acquired to studies of VIIIth nerve degeneration and of Hartridge's phase-reversal phenomenon, both of which turned out to be relatively unprofitable. Meanwhile, the initiative in single-unit recording from the auditory system was left to the St Louis group (Galambos & Davies 1943).
In 1940 he joined the scientific staff of the Medical Research Council and moved to the National Hospital, Queen Square, where he was appointed Assistant Aural surgeon. In 1944 this appointment was changed to that of Aural Physician, a post he held until retirement in 1967. At the same time he became Director of the Otological Research Unit, a parallel appointment to that of Dr E. A. Carmichael, Director of the Neurological Research Unit, and a useful collaboration developed between the units. Here Hallpike began to apply quantitative methods to the diagnosis of aural and vestibular conditions, and to develop further the study of the histology of the cochlea. He had started this work at the Ferens Institute and had faced the difficulties of sectioning temporal bone, the hardest bone in the body. Naturally microtome knives become blunt very quickly when cutting sections of bone, and the problem was to find an appropriate steel and to study methods of sharpening the knife and finding the best cutting angle. In its final form, the knife had an edge of stellite, a non-ferrous alloy, which was sharpened on a special machine after every few cuts. The Metrology and Metallurgy Divisions of the National Physical Laboratory provided help, as did Dr E. H. J. Schuster of the National Institute for Medical Research. Hallpike’s technician, C. Best, did the work and played an important part in its development.

In 1938 Hallpike published with Sir Hugh Cairns the first description of the histopathology of the cochlea and vestibular apparatus in Ménière’s disease. He observed distension of the endolymph system, ‘an endolymphatic hydrops’ particularly of the cochlear portion and the saccule, as well as degeneration of the hair cells of the organ of Corti. These changes he ascribed to interference with the normal secretion of endolymph by the stria vascularis. Previously Ménière’s disease had been thought to be due to haemorrhage. Hallpike’s elegant discovery caused quite a sensation in otological circles. This work led to the investigation of the osmotic pressure of the endolymph, and later to an analysis of its chemical composition in health and disease (Aldred, Hallpike & Ledoux 1940; Ledoux 1950). Smith et al. (1954) found in the guinea pig that perilymph resembled cerebrospinal fluid in its concentration of sodium and potassium, whereas in endolymph the concentration of sodium was only 20 mequiv l⁻¹ and that of potassium was 140 mequiv l⁻¹. Similar differences were seen in the cat.

Although ‘caloric’ tests for vestibular function had been used since the work of Barany in 1907, they were not quantitative, and, if ice-cold water were used, could be disagreeable. When Sherrington demonstrated the test on a student, he is reported to have said ‘I thought the subject would never stop vomiting!’ Hallpike’s modification was to run warm water at 44 °C (7 °C above body temperature) into the external auditory meatus
for 20 seconds, and observe the duration of the resulting nystagmus. After a pause, water at 30 °C (7 °C below the body temperature) was run in for an equal time, so causing in healthy subjects an opposite and almost equal nystagmus. This argument applies strictly only to tissues without a blood supply, since changes in blood flow induced by cold and by warm water very greatly affect the rate at which heat is conducted away from the tissue. Fortunately this effect is small in the ear, and the nystagmus after cold water only lasts for 10–15 seconds longer than that after warm water, which in normal subjects continues for about 100 seconds.

The temperature changes induce convection currents in the most exposed canal, the lateral semicircular canal, which bulges into the medial wall of the middle ear. This canal can be made vertical by appropriate positioning of the head. This method not only picks out the affected ear in unilateral vestibular damage (canal paresis), but can also show ‘directional preponderance’ when, say, cold water in the left ear and warm water in the right ear cause more prolonged nystagmus to the right, compared with the nystagmus to the left from the opposite combination. This is particularly seen in unilateral lesions of the vestibular nuclei, in partial unilateral lesions of the labyrinth, and in lesions of the posterior part of the temporal lobe. Hallpike was the first person to show that caloric tests can provide important information about ‘central’ lesions in the brain.

As a further complication one may have both canal paresis and directional preponderance. This provides a most useful test of vestibular function, as abnormal responses are found in 90% of patients with Ménière’s disease and in almost 100% of patients with tumours of the VIIIth nerve and vestibular neuronitis. This method was also adapted to objective measurement of eye movement by Hallpike and his Unit, who recorded the electrical changes picked up from the skin as the eye moves: electronystagmography.

Rotational stimulation of the semicircular canals has the disadvantage compared with caloric stimulation that it is necessarily applied to both ears at once, and also that some adaptation occurs to repeated stimuli. The theoretical advances in this field were mostly made by van Egmond, Groen & Jongkees and others at Utrecht, but Hallpike made a practical contribution by designing a rotating chair for human subjects, together with an optical system for continuous observation of the subject’s eyes. The actual velocity of the slow movement of nystagmus was measured by balancing it against controlled movement of a spot of light in the opposite direction until no apparent movement of the light occurred (Hallpike & Hood 1953).

His elucidation of the aetiology of Ménière’s disease and his development of readily applicable quantitative caloric tests of the peripheral and central vestibular system were Hallpike’s main and lasting contributions to otological science and practice, but many other important advances
were made by the Unit. The application of a simple quantitative method for the measurement of hearing loss led to the recognition of ‘loudness recruitment’, a condition in which the auditory threshold is raised in one ear, but on increasing the intensity of the stimulus the difference between the loudness of the sound heard in the two ears decreases, a condition first described by Fowler (1936). This is seen in deafness produced by nerve damage, whereas in conduction deafness due to middle-ear disease the difference in loudness between the two ears remains constant over the whole range of intensities used. Dix, Hallpike and Hood held that loudness recruitment is a consequence of damage to nerve endings in the cochlea, and is not seen in damage confined to nerve fibres. The effect can be produced by interference with the cochlear blood supply, and is essentially an inability to maintain afferent cochlear discharge with maintained stimuli. This is supported by the fact that the ‘on’ effect may be normal. The measurement of loudness recruitment is another technique with considerable diagnostic value.

Among other subjects studied there was an investigation of positional nystagmus of the benign paroxysmal type, first described by Robert Barany. This is abolished by section of the VIIIth nerve. Hallpike described the pathological findings and showed that the disorder was due to a lesion of the utricle. A new method of measuring bone conduction by using narrow-frequency band masking provided another useful diagnostic technique. An interesting observation with M. R. Dix suggested that the slow components of optokinetic nystagmus and vestibular nystagmus had separate neural components, since after streptomycin treatment, which is believed to destroy the vestibular nuclei completely, optokinetic nystagmus is quite unaffected.

Hallpike was also deeply interested in practical aspects of hearing. He was a member of the Flying Personnel Research Committee of the Air Ministry from 1938 to 1955, and of the Military Research Committee of the Medical Research Council. He became liaison officer to the Medical Research Council’s Hearing Committee and helped to provide the scientific basis for the Medresco hearing aid developed by the Ministry of Health. The ‘peep-show’ technique for audiometry in young children was another of his practical devices.

Retirement and honours

After his retirement from the Directorship of the Otological Research Unit in 1965, he returned to the Ferens Institute as Director of Research until 1968, and continued to published papers and review articles almost up to the date of his death. In 1980 the *Journal of Laryngology and Otology* republished his paper of 1938 with Sir Hugh Cairns on the pathophysiology of Ménière’s disease as a final tribute.
He received the Gamble Prize of the Royal Society of Medicine in 1934 and again in 1947, when he also received the Dalby Prize. He was awarded the William Mickle Fellowship of the University of London in 1941 and the Shambaugh Prize of the Collegium Otolaryngologicum Amicitiae Sacrum in 1955. The Barany Prize of the University of Uppsala followed in 1958, and the Guyot Medal of the University of Groningen in 1959. In 1967 he was awarded the Hughling Jackson Medal of the Royal Society of Medicine. He was elected F.R.C.P. in 1945, and in 1956 became the first otologist to be elected to the Royal Society. He was appointed C.B.E. in 1959, was President of the Section of Otology of the Royal Society of Medicine in 1965, and was elected an Honorary Fellow of the Royal Academy of Medicine of Ireland in 1952.

**Personal characteristics**

Because of his hip, Charles Hallpike walked with crutches and was in pain for his adult life, until an operation to fuse the joint in his late fifties. When he was Director of the Otological Research Unit he would tend to stay put in his office or in the out-patients department rather than move about the hospital, and people would come to him. Colleagues and staff would be summoned, the usual method of procedure being a half-jovial interrogation. Fools were not suffered, the chosen reaction being silence. The general style of government of the Unit was paternalistic. Hallpike knew exactly what he wanted and the Unit was organized to pursue it. Independence of outlook was encouraged only within this framework. Some of his staff did not find this congenial and left, but the continuance of the Unit by the M.R.C. and its history since Hallpike’s retirement as Director show clearly enough that there were able members of his staff who stayed.

Hallpike ruminated long about the scientific problems that interested him, pondered his own experiments and read widely, notably in the German literature. Having then decided what he thought on a subject, his views were not easily influenced. Great care was taken to put them down on paper lucidly, and with success. This self-contained kind of attitude to science has obvious dangers, but Hallpike only rarely came to grief, as with the Hartridge phase-reversal work.

Lunching in the hospital staff canteen, Hallpike was at his most relaxed. He would set conversation going with some humorous and provocative remark usually put in a mildly pedantic style: ‘Doctor X, steer clear of legal and theological physiology’, by which he meant laws and doctrines. He himself published a paper ‘On the case for repeal of Ewald’s second law’ (which claimed to codify the results of unilateral VIIIth nerve section). He was of a dark cast of complexion and no doubt pigmented rapidly in sunlight. Once he told how he was sitting in a deck-chair in Biarritz, ‘looking a bit of a dago’, as he put it, and was approached
Charles Skinner Hallpike

by a member of an English party: ‘Jouez-vous au bridge, monsieur?’ ‘I

by a member of an English party: ‘Jouez-vous au bridge, monsieur?’ ‘I
can, but I don’t care to.’ ‘You speak English remarkably well, if I may say
so.’ ‘You’re not so bad yourself.’ This abrupt exchange will be recognized
by those who knew him as highly characteristic.

For his relaxations also he preferred simple and precise activities. He
was an excellent rifle shot, and captained the Public Schools’ Veterans

For his relaxations also he preferred simple and precise activities. He
was an excellent rifle shot, and captained the Public Schools’ Veterans
team at Bisley. He also played billiards well, in spite of his disability. In
July 1935 he married Barbara Lee Anderson, who survives him, as do two
sons. His daughter, Janet, who had read English and Theology at Girton
College, Cambridge, died in 1966. Hallpike was much affected by the
death of his daughter. He said to one of us (P. A. M.) that the only thing

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The photograph reproduced was taken by Tunbridge in 1956.

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